

Research on spatial and temporal characteristics of drought based on GIS using Remote Sensing Big Data

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Abstract Drought is a stochastic natural hazard that is caused by intense and persistent shortage of precipitation. Spatial and temporal patterns of drought have been analyzed by several methods, ranging from satellite images to historical records; however, drought is generally identified by climate elements. Drought indices are quantitative measures that characterize drought levels by assimilating data from one or several variables (indicators). A number of different indices have been developed to quantify droughts, each with its own strengths and weaknesses. In this paper, using the remote sensing image to acquire the vegetation cover data, and combined with meteorological data and the Geographic Information System (GIS) technology to discuss the spatial and temporal characteristics of the drought. Based on precipitation observations Pu'er City, Yunnan Province, ten counties (districts) ten meteorological observation stations from 1961 to 2010 monthly for 50 years, mainly in ArcGIS10.1 analysis platform, using Mann–Kendall nonparametric trend test method for time-series trends in precipitation was tested, using ArcGIS in inverse distance weighting interpolation tool were precipitation the amount and distribution of precipitation anomaly percentage. Finally, precipitation anomaly percentage grading standards drought intensity distribution of drought The results showed that: Pu'er City under the effect of temperature, altitude, vegetation cover, and many other factors, forming the situation that the rainfall is a little more in north–south and less in east–west, the drought inci-

dence appears more in northwest and less in southeast, more in spring and winter and less in summer and fall.

Keywords RS · GIS · Meteorological · Drought · Spatial and temporal characteristic

1 Preface

Drought is a stochastic natural hazard that is caused by intense and persistent shortage of precipitation. Temperature, high winds, and low relative humidity also play a significant role in the occurrence of droughts. Drought is a common natural disasters, have different levels of negative impact on the various areas of human life. Drought is now recognized academic definition includes meteorological drought, agricultural drought, hydrological drought and socioeconomic four types of drought, and current research in the area of drought scales focused on agriculture in arid and arid Arid Meteorology two types [1]. Agricultural drought is crop water deficit phenomenon that due to the continuing shortage of soil moisture in the crop growth period, meteorological drought is the shortage of water phenomenon that due to the imbalances between evaporation and precipitation within a certain time period. Drought identification and characterization is a prerequisite to drought frequency analysis. In general, drought is often characterized by its duration, severity, intensity and spatial extent. Yevjevich [2] proposed the one-dimensional truncation method to extract drought duration, severity, and intensity from drought index sequence. But this method discards much of the spatio-temporal information by reducing drought events to a one dimensional subspace, thereby not enabling to capture the real drought structure in space–time dimensions. Andreadis et al. [3] proposed a clustering algorithm to extract the voxels of drought

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connected in space. Lloyd-Hughes [4] extended the clustering algorithm to three-dimensional space (longitude, latitude, and time), fulfilled the complete spatio-temporal representation of the drought event. On this basis, Xu et al. [5] proposed a three-dimensional drought identification scheme and used it to analyze the spatio-temporal variation of drought in China during 1961–2012.

Spatial and temporal patterns of drought have been analyzed by several methods, ranging from satellite images to historical records; however, drought is generally identified by climate elements. Drought indices are quantitative measures that characterize drought levels by assimilating data from one or several variables (indicators), such as precipitation and evapotranspiration, into a single numerical value. A number of different indices have been developed to quantify droughts, each with its own strengths and weaknesses. Among them, the Palmer Drought Severity Index (PDSI) is the most prominent index of meteorological drought used in the world. The PDSI was one of the first procedures to demonstrate success at quantifying the severity of droughts across different climates. Instead of being based purely on precipitation, the PDSI is based upon a primitive water balance model. A common critique of PDSI is that the behavior of the index at various locations is inconsistent, making spatial comparisons of PDSI values difficult. The self-calibrating PDSI (SC-PDSI) automatically calibrates the behavior of the index at any location by replacing empirical constants in the index computation with dynamically calculated values. An evaluation of the SC-PDSI at 761 sites within the U.S. states of Nebraska, Kansas, Colorado, Wyoming, Montana, North Dakota, and South Dakota, as well as at all 344 climate divisions, showed that it is more spatially comparable than the PDSI.

Yunnan has a complex topography, coupled with repeated multiple effects instability monsoon circulation and different weather systems, has become a frequent meteorological disasters zone. Yunnan has suffered drought Once in a century during the 2009–2010, both in the affected range, duration, and other aspects of the severity of losses are rare in history, combined with Yunnan is a big agricultural province, the occurrence of drought extremely significant impact on agricultural production [6], directly endanger people's production and life. As of the end of 2010, the drought has led to the province's 597 million people, 3.59 million livestock drinking water, more than 330 million people living difficulties caused by drought need a government bailout, wheat, barley, beans, potato, rapeseed, vegetables, sugar cane and other winter sown crops affected area of more than 85 percent, spring grain (grain) to more than 50% natural calamities, woodland affected area of over 4300 acres, 400 acres of scrap, agricultural drought in the province more than 10 billion Yuan in direct economic losses [7], shocking disaster. However, because the province lacks of the awareness of

drought's spatial and temporal characteristic under the background of global climate change, in the face of escalating drought and devastated natural environment, only a passive response that to accept losses caused by drought. Therefore, the government and people realize the need to do depth analysis of drought-spatial and temporal variations in the reflection and the urgency to do drought early warning well [8–11].

In this paper, using the remote sensing image to acquire the vegetation cover data, and combined with meteorological data and the Geographic Information System (GIS) technology to discuss the spatial and temporal characteristics of the drought. Based on precipitation observations Pu'er City, Yunnan Province, 10 counties (districts) 10 meteorological observation stations from 1961 to 2010 monthly for 50 years, mainly in ArcGIS10.1 analysis platform, using Mann–Kendall nonparametric trend test method for time-series trends in precipitation was tested, using ArcGIS in inverse distance weighting interpolation tool were precipitation the amount and distribution of precipitation anomaly percentage. This study extends the application of the recently developed model in drought forecasting by Madadgar and Moradkhani [12]. In the previous application, the forecast model predicted the future droughts of the Gunnison River Basin (GRB) in Colorado, USA, using the flow volume at the basin outlet. The promising results of that study have encouraged the authors to apply their forecast model in estimating the spatial variation of future droughts using the runoff volume at different grid cells across the basin. This study aims at extending the application of the proposed copula-based method to estimate the spatial variation of future drought probabilities across the Yunnan. For this purpose, the runoff generated across the basin is used to evaluate the spatial variation of droughts; while in the previous study, the stream flow observations at a particular point were used for drought forecasting.

Following the introduction, the remaining parts of this paper are organized as follows. Section 2 presents the research area situation. Section 3 introduces the materials and methods. Section 4 presents the temporal and spatial characteristics of the proposed method. Section 5 discusses the drought influencing factors. Section 6 gives the related work. Finally, the main conclusions are given in Sect. 7.

2 Research area situation

Pu'er City is located in southwestern Yunnan–Guizhou Plateau, land area 45,385 square kilometers, the region accounted for 98.3% mountainous area, located at latitude $22^{\circ}02'–24^{\circ}50'$, longitude $99^{\circ}09'–02^{\circ}19'$ between the north regression line across the middle, at an altitude between 376 to 3306 m, east to Honghe, Yuxi, south of Xishuangbanna, northwest to Lincang, north to Dali, Chuxiong (shown in Fig.

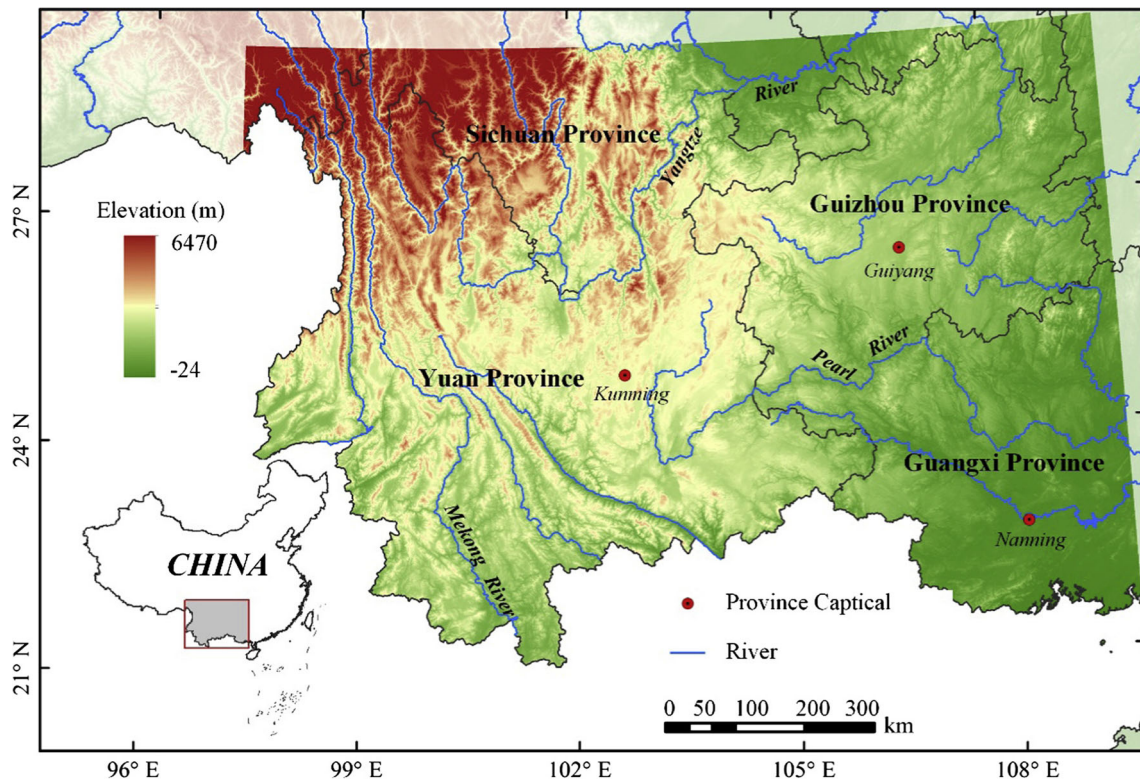


Fig. 1 Location and topography map of Southwest China

1). Southeast with Vietnam, Laos, and Myanmar adjoining the southwest, the border is about 486 km (303 km border with Myanmar, Laos 116 km, Vietnam 67 km) [13], is the largest land area in Yunnan Province, and is earthquake-prone and frequent meteorological disasters in the region. The whole city have nine counties and one area, nine counties are minority autonomous counties where inhabited by 14 ethnic minority, 61 % of the total population of the minority population. Pu'er City, having the territory of rolling hills, rivers, with the effects of solar radiation, circulation, the atmosphere and the specific topography, forms a complex of low-latitude mountain monsoon climate. Affected by monsoon and winter half, Pu'er City summer half distinct weather systems to form a summer and rainy, winter and spring drought, distinct wet and dry season monsoon climate. The city's average annual rainfall is 1131.6–2739.3 mm, forming the spatial distribution characteristics of annual precipitation that more in south than in the north. The old town' rainfall in Jiangcheng, Ximeng is over 2000 mm, one of largest rainfall region in the whole city even the whole province, while in the north precipitation, Jingdong, Zhenyuan, Jinggu, is less than 1300 mm, very uneven distribution of precipitation [9], and therefore prone to droughts in winter and spring, and summer and autumn and prone to a single point of local floods and landslides triggered by and landslides and other geological disasters. The city has 10 meteorological stations,

they are Pu'er Station, Jingdong, Lancang, Jiangcheng first level station, Ninger, Jinggu, Mojiang, Zhenyuan, Ximeng and Menglian second level stations. Xu et al. [14–18] proposed an image data processing framework using intelligent sensing method.

3 Materials and methods

3.1 Data source

Data collection and processing is the basis of the study, the degree of accuracy and detailed data to determine the accuracy of the research results. Therefore, to choose the data, the primary task is to understand the types, characteristics, sources and accuracy of data. Second, the selected data conforms to the national standard. The city is located in the Yunnan–Kweichow Plateau in the southwest, the region accounted for 98.3 % of mountain area, is also a frequent meteorological disasters area. So in the choice of data are fully taken into account the situation and background of the area. The data used in this study include: (1) the monthly precipitation data of 10 stations into city from 1961 to 2010; (2) Remote Sensing image in Simao region. Rainfall data from Yunnan Meteorological Bureau, Simao district as the TM remote sensing image data of 30 meters resolution.

3.2 Research methods

This selection of precipitation and precipitation anomaly percentage (Pa) as a main indicator of drought intensity classification to non-parametric Mann–Kendall trend test method test out the general trends and changes in rainfall conditions in the study area over the years, and the use of inverse distance weighting interpolation variation of drought space analysis, mapping the spatial distribution of drought in ArcGIS10.1 Pu'er City, the last factor correlation analysis of the effects of drought in the spatial and temporal variation of the conclusion, based on the use of statistical methods and historical test data analysis phase of drought the method of determining a combination of factors caused by drought.

3.3 Precipitation anomaly percentage (Pa) method

Precipitation anomaly percentage is one of the unusual method of characterizing a period of precipitation, rainfall anomalies can directly cause by the drought response; often use in the ordinary course of business of the weather, used to assess monthly, quarterly, drought events occurred in [8], the easiest method is to calculate, using the most widely used features of drought analysis method has the advantages of intuitive results. The results were calculated as follows:

$$Pa = \frac{P - \bar{P}}{\bar{P}} \times 100\% \quad (1)$$

where P is a period of precipitation, \bar{P} is the average rainfall over the same period for many years, calculated as follows:

$$\bar{P} = \frac{1}{n} \sum_{i=1}^n P_i \quad (2)$$

where P_i is the precipitation period, n is the sample number [19].

3.4 Mann–Kendall (nonparametric trend test method)

Mann–Kendall method is a non-parametric statistical tests, because variables can not have a normal distribution characteristic, and therefore suitable for hydrological variables trend test [20, 21]. This method can be used time and spatial distribution of precipitation characteristics studied. Based on the theory as follows:

The original hypothesis H_0 for time-series data (x_1, \dots, x_n) , represents there were n independent, identically distributed random variables samples; the alternative hypothesis H_1 is a two-sided test, for all $k, j \leq n$, and $k \neq j$, x_k and x_j distribution is not the same, testing statistical variables S is calculated as follows:

$$S = \sum_{j=1}^{n-1} \sum_{k=j+1}^n \text{sgn}(x_k - x_j) \quad (3)$$

wherein,

$$\text{sgn}(x_k - x_j) = \begin{cases} 1 & x_k - x_j > 0 \\ 0 & x_k - x_j = 0 \\ -1 & x_k - x_j < 0 \end{cases} \quad (4)$$

S is normally distributed with mean O and variance $\text{Var}(S) = n(n-1)(2n+5)/18$. When $n > 10$, the standard if normality statistical variables calculated as follows:

$$Z = \begin{cases} \frac{S-1}{\sqrt{\text{Var}(S)}} & S > 0 \\ 0 & S = 0 \\ \frac{S-1}{\sqrt{\text{Var}(S)}} & S < 0 \end{cases} \quad (5)$$

At a given α confidence level, if $|Z| \geq Z_{1-\alpha}$, then reject the null hypothesis. That is say when the confidence level upon α , then the time series data exists a clear upward or downward trend. By the size of the change trend, calculated as follows:

$$\beta = \text{Median} \left(\frac{x_k - x_j}{k - j} \right), \quad \forall j < k \quad (6)$$

If $\beta > 0$, indicating an upward trend; if $\beta < 0$, indicating a downward trend [20, 21].

3.5 Correlation analysis

Correlation analysis is a statistical analysis method investigated linear relationship between two variables, the popular talk is a measure of the closeness of two or more variables associated with elements of the correlation analysis between. Requires the presence of certain elements of the correlation between the probability of contact or correlation analysis can only be performed, such as temperature and precipitation in this article, the experience is generally considered among the high evaporation temperature to promote evaporation of moisture, moisture and precipitation also there is a certain relationship, so the temperature and precipitation associated with a certain probability. The main correlation formula is:

$$r_{xy} = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^n (y_i - \bar{y})^2}} \quad (7)$$

Wherein: the correlation coefficient between the elements; elements and represent the average of two sample values, i.e.,

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i, \quad \bar{y} = \frac{1}{n} \sum_{i=1}^n y_i \quad (8)$$

The correlation coefficient ranges from $[-1, 1]$, $r < 0$ the test sequence was negatively correlated, $r > 0$ were positively correlated, the greater the absolute value of the correlation is stronger, usually judged by the following ranges power related variables: the absolute value of $0-0.09$ is not correlation, $0.1-0.3$ is weak correlation, $0.3-0.5$ is relevant medium, $0.5-1.0$ is a strong correlation [22].

4 Temporal and spatial characteristics of drought in Pu'er City

4.1 Time variation of drought in Pu'er City

Mann–Kendall trend test results show that, in addition to the time series of rainfall in Ximeng showed a significant downward trend, majority of the other site data showed a decline, but not significant trend, only three sites showed a rising trend, but not significant. Within the city, the rainfall showed a slight downward trend.

From the city's perspective precipitation trend (Fig. 2), experienced a 5–10 year period fluctuated historically low

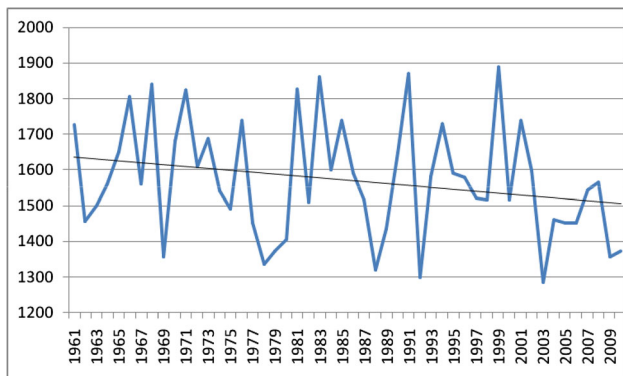


Fig. 2 The trend of Pu'er annual average precipitation

rainfall values in the period 2001–2002, show that in 2001 the province of the great drought in the background Pu'er City has also been a great shock. After 2002, Pu'er City, rainfall continued at a low level, the situation worsened and from 2009, a sharp decrease in rainfall 234.3 mm/a rate, ushered the biggest drought in 50 years (Table 1).

4.2 spatial distribution of drought in Pu'er City

According to the Four Seasons precipitation anomaly percentage obtained for each station, Pu'er City, mainly arid type is spring and winter drought, and has been validated in Pu'er City drought and drought overview of the calendar year. Table 2 shows the precipitation and precipitation anomaly percentage of each station's mean, a combination of both types of analysis result of drought. The following Table 3 mild and moderately severe drought frequency statistics out according to each station precipitation anomaly percentage of quarter-scale drought classification standards. Thus, Jingdong, Zhenyuan, Menglian, Simao, Mojiang, Jinggu is to occur at higher frequencies arid zone of Pu'er.

According to the results of similar precipitation and precipitation anomaly percentage interpolates the results, reflected in greater likelihood of drought are: Jingdong, Zhenyuan northern Mojiang, jinggu, Ning'er and northern Pu'er (due to its scarce rainfall than other regions, while the percentage of indicators of low precipitation anomaly compared to other regions, so that these areas are likely to occur in arid regions), and are consistent with the frequency of droughts in accordance with the conclusions. Also, because the hydrological, meteorological factors are subject to wet and dry season, coupled with changes in precipitation are inextricably linked with the seasons, four seasons of rainfall anomaly percentage interpolated separately, the results showed: Spring reaches the most moderate severity, Zhenyuan region of moderate drought, some areas Jingdong, Lancang, Menglian and Mojiang, Jinggu for mild drought;

Table 1 Trend test results of Pu'er City precipitation series

Station	Z statistic	Slope estimate (β)	Trend (two-tails)
Jingdong	0.50	0.08	Upward trend
Zhenyuan	-0.45	-0.09	Downward trend
Jinggu	0.25	0.03	Upward trend
Mojiang	-0.93	-0.18	Downward trend
Ning'er	1.05	0.33	Upward trend
Simao	-1.21	-0.23	Downward trend
Jiangcheng	-0.79	-0.14	Downward trend
Lancang	-1.08	-0.16	Downward trend
Menglian	-0.89	-0.13	Downward trend
Ximeng	-3.83	-1.63	Downward trend
PU'ER	-1.74	-2.81	Downward trend

Table 2 Pu'er City seasons average of precipitation and percentage of precipitation anomalies

Station	Average of precipitation				Percentage of precipitation anomalies				Types of drought
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	
Jingdong	151.04	607.58	320.82	50.26	-0.3347	-0.3221	-0.1750	-0.1502	Spring and winter droughts
Zhenyuan	165.36	708.84	337.46	52.94	-0.2716	-0.2092	-0.1322	-0.1049	
Jinggu	171.12	728.52	340.88	49.78	-0.2462	-0.1872	-0.1234	-0.1583	
Mojiang	229.36	710.66	314.96	66.50	0.0104	-0.2071	-0.1901	0.1244	
Ning'er	226.66	806.30	353.08	58.06	-0.0015	-0.1004	-0.0921	-0.0183	
Simao	227.08	849.30	360.60	55.36	0.0003	-0.0525	-0.0727	-0.0639	
Jiangcheng	380.90	1266.94	501.12	94.88	0.6779	0.4135	0.2886	0.6043	
Lancang	225.12	901.88	418.66	53.62	-0.0083	0.0062	0.0766	-0.0934	
Menglian	189.74	756.60	368.64	42.42	-0.1642	-0.1559	-0.0521	-0.2827	
Ximeng	303.72	1626.54	572.62	67.60	0.3379	0.8147	0.4725	0.1430	
PU'ER	227.01	896.32	388.88	59.14	0	0	0	0	

Table 3 Pu'er City drought frequency of heavier than slight drought and severe drought

Station	The following mild drought frequency (unit: times)				The following severe drought frequency (unit: times)			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Jingdong	30	37	20	24	6	0	0	5
Zhenyuan	26	19	19	28	3	0	0	8
Jinggu	30	18	19	29	1	0	0	8
Mojiang	10	21	24	22	0	0	0	8
Ning'er	18	11	12	19	1	0	0	9
Simao	10	7	11	27	1	0	1	12
Jiangcheng	1	0	3	8	0	0	0	1
Lancang	15	4	10	25	1	0	0	6
Menglian	23	13	12	32	2	0	0	11
Ximeng	4	0	1	18	0	0	0	6

summer except Mojiang and Simao for mild drought, the rest for no drought; autumn except Jingdong there is light drought phenomenon, the remaining areas without drought; winter drought appeared more abundant levels, which reached a severe drought Ximeng extent to Jingdong, Ximeng for the proliferation of regional centers (including Zhenyuan and Lancang of part town) are also more serious degree of drought zone (Fig. 3).

4.3 spatial season drought in Pu'er City

According to the meteorological drought index C_i and identified indicators, Yunnan Province, from 1956 to 2010, it is calculated that four time segments of different degrees of drought frequency. The results show that there have different degrees of drought in the different parts of the province. The total number of days each strength droughts is large. The slight drought occurred in most of days, the second is

the moderate drought, the special heavy drought occurred least of days. From northwest to southeast the spatial distribution of drought overall shows a major feature of the gradually increasing. The maximum number of dry days is found in southeastern Yunnan. The maximum average number of years special heavy dry weather is more than 28 days. The maximum number of average medium dry weather days for years is more than fifty and the maximum number of average light drought weather days for years is more than 64. The northwestern Yunnan drought days are less. Province average special heavy drought is about 24 days, in t moderately drought is about 44 days, slight drought is about 60 days.

The year change of drought is reflected on the change of the monthly drought days. Based on the meteorological drought index C_i grading standards, the curve of Yunnan Province about 1956–2010 years of the average monthly drought days was calculated. The study showed that from

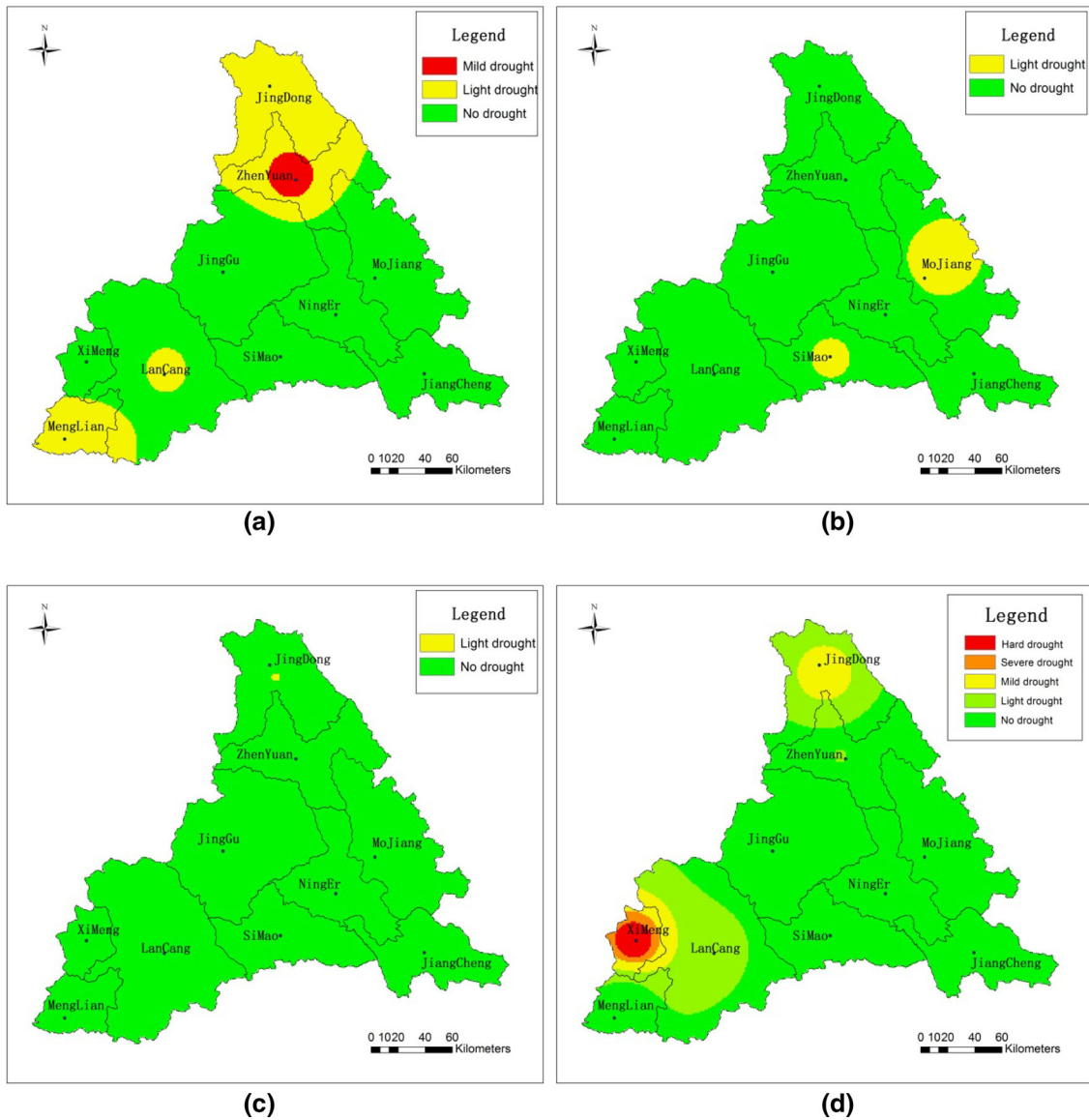


Fig. 3 Seasons drought severity distributed Pu'er City (a–d spring to winter)

the drought month, August is the month of drought days at least and on average only 5–6 days of drought. After August the drought days is of a clear upward trend, it would to a peak in December. In December there are about 15 drought days. After March, the fluctuation exhibits a stable state. Subsequently showing a clear downward trend, to reach the lowest value in August. January, February, March, November and December are the months of the most special serious drought, but the winter is a slack season has less impacted on the human agricultural production activities. And the drought has a serious impact on spring of March, April, May. In normal years summer drought occurred in low probability, but some particular years will be affected by the spring drought phenomenon. Autumn drought is relatively not serious. Overall, the winter and spring continuous drought is easy to intensify

the drought disaster in Yunnan. We should attach adequate importance to it.

5 Drought influencing factors

Because of the drought occurs with location, altitude, slope, aspect, distance of major river systems, vegetation coverage level, the greenhouse effect and other factors associated with the presence of a certain degree [23], this article applies to select a small area studies altitude, slope, aspect, precipitation, temperature and vegetation six factors related discussions.

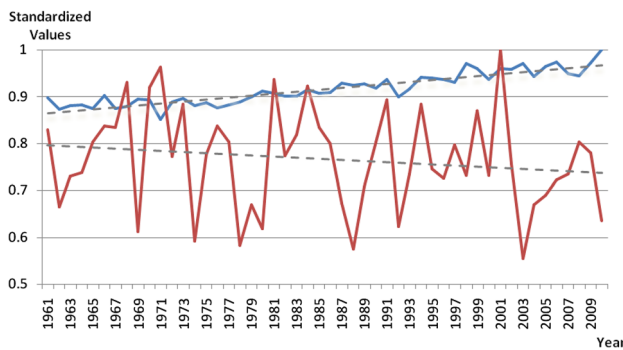


Fig. 4 The Standardization of Simao region annual average trends of precipitation and temperature

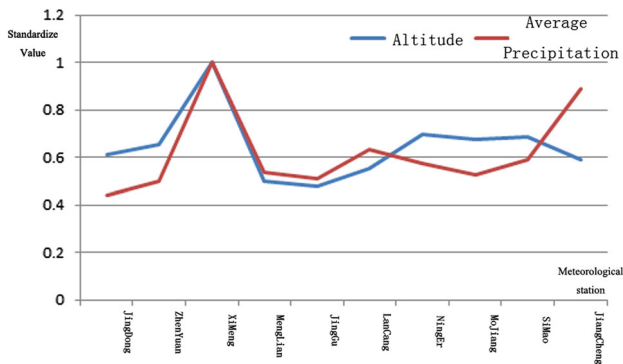


Fig. 5 The standardization of different stations annual average trends of precipitation and elevation

5.1 Precipitation, temperature

International “meteorological drought level” (GB/T 20481-2006) the meteorological drought is defined as “a period of water shortage due to the imbalance of evaporation and precipitation, water expenditure is greater than revenue caused by water, other professional Drought research and business base, ”by definition, the formation of drought has a direct relationship to rainfall. On the map of Chinese precipitation distribution, 200 mm as a boundary to distinguish the arid and semi-arid areas, showing how much precipitation can be one of the indicators to determine the level of drought, rainfall duration longer scarce or non-continuous the longer the time precipitation, the more severe drought.

Analysing the precipitation and temperature in Simao zone of Pu’er correlation results that annual precipitation and temperature inverse correlation was weak, and the correlation coefficient was -0.175 , not by $\alpha = 0.05$ significance level of inspection. It is clear that the general trend of precipitation and temperature by Fig. 4, precipitation decreased gradually and temperature increase year by year, the weak correlation test confirms the inverse correlation between the degree of conclusions reached and this relationship is the most significant period in the vicinity of 2009, this time the temperature reached a record high, while precipitation also to

a relatively low level, and historical data also shows that during 2009–2010, Simao area has undergone major droughts once in 5 years. Starting from the historical data, a severe drought appear in 2001 before the 2009–2010 drought, can be seen from Fig. 5. A large fluctuations in precipitation between 2001 and 2002, a sharp decrease in precipitation and temperatures are rising year by year the formation of a non-negligible cause of drought.

5.2 Altitude

Pu’er City is in the rolling hills, at an altitude between 376 to 3306 meters, while the altitude the effects of drought can initially diagnose as through indirect effects of temperature (1000 m altitude rising temperature drops per 6°C). Precipitation and altitude of Pu’er City, 10 sites drawn from the analysis of the correlation between average annual precipitation and altitude showed a strong positive correlation, the correlation coefficient was 0.616, not by $\alpha = 0.05$ significance test. By Fig. 6 it is clear that they have the same diversification, those serious drought areas with low precipitation, Jingdong, Menglian, jinggu altitude is relatively low.

Zhao Rong found that Altitude increased every 100 m, the drought index fell 0.22 conclusions from drought index derived elevation in the western region of the Tianshan [24], because of the bigger the drought index the greater the intensity of meteorological drought [25], the introduction of drought and elevation negative correlation between: the higher the altitude, the extent alleviates the drought; contrary, the more severe the drought is consistent with the relevant test results.

5.3 Vegetation coverage

Statistics show that the history of high forest coverage Yunnan Song formerly Northwest was 70 %, and 90 % in southern Yunnan, since the Ming and Qing dynasties, the forest coverage rate slow down, but there are still about 70 % by the mid-Qing Dynasty, 1935 forest coverage rate dropped to 50 %, 47 % at the beginning of the 1950s, 1970s, 24 %. Obviously, Yunnan drought in the history of the forest coverage rate has increased every year and every year to reduce significantly related to lower forest cover, the more drought [26].

In this paper, using the Remote Sensing image data to acquire the vegetation cover data. And in the same time, the study also use the normalized difference vegetation index (NDVI) and the vegetation coverage of the relational model to convey that the vegetation cover information in Simao from 2009 to 2012 [27]. The results show that the vegetation cover did occur a certain degree of degradation before and after continuous drought, it means that for the Simao region, the vegetation coverage alters has a significant relationship with the drought.

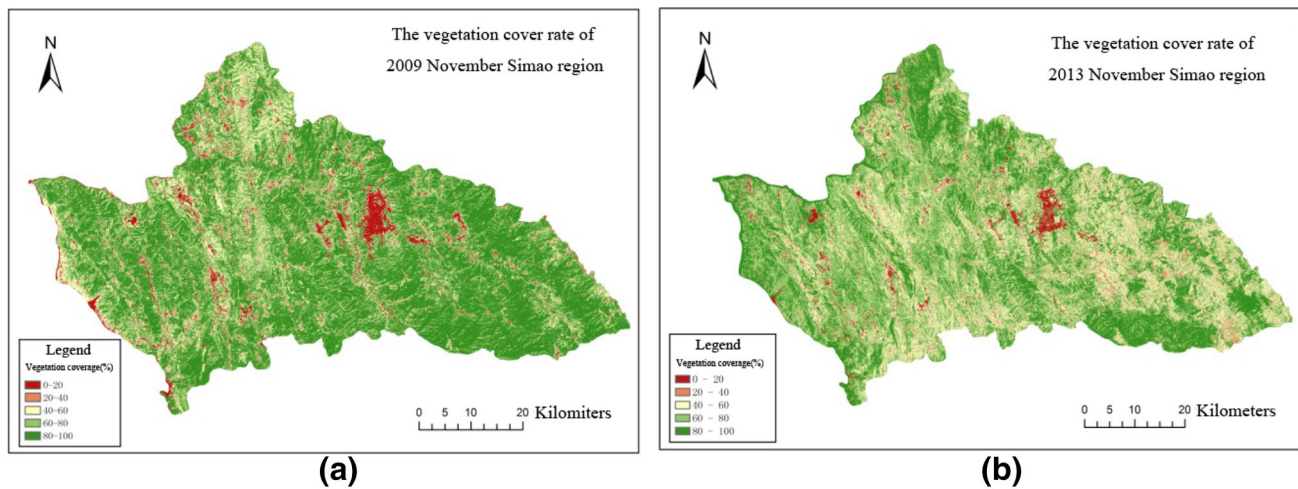


Fig. 6 The vegetation cover rate of 2009 and 2013 Simao region

5.4 Other factors

In the five individual meteorological drought index, the soil moisture drought index is to measure soil moisture level of the drought, according to the soil water content, water retention capacity can be directly reflects the extent of the drought. The aspect, slope, slope position topographical factors such as soil moisture are affected by the formation of drought [28].

Meteorologists believe that the relationship between the slope, aspect, wind and precipitation must be added to the discussion, that the windward and leeward slope will form a significant difference in precipitation landscape: As leeward prevalent downdraft while warming leads to hard into the cloud caused by rain, less precipitation, easier to form arid climate, while the windward slope opposite.

In short, the factors causing droughts are varied, natural factors beyond the control of the human, but the human factor can be set up by human-made, environmentally friendly ideas to avoid as much as possible.

6 Related work

Droughts have strong impacts on the water supply and quality; society and public health; crop production and agriculture; plants, wild fires, and living environments. A variety of studies in the past decades have examined the different aspects of drought events, such as developing different drought indicators [29], monitoring and characterizing the droughts [30], climate change impacts on future droughts [31], and developing early warning systems to survive in drought conditions. There are also a number of studies focused on drought forecasting and estimating the likely drought conditions in the future. In an earlier study, Karl et al. [32] evaluated the probability of receiving a sufficient amount of precipitation to recover from an ongoing drought over a particular period of time. They rewrote the Palmer Drought

Severity Index [33] and utilized the unconditional gamma distribution to obtain the probabilities of future droughts. However, this is disputed for ignoring the dependency and auto-correlation in a precipitation record. Since then, several other methods have been developed and tested in drought forecasting such as Markov Chain model [34], and artificial neural networks [35]. Cancelliere et al. [36] discussed the validity of Markov Chain model for making significant errors in transition probabilities of the Standardized Precipitation Index and then derived the transition probability matrix by an analytical study on the statistics underlying the SPI equations. However, Madadgar and Moradkhani [12] recently argued, in an analytical framework, that the assumption of independent and normally distributed aggregated precipitation volumes is not always true, especially for other hydrologic variables such as runoff and streamflow. They also discussed that for frequency analysis of different drought states, the intense process of obtaining the transition probability matrix from the index equation could be avoided by using multivariate modeling based on copula functions. In several other studies, the climate forecast products of NOAA Climate Prediction Center (CPC) are used for developing probabilistic drought forecasts [37].

7 Conclusions

(1) Spatial and temporal characteristics of drought in Pu'er City: the time, the precipitation data of every station in Pu'er have different degrees of decline, drought events have occurred over the years, according to the frequency division, Jingdong, Jinggu, Zhenyuan, Menglian, Simao, Mojiang areas. The city, the 50-year scale Pu'er City every 10 years on average once or more than once experienced a major drought in the twenty-first century after a major surge in the frequency of droughts, the year occurred in 2001, 2005, 2009 and 2010. Spatially, the northern Pu'er City (Jingdong,

Zhenyuan, North of Mojiang and North of Jinggu) is large and the degree of probability of occurrence of drought is more serious areas to the north and Western (Lancang, Menglian) direction for the mild to moderate drought prone area, while the eastern (Jiangcheng) is sufficient rainfall zone, the probability of occurrence of drought is minimal.

(2) The impact factors of drought in Pu'er: the presence of drought occurrence its universality, statistical analysis of the results by relevance, temperature, altitude and rainfall showed correlation with the formation of drought events indirectly related to vegetation cover and drought events reinforce each other.

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