ASSESSMENT OF DROUGHT DISASTER-CAUSING FACTORS AND DROUGHT RISK REGIONALIZATION IN GUANGDONG PROVINCE

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ABSTRACT: As a serious natural disaster, drought has a critical impact on social economy and people's life. It is of great significance for agricultural management and ecological environment protection to study drought disaster-causing factors and drought risk zoning. Compared with other provinces, Guangdong has higher vegetation coverage and better vegetation growth. However, due to the large inter-annual variation and the uneven distribution within the year of precipitation, Guangdong Province has been troubled by seasonal drought for a long time. Because of its simple calculation method and high sensitivity to vegetation coverage area, Vegetation Condition Index (VCI) was selected as an index to evaluate drought. Based on an 8-day composite Moderate Resolution Imaging Spectroradiometer (MODIS) data, the VCI of Guangdong Province from 2003 to 2017 with a spatial resolution of 250m was calculated. The frequency and intensity of drought are regarded as drought disaster causing factors, the harmfulness of drought causing-factors was discussed. Based on these indexes, the drought risk of Guangdong was analyzed month by month according to different land cover types. The following conclusions are obtained: 1) Compared with other regions of study area, the risk of drought in Leizhou Peninsula is relatively high, and agricultural accounts for a large proportion in this area. 2) In general, the drought risk of agricultural land type is higher than other two land types. It was 7.0% higher than the mixed forest grass land and 23.7% higher than the forest land. 3) The drought risk in March and April is higher than that in other months, and the drought risk in March is the highest. In addition, the drought risk from October to December is also very high, which is consistent with the situation of spring drought and autumn winter continuous drought in Guangdong Province. 4) The risk of drought disaster in agricultural areas is relatively high from January, which is connected with the end of the previous year, resulting in high drought risk from October to April of the next year. The drought risk of agricultural is lower than that of other vegetation types in May and June, and higher than other vegetation types in other times.

1. INTRODUCTION

Drought has seriously affected social economy and people's life (Gu et al., 2011). When the drought reaches a certain degree, it will become a disaster. It is of great significance for agricultural management and ecological environment protection to study the drought disaster-causing factors and divide the drought risk areas.

The traditional discussion on drought risk mainly considers the risk of disaster-causing factors, the exposure of bearing body, environmental vulnerability (Hayes, Wilhelmi, and Knutson, 2004; Hu et al., 2010) and the ability of human disaster prevention and mitigation (Yao et al., 2013). The assessment indexes of different types of exposure and vulnerability are different. Due to the convenient access of indicators to measure the exposure and vulnerability in agricultural areas, the research on drought risk is mostly in agricultural areas (Wang et al., 2005; Wang and Lou, 1997; Liu et al., 2006). On the contrary, the risk assessment index of disaster-causing factors can be unified no matter under any land cover type. The drought disaster-causing factors should be the indexes that can describe the drought intensity. Usually, we can directly use the drought index that can describe drought intensity (Wang et al., 2015) or a drought index as the basis to select some statistical indicators that can describe the drought intensity (Wulan, 2017).

In this paper, drought level and drought frequency, which can represent the severity and frequency of current drought are selected as drought disaster-causing factors. Based on the VCI calculated by MODIS 250m data, the drought disaster-causing factors and drought risk in Guangdong from 2003 to 2017 were analyzed. It provides scientific and technical support for drought resistance.

2. STUDY AREA AND DATA SOURCE

2.1 Study Area

Guangdong is located in the southernmost part of the mainland of China, with a latitude between 20°13′ and 25°31′ and a longitude between 109°39′ and 117°19′. Guangdong belongs to the East Asian monsoon region, with the climate of middle subtropical, south subtropical and tropical climate from north to south, which is one of the most abundant areas of light, heat and water resources in China (Wang, 2018). From north to south, the annual average sunshine hours increased from less than 1500 hours to more than 2300 hours, and the annual average temperature was about 19 ℃ - 24 ℃. Guangdong has abundant precipitation, the annual average precipitation is between 1300 mm and 2500 mm, with an average of 1777 mm (Li and Wang, 2019). The spatial distribution of rainfall is basically higher in the south and lower in the north. The annual distribution of precipitation is uneven, and the inter-annual variation is also large. The precipitation in rainy years is more than twice that in less rainy years (Yang, 2008).

2.2 Data Source

MODIS is mainly carried on terra and aqua satellites (Schell, 1973) In this paper, MODIS data of 250 m surface reflectance over 8 days from 2003 to 2017 was used. There are 46 periods per year and 690 periods during the study period. NDVI and VCI were calculated by using the red band and near-infrared of each period. The land use/land cover data of MODIS is also used in this paper. The classification data of IGBP are integrated into forest, forest grass mixture, agricultural and other types of low vegetation cover.

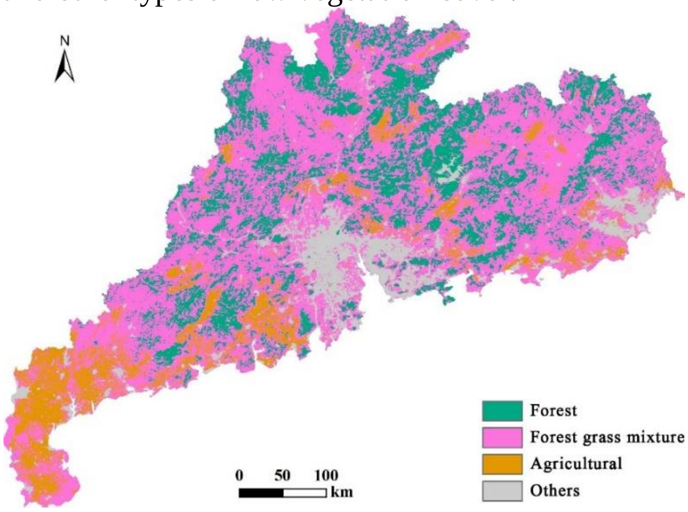

Figure 1 Land use/Land cover map of Guangdong

3. METHODOLOGY

3.1 Calculation of VCI

NDVI was originally proposed by Rouse et al. (Schell, 1973) based on the following function:

$$NDVI = (NIR - R) / (NIR + R) \quad (1)$$

The range of NDVI values is -1 to 1. Negative value indicates that the ground cover is cloud, water, snow, etc.; 0 means rock or bare soil; positive value indicates that there is vegetation coverage, which increases with the increase of coverage.

VCI was originally proposed by Kogan (KOGAN, 1990). it is a remote sensing drought index based on NDVI. The formula is as follows:

$$VCI = 100 \times (NDVI_i - NDVI_{min}) / (NDVI_{max} - NDVI_{min}) \quad (2)$$

where $NDVI_i$ is the NDVI of phase i of the current year; $NDVI_{max}$ and $NDVI_{min}$ are the maximum and minimum values of NDVI in period i. The maximum and minimum values of denominator reflect the best and worst condition of vegetation growth in period i, and the difference represents the habitat of vegetation in a certain sense. The smaller the difference between NDVI and minimum value in a certain year, the worse the vegetation growth in this period in the current year (KOGAN, 1990). The range of VCI is 0 to 100. The smaller the value is, the worse the growth of vegetation and the more serious the drought is (Shen et al., 2017; Liang et al., 2017).

VCI is divided into three levels (Liang et al., 2017; Guo and Guan, 2007). If the VCI ranges from 70 to 100, it indicates normal vegetation conditions and no drought. A value between 30 and 70 indicates moderate vegetation conditions and moderate drought, and below 30 indicates extremely poor growth conditions and severe drought.

3.2 Calculation of drought frequency

The calculation formula of drought frequency of different grades is as follows (Qian et al., 2016):

$$f = n / N \quad (3)$$

where f is the frequency of drought, N is the total number of data (N = 690), and n is the number of different degrees of drought.

3.3 Calculation of drought risk

The drought risk is obtained by multiplying the frequency of drought with the severity of drought. The formula is as follows (Li et al., 2012):

$$R = \sum_{i=1}^{n} Q_i \times f_i \quad (4)$$

where i represents different levels of drought. Q is the weight of different levels of drought. The value of Q for no drought is 0, the value of Q for moderate drought is 1, and the value of Q for severe drought is 2. f is the frequency of drought of different grades. If the degree of drought is deeper and the frequency of drought is greater, the value of drought risk R is greater.

4. RESULT

4.1 Analysis of Drought Disaster-causing Factors

Taking the average value of VCI per pixel, the spatial distribution of the overall drought from 2003 to 2017 was obtained. And it is divided into three levels according to Table 1. The higher the level of drought, the greater the risk of drought becoming a disaster. The average VCI of Guangdong is 66.8. It can be seen from the spatial distribution map of drought level that the average VCI value of Guangdong is medium and slightly higher. It is mainly characterized by moderate drought and no drought. Based on the statistics of drought frequency in Guangdong from 2003 to 2017, the spatial distribution of drought frequency was obtained. The higher the frequency of drought, the greater the risk of drought becoming a disaster. The average frequency of Guangdong is 0.46. It can be seen from the spatial distribution map of drought frequency that the average frequency of Guangdong is medium and slightly lower. The frequency of drought in most parts of the province is below 0.6.

The drought level and frequency of Leizhou Peninsula are higher than other regions. It is the main concentration area of moderate drought. And the drought frequency in this area is between 0.4 and 0.6. This area is dominated by agricultural land, so drought has a greater impact on this area. Compared with the surrounding areas, the drought level and frequency in the Pearl River Delta region are higher. This is due to the fact that the basic drought index is the VCI index representing the situation of vegetation. The urbanization process around the Pearl River Delta region is rapid, and the cities expand outward year by year. The decrease of vegetation in the process of urbanization leads to the decrease of water holding capacity of surface soil and the increase of drought frequency. At the same time, the decrease of vegetation will lead to the decrease of VCI.

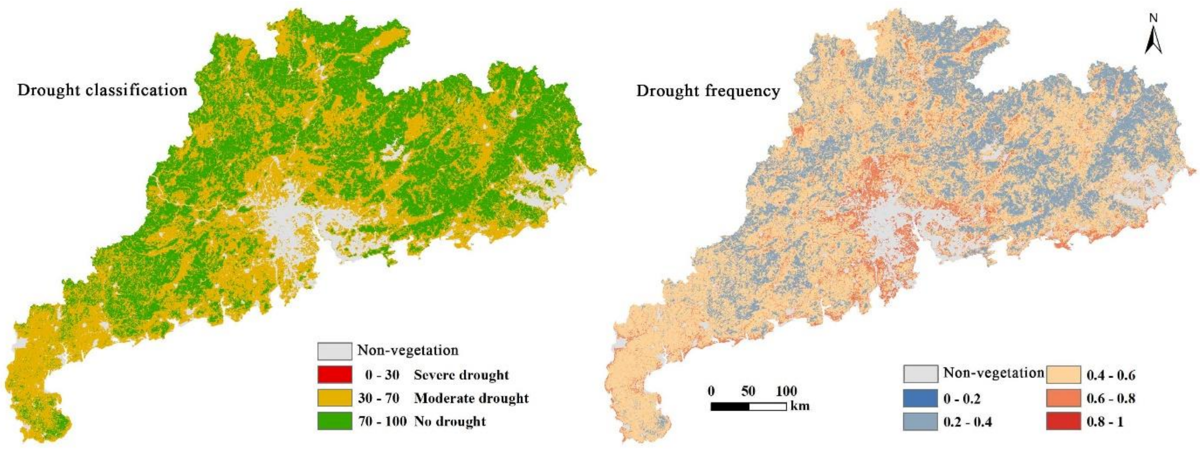

Figure 2 Spatial distributions of drought disaster-causing factors of Guangdong

The average frequency of moderate drought in Guangdong is 0.39, which is in the middle low level. The frequency of moderate drought in most areas of the province is less than 0.6, and even below 0.4 in some areas. The frequency of moderate drought in Leizhou Peninsula is between 0.4 and 0.6, which is higher than that in other areas. The frequency of severe drought in Guangdong is basically below 0.2, and the average frequency of severe drought is 0.07. This shows that the main drought in Guangdong Province is moderate drought, and severe drought is rare.

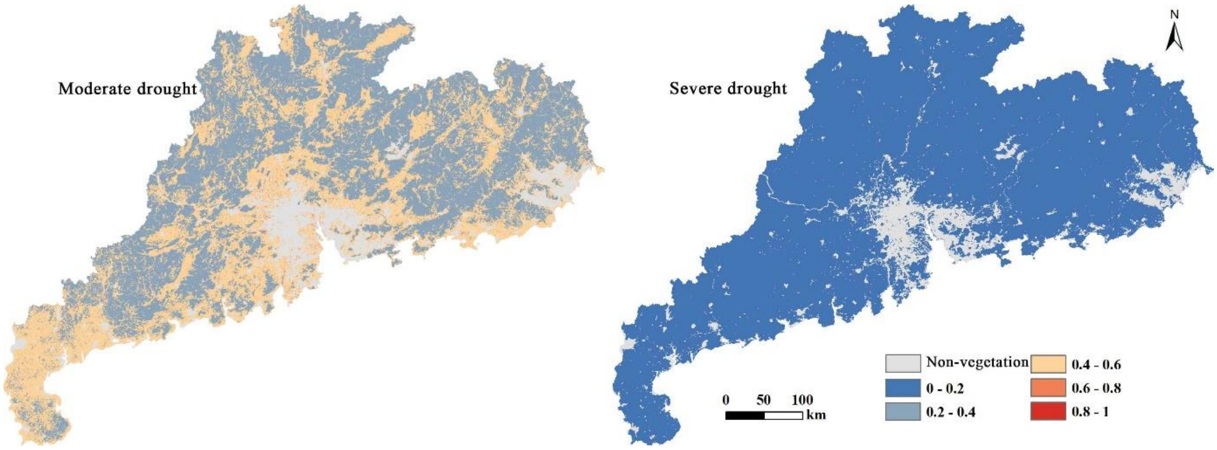

Figure 3 Spatial distribution of drought frequency at different levels of Guangdong

4.2 Drought Risk Zoning Map

The drought risk in Guangdong Province is generally ranging medium to low. It is highest for the agricultural area and lowest for the forest area. The drought risk of agricultural area is 23.7% higher than that of forest area, 7.0% higher than that of forest grass mixture area, and 10.2% higher than that of the total Guangdong, respectively. The drought risk of Leizhou Peninsula is a little higher than that of other regions.

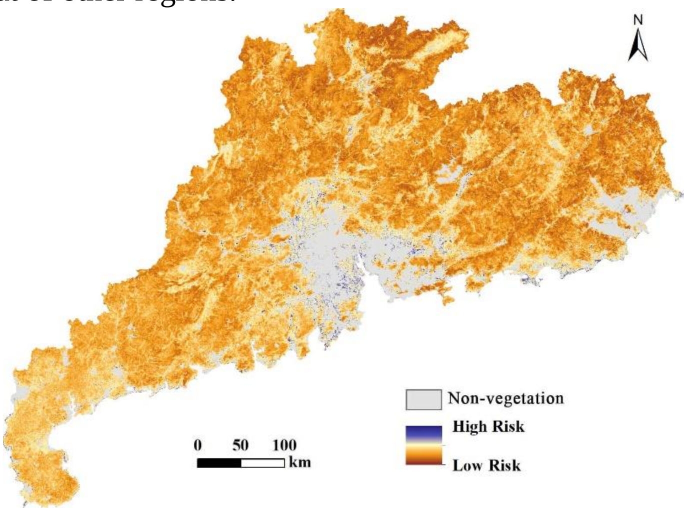

Figure 4 Spatial distribution of drought risk assessment in Guangdong Province

4.3 Monthly drought risk analysis

The drought risk in Guangdong Province reached the highest from March to mid-April, followed by October to December. This is consistent with the frequent occurrence of spring drought and autumn winter continuous drought in Guangdong.

Except for early-May and mid-June, the drought risk of forest area was lower than that of other land types, especially in January, February and September to December. The vegetation coverage of forest area is better than other land types, and the self-regulation ability is also better, so it is not easy to drought, and the risk of drought of forest area is low. The drought risk of forest fluctuated at a relatively high level from March to June. It began to decline slowly in July and remained at a relatively stable level in September

The drought risk of forest grass mixed area was higher from mid-March to mid-April and late October to December. The vegetation cover of this type is sparse than that of forest, and it is more easily affected by environmental factors. Under the same dry and wet conditions, the possibility of drought was higher in the forest grass mixed area than that in forest area. The drought risk of forest grass mixed type reached the peak in March, and then showed a downward trend although fluctuated, until October.

The drought risk in agricultural areas was at a relatively high level from January to the end of April, and then increased again in early October until December. It will reach a slightly lower level in May, then fall to a lower level in late August and then rise to a higher level in early October. Except for May and June, the risk of drought in agricultural areas has been higher than other types.

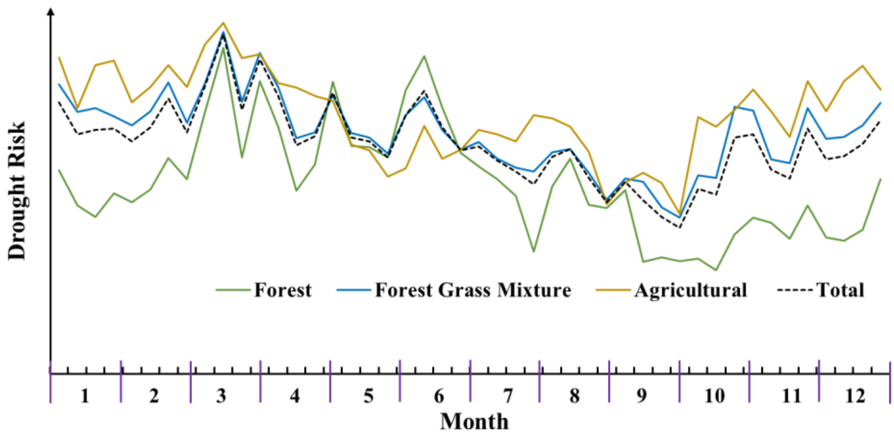

Figure 5 Statistical chart of drought frequency of different months

5. CONCLUSIONS

In this paper, we calculated VCI using an 8-day composite, 250m resolution MODIS data from 2003 to 2017 in Guangdong province. Based on VCI data, the drought risk factors and drought risk of different land cover types in Guangdong Province were analyzed. The following conclusions are obtained：

1) The average VCI of Guangdong is 66.8, which is above the middle level. The average frequency of Guangdong is 0.46, which belongs to the lower middle. The frequency of drought is below 0.6 in most areas of the province. The drought in Guangdong is mainly moderate drought. The drought level and frequency of Leizhou Peninsula are higher than other regions. It is the main concentration area of moderate drought.

2) The drought risk is highest in the agricultural area and lowest in the forest area. In Guangdong, the drought risk is in the middle low level and Leizhou Peninsula is a little higher than that of other regions.

3) The drought risk in Guangdong reached the highest from March to mid-April, followed by October to December. Unlike other land cover types, the drought risk of forests is very low in January, February and September December. From October to April of the following year, the agricultural area has been a period of high drought risk.

Using remote sensing data to analyze drought risk can make up for the inaccuracy of the traditional point-based monitoring data in large-scale drought risk analysis. It is worth noting that land cover changed from 2003 to 2017, and the change from vegetation to non-vegetation will have a greater impact on our research (Li and Wang, 2020). In the analysis of drought risk, in addition to drought level and frequency, the duration of drought may also have a certain impact on drought risk. In the follow-up study, the duration of drought can be used as a new drought disaster-causing factor. In addition, Guangdong province is a cloudy area, and its remote sensing image has poor quality due to frequent cloud occlusion. Therefore, the study of drought index model in cloud-covered area on the basis of VCI is also a worthy work in the future.

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