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Procedia Environmental Sciences 2 (2010) 1679–1691

Procedia Environmental Sciences

International Society for Environmental Information Sciences 2010 Annual Conference (ISEIS)

The Impact of Sustained Drought on Vegetation Ecosystem in Southwest China Based on Remote Sensing

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Abstract

Southwest China is an important ecological shelter and ecologically vulnerable area. Since last winter and this spring, southwest china have suffered from sustained drought that rarely happened in the same season of past years, severely threatening the health of vegetation ecosystem. Annually contemporaneous difference of NDVI is used as an evaluation indicator in this analysis, in which vegetations are monitored and analyzed in a macro-scale. The results indicate that from August 2009 through March 2010: 1) vegetation in southwest China was remarkably impacted by sustained drought, leading to the ascendant trend of threatening degree. 2) the area of vegetation ecosystem that suffered from this disaster in Yunnan, Guangxi and Guizhou accounts for more than 80% of the total area of the vegetation ecosystem in these three administrative regions. 3) farmland vegetation was seriously damaged, resulting in large areas of crops dying off and failing and reservoirs and ponds drying up; 4) The effect on natural vegetation was obvious and the growth was apparently suppressed. Large areas of vegetations in dry-hot valley and Karst area degenerated, threatening the local biodiversity. Verification showed that study result is consistent with the result of practical monitoring, indicating that annually contemporaneous difference of NDVI responds strongly to the spatial and temporal sustained drought, which could precisely represent the occurrence and progress of drought and detailed spatial distribution.

Keywords: MODIS; NDVI; Sustained Drought; Southwest China; Vegetation Ecosystem

1. Introduction

Sustained drought has major impact on the composition, structure and function of the vegetation ecosystem[1-2], even leading to reduction of biodiversity and degradation of vegetation, which has been verified by various studies [3-4]. Since autumn 2009, most part of the Southwest China has suffered from sustained drought succeeding in seasons from autumn to next spring that rarely happened in the past. The drought showed the characteristics of long duration, widespread range and serious impact. The regions affected include Yunnan, Guangxi, Guizhou, Sichuan and Chongqing. Since the beginning of autumn in 2009, the precipitation in that region had been reduced no less

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doi:10.1016/j.proenv.2010.10.179

than 50% compared to the same periods in the past several years, while the precipitation of parts of the region had been reduced 70%-90%. Furthermore, the temperature was relatively higher than that of the same periods in the past years, leading to serious impact on agricultural production in central parts of the areas suffered from drought and on the supply of drinking water to the inhabitants [5]. The safety of vegetation ecosystem in that region would also be severely threatened.

Southwest China is the hotspot area for the biodiversity conservation around the globe, and important ecological barrier and ecologically fragile area in China, including various fragile vegetation ecosystems formed by dry-hot river valley, karst landform and other complex environments [6-11]. The sustained drought caused evident change in regional conditions of water and heat, disturbing the normal succession of the vegetation, influencing the functioning of the vegetation service and consequently resulting in the serious impact on fragile ecological environment in Southwest china. The analysis of the impact of sustained drought on vegetation in Southwest China will have important reference value for the protection of vegetation service and restoration of fragile ecological environment.

2. Research Area

The Southwest China referred to in this article includes five provinces (municipality, autonomous region) of Yunnan, Guangxi, Guizhou, Sichuan and Chongqing, with the total area of the region reaching at about $1.37\times10^6 km^2$， accounting for 14.3% of the area of territory(fig.1). The region is located at the transition zone connecting Qinghai-Tibet Plateau and the eastern and southern plains in China. The conditions of light and heat are preferable, while the precipitation distribution is not even annually and within a year as a result of the obvious impact of monsoon climate and the landform of hill [12].

Southwest China is the cradle of main rivers in Asia, lying in the upstream of Yangtze River, Zhujiang River, Brahmaputra and Lancang River. The protection of ecological environment is of great importance for the regional ecological safety in downstream. The region is also one of those areas that claim most abundant species and vegetations in China, including at least 10000 types of higher plants, among which more than 700 types appear only in that region. 44% of tree species and main vegetations in northern hemisphere could be found here [13].

Vegetation Ecosystem in this region is highly fragile as a result of the impact of special geology, landforms and climate. Karst landform is broadly distributed in the east where the exposure of limestone is very serious. Dry river valleys are broadly distributed in the west where vegetation is sparse and water and soil loss is severe, which will likely to cause degradation of vegetation under disturbance.

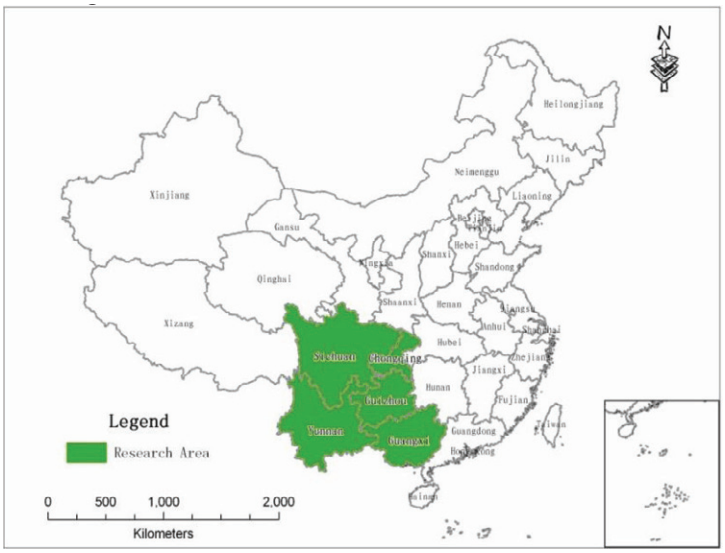


Fig.1. The Position of Southwest China

3. Research Data and methods

3.1. Data source and data processing

NDVI（Normalized Difference Vegetation Index）is an important indicating factor reflecting the growth and activity of vegetation, and also the important index for estimation of the crop production, which is sensitive to the variation of precipitation during the whole growing period of crop in arid and semi-arid areas [14-17]. The essay selects NDVI as the assessment index to provide monitoring and quantitative investigation of vegetation on a large scale using remote sensing and assess rapidly the impact of drought on vegetation ecosystem succession, stone desertification progress, crop production and water and soil conservation in five provinces (municipality, autonomous region) of Southwest China through analysis of NDVI variation in the same period annually.

Data source: The US earth observation satellite TERRA and AQUA MODIS data with spatial resolution of 250 meters are selected, including: ①MODIS HDF data from August 2008 to March 2010;②largest NDVI synthetic data（NASA）during 16 days from August 2008 to March 2010;③landuse type data in Southwest China in 2007; ④precipitation and drought and flooding data in parts of Southwest China from June 2009 to March 2010（China Meteorological Administration）.

Data processing: ①Images with less residual cloud and are ready for atmospheric correction, geometric correction and resampling will be selected from the MODIS data products for atmospheric correction, geometric correction and cloud removal;②NDVI maximum value technology will be used to make comparison among NDVI values of every pixel on a daily basis and Maximum Value Compositing adopted to remove the impact of solar altitude and cloud and create semimonthly and monthly NDVI data [18];③calculate annually NDVI difference in the same period and represent the seriousness of impact of drought on vegetation using variation value.

3.2. Research Method

Macro and local levels will be combined in the selection of research areas: macro areas consisting of five provinces (municipality and autonomous region) in Southwest China will be the representation of overall change as a result of the impact of sustained drought on regional vegetation ecosystem; local areas will instead be selected as the typical areas in Southwest China to verify the connectivity of vegetation growth and degree of drought.

Based on the difference of $NVDI_{variation}$, degree of impact will be categorized as: no variation, minor variation, moderate variation and strong variation. That is, $NDVI_{variation} \geq 0$ denotes vegetation growth being equal to or better than that before the drought and is regarded as no change; $-0.05 \leq NDVI_{variation} < 0$ denotes minor variation; $-0.1 \leq NDVI_{variation} < -0.05$ denotes moderate variation; $NDVI_{variation} < 0.1$ denotes strong variation.

4. Result and analysis

4.1. Remote sensing analysis of the change in the same period in the vegetation of Southwest China under the impact of sustained drought

Through the study of the change of NDVI in the same period from August 2009 to March 2010, the impact of sustained drought on vegetation in Southwest China will be analyzed. In general, vegetation in Southwest China suffers from serious drought, with the area of vegetation in Guizhou, Guangxi and Yunnan affected by drought accounts for more than 80% of the total area of the three provinces (autonomous region) (fig.2 and table 1). Vegetation with strong variation center at mideast areas of Yunnan province, southwest areas of Guizhou province and northwest areas of Guangxi autonomous region (fig.3).

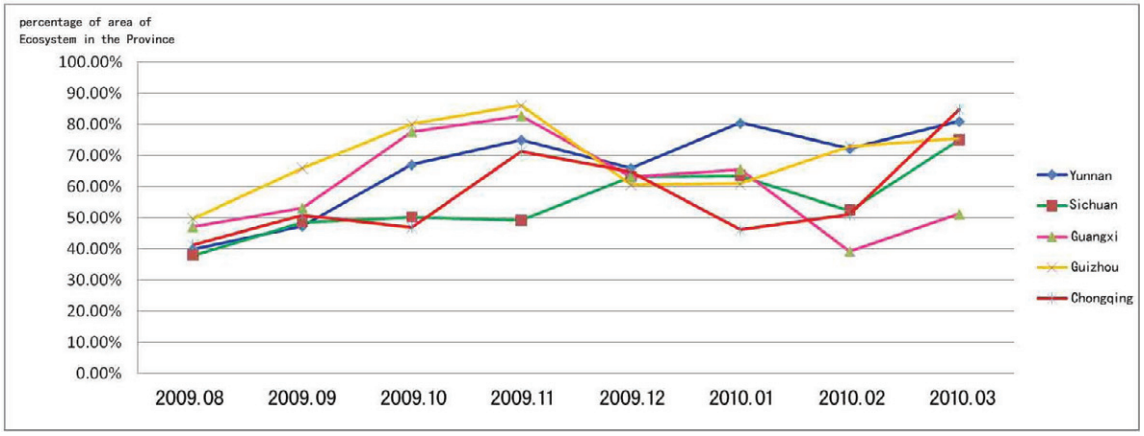
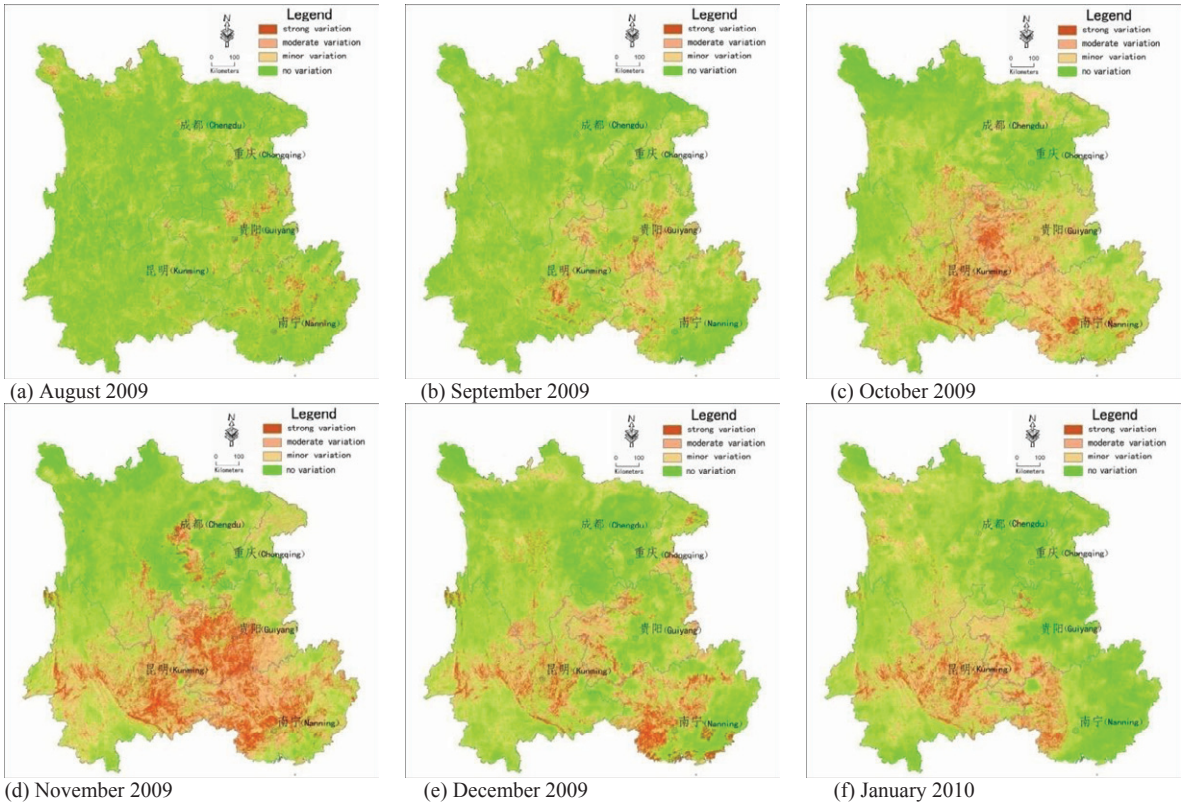


Fig.2. Dynamic change of remote sensing monitoring of Impact of sustained drought on vegetation in Southwest China

Table 1. Result of remote sensing monitoring of Impact of sustained drought on vegetation in Southwest China（2009.8-2010.3）

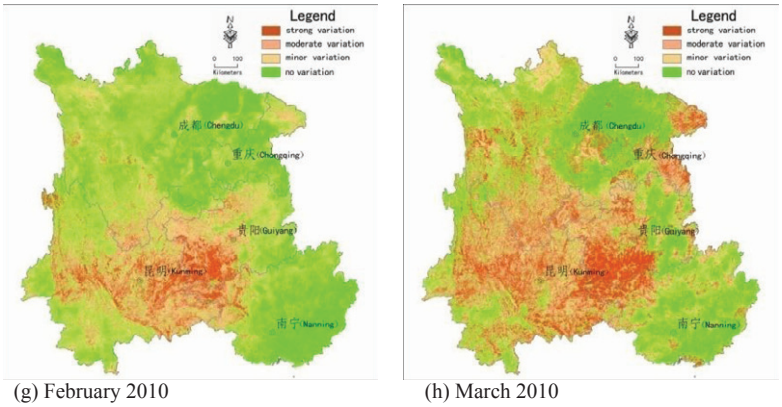
Province/Period		Affected Vegetation		Affected Natural Vegetation		Affected Farmland Vegetation	
		Area（km^2）	Percentage of area of Vegetation in the province（%）	Area（km^2）	Percentage of area of natural vegetation in the province（%）	Area（km^2）	Percentage of area of farmland in the province（%）
Yunnan	Aug 2009	152407.5	39.8	117945.0	38.6	32371.5	44.5
	Sep 2009	180476.8	47.2	140450.3	46.0	37462.3	51.5
	Oct 2009	256038.5	66.9	201051.0	65.8	52512.3	72.2
	Nov 2009	286446.3	74.9	227193.5	74.3	56891.3	78.2
	Dec 2009	251968.5	65.9	199663.5	65.3	50157.0	68.9
	Jan 2010	307216.3	80.3	243946.0	79.8	61068.3	83.9
	Feb 2010	275889.5	72.1	218566.3	71.5	55334.8	76.0
	Mar 2010	309262.5	80.9	245982.3	80.5	60860.5	83.6
Sichuan	Aug 2009	185888.8	37.8	124951.8	39.3	47648.3	34.8
	Sep 2009	238210.3	48.4	160793.5	50.6	56460.5	41.2
	Oct 2009	246523.0	50.1	150261.5	47.3	80336.5	58.7
	Nov 2009	241323.0	49.1	147042.0	46.3	79378.0	58.0
	Dec 2009	310369.3	63.1	195817.8	61.6	91871.0	67.1
	Jan 2010	312025.5	63.5	212014.8	66.7	76557.0	55.9
	Feb 2010	257035.8	52.3	175307.8	55.2	60416.0	44.1
	Mar 2010	285139.8	58.0	203453.8	64.0	60193.5	44.0
Guangxi	Aug 2009	111219.0	47.1	78504.3	44.7	31509.5	54.4
	Sep 2009	125431.3	53.2	95178.8	54.1	29437.0	50.9
	Oct 2009	182917.0	77.5	132856.0	75.6	48424.3	83.7
	Nov 2009	194810.0	82.5	143895.5	81.9	49561.0	85.6
	Dec 2009	148907.8	63.1	109045.0	62.0	38481.0	66.5
	Jan 2010	154434.8	65.4	121806.3	69.3	31709.0	54.8

	Feb 2010	92468.8	39.2	74216.8	42.2	17648.0	30.5
	Mar 2010	120653.0	51.1	92112.5	52.4	27133.5	46.9
	Aug 2009	87340.3	49.6	54450.3	46.3	32646.8	56.1
	Sep 2009	116062.0	65.9	75022.3	63.8	40516.0	69.6
	Oct 2009	140687.0	79.9	93035.0	79.1	47133.5	80.9
Guizhou	Nov 2009	151387.8	86.0	100797.0	85.7	50170.0	86.2
	Dec 2009	106496.0	60.5	71022.3	60.4	35176.5	60.4
	Jan 2010	107135.0	60.8	75260.0	64.0	31825.3	54.7
	Feb 2010	128267.8	72.9	86479.0	73.6	41653.5	71.5
	Mar 2010	132728.8	75.4	90511.8	77.0	42004.8	72.1
	Aug 2009	34133.3	41.3	12886.0	37.0	20821.0	44.1
	Sep 2009	42038.0	50.8	15062.5	43.3	26513.5	56.1
	Oct 2009	38760.3	46.8	18780.0	54.0	19724.3	41.8
Chongqing	Nov 2009	58897.8	71.2	25696.0	73.9	32838.8	69.5
	Dec 2009	53566.3	64.7	22227.8	63.9	30928.8	65.5
	Jan 2010	38136.0	46.1	17542.3	50.4	20248.8	42.9
	Feb 2010	42126.0	50.9	16237.5	46.7	25463.8	53.9
	Mar2010	46898.0	56.7	21098.5	60.7	25543.0	54.1



(a) August 2009 (b) September 2009 (c) October 2009

(d) November 2009 (e) December 2009 (f) January 2010

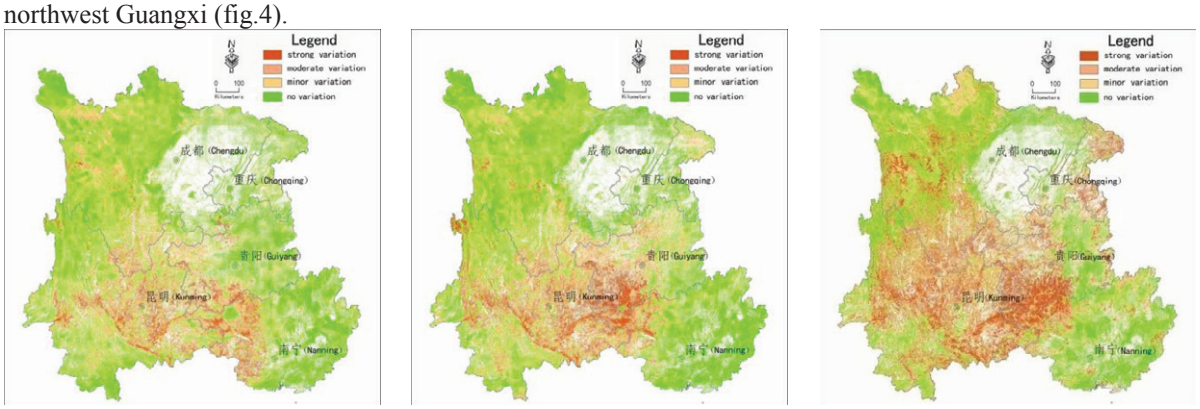


(g) February 2010 (h) March 2010

Fig.3 Distribution map of the ecological impact of drought in Southwest China

The result of remote sensing monitoring of the impact on vegetation indicates that the impact of drought on the vegetation in Southwest China is on the rise (fig.3a-d). Area of vegetation affected in Guizhou and Guangxi account for more than 80%, and in Yunnan and Chongqing account for more than 70% of total area of the provinces in November. Extensive vegetation with strong variation appear in central and eastern part of Yunnan, western Guizhou and northwestern Guangxi. After the precipitation process in December 2009, drought in almost all provinces (municipality, autonomous region) was mitigated, showing moderate variation in general, except for Sichuan where the area of vegetation affected was increasing (fig.3e). Drought was fluctuating when entering into the year of 2010 in which March had seen a resurgence of drought. Area of vegetation affected in Yunnan account for more than 80%, while the percentage in Guizhou is close to 75% and correspondent numbers in Sichuan, Chongqing and Guangxi are more than 50% respectively. Extensive regions with strong variation center at southwest Guizhou and northwest Guangxi. While northeast Chongqing, Southern Sichuan and most part of Yunnan were dominated by moderate variation areas (fig.3 f-h).

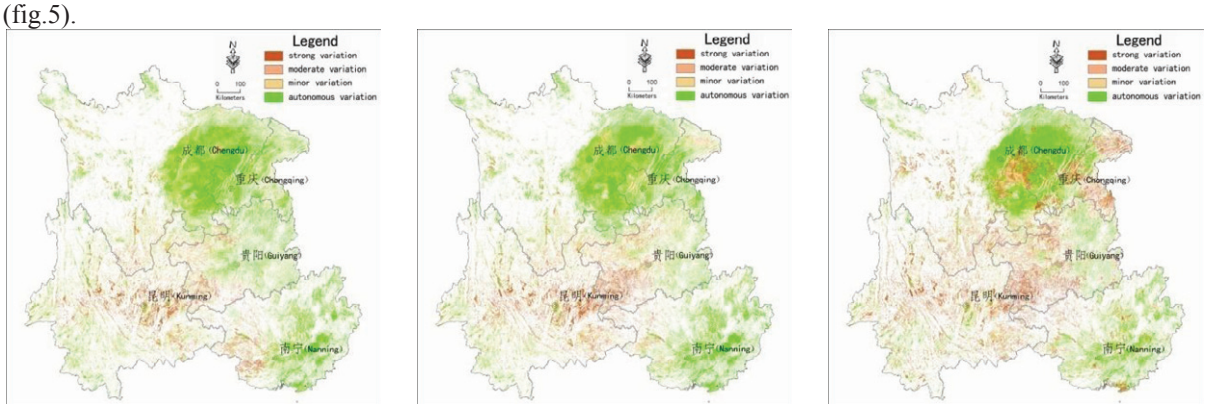
The result of remote sensing monitoring of the impact on natural vegetation indicates that the impact of sustained drought on natural vegetation was relatively moderate, while the impact on grass vegetation and man-made forest in dry-hot river valleys and karst topography was severe, leading to death of plants in a large area or mosaically. Under the influence of sustained drought, natural vegetation demonstrated the characteristics of minor variation, with some parts showing moderate variation and few parts showing strong variation in the early stage. Until March 2010, affected natural vegetation in Yunnan accounted for 80% of all natural vegetation in the whole province, and in Guizhou the correspondent percentage is 70%. Areas with strong variation center at southwest Guizhou and northwest Guangxi (fig.4).



(a) January 2010 (b)February 2010 (c)March 2010

Fig.4 Distribution map of the ecological impact of drought on natural vegetation in Southwest China

The result of remote sensing monitoring of the impact on farmland vegetation indicates that farmland vegetation suffered from great loss, leading to the death of large area of crops or total crop failure. The impact of sustained drought on farmland vegetation appeared earlier. Affected areas had appeared separately in Guangxi, Guizhou and Yunnan in September 2009; the impact in November was most severe and the area of farmlands affected by drought in Guizhou and Guangxi accounts for more than 80% of the total area of farmland in the whole province. Change of Vegetation with strong variation center at central and eastern part of Guizhou, central and eastern part of Guangxi and eastern Yunnan. Until March 2010, percentage of farmland vegetation affected by drought was decreasing in a certain degree, except for Yunnan where the area of farmlands affected by drought in Yunnan accounts for more than 80% of the total area of farmland in the whole province and for Guizhou whose percentage is close to 70% (fig.5).



(a)January 2010 (b)February 2010 (c)March 2010

Fig.5 Distribution map of the ecological impact of drought on agricultural vegetation in Southwest China

4.2. Analysis of impact of vegetation ecosystem in the typical areas

The study was based on the statistics of precipitation and temperature in the main cities in Southwest China from November 2009 to February 2010. The cities of Xichang, Lijiang, Xingren, Mengzi, Kunming, Guiyang and Dali where the precipitation reduced by 60% compared to the same period in the past was selected as the typical areas (fig.6). Semimonthly maximum NDVI variation analysis was employed to study the NDVI variation trend of farmlands and forest vegetation in typical areas from August 2009 to March 2010.

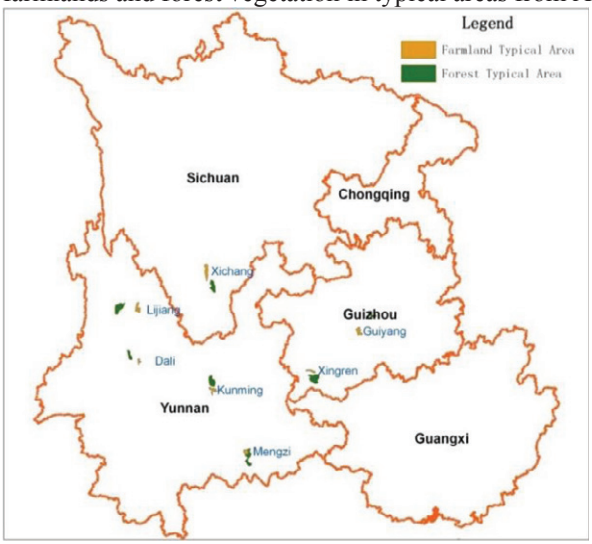


Fig.6 Distribution of typical regions where the precipitation declined by more than 60% in corresponding period in Southwest China

The monitoring result of ecological impact indicates that generally the growth of vegetation in typical areas in Southwest China has been worse compared to the same period in last year and shown a deteriorating trend by month since september 2009, indicating a positive correlation with anomaly percentage of precipitation. Except for Guiyang, monitoring results of farmland quadrat of the other six typical areas were getting worse in December, with a high ratio of moderate variation (fig.7). Among which, Guiyang had encountered precipitation process from the end of November to the early December and drought was mitigated in a certain degree and vegetation growth was getting better, while the trend was getting worse in general. The forest vegetation presented the same pattern with the variation intensity and variation rate being lower than that of farmland vegetation, showing a strong ability of anti-drought of natural vegetation in a certain degree (fig.8).

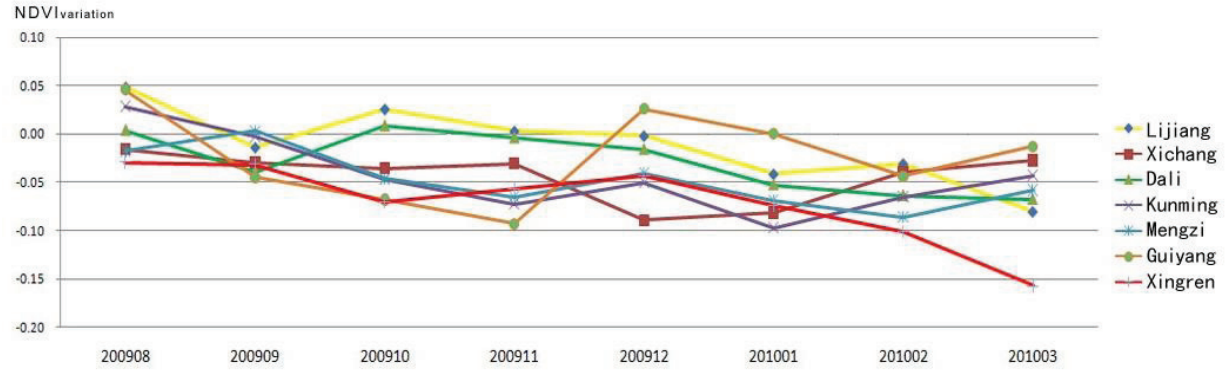


Fig 7 Comparison of change in NDVI of farmland in corresponding period in Southwest China (Dec.2009-Feb.2010)

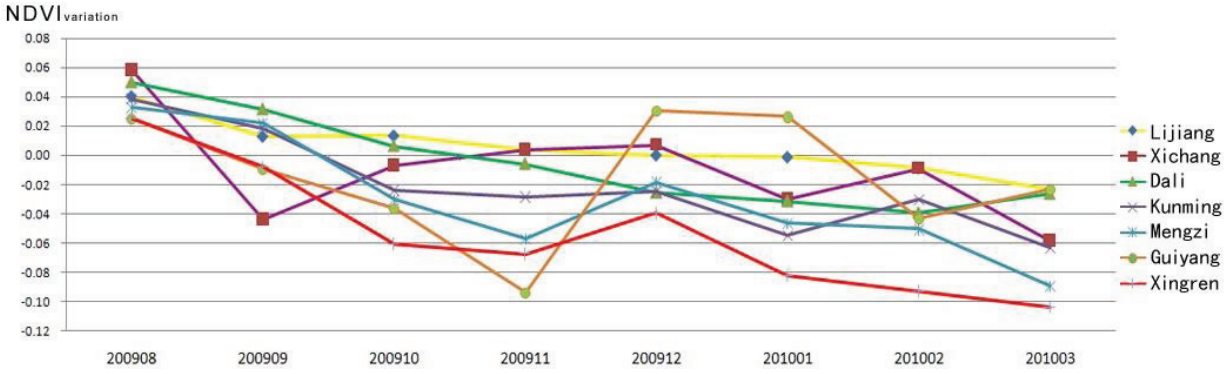


Fig 8 Comparison of change in NDVI of forest vegetation in corresponding period in Southwest China (Dec.2009-Feb.2010)

5. Conclusion

As the most common meteorological disaster in the nature, the impact of drought on ecological environment is far beyond that of other natural disasters. Myriad research projects have been initiated on the impact of drought nationally and internationally, including the impact of drought on plant growth, on amount of evaporation and dissipation, on the drop in crop yields, on hydrological process of the surface and on vegetation [19-24]. Technological methods of research have transferred from traditional record of meteorological materials and measurement of soil moisture to the combination of multi-platform dominated by remote sensing monitoring and assisted by surface monitoring. The scale of remote sensing monitoring of drought is in progress from specific region to the nation and monitoring methods from case study to extensive simulation [25].

Annually contemporaneous difference of NDVI is selected in this study to represent the seriousness of impact of drought on vegetation. The result indicates that NDVI have a strong response spatially and temporally to the sustained drought, precisely reflecting the occurrence, progress and detailed spatial distribution of the drought. As for the analysis of impact of sustained drought on vegetation, presently vegetation index is mainly adopted to analyze the impact of drought [25-27], for example the anomaly vegetation index adopted by Chen weiying et al. (1994) to assess the super drought occurred throughout the country in 1992 and the assessment of high temperature drought in Sichuan and Chongqing in summer 2006 based on NPP by Mao liuxi et al.(2007). Given the extensive range of this study area and diversified vegetation within the region, on site monitoring could not meet the needs of prompt and comprehensive assessment, thus remote sensing is necessary for the monitoring of vegetation in a macro scale. Annual variation of vegetation index ($NDVI_{variation}$) derived from remote sensing reflects not only the change of vegetation, but also the impact of weather on vegetation. The adoption of annual variation of vegetation index in this study indicates that: in terms of spatial response, annual $NDVI_{variation}$ demonstrates evident shift of drought from Yunnan to south Guizhou and Northwest Guangxi; and in terms of temporal response, in shows a change from moderate variation to local strong variation for forest vegetation. The uniform strong variation of farmland vegetation from January to February indicates that forest and other natual vegetation can use the soil moisture in the deeper layer underground. Despite the fact that growth of vegetation is weaker compared to the same period in the past, while the ability of anti-drought is far better than that of farmland, which is consistent with the result of eco-meteorological monitoring and assessment of high temperature drought in Sichuan and Chongqing in summer 2006 by Mao liuxi et al.

Study areas for the research on impact of sustained drought in China were concentrated in arid and semi-arid regions such as Northwest and North China in the past, while the research on impact of sustained drought on vegetation was relatively absent, given the fact that weather is warm and moist and precipitation abundant in Southwest China. This study claims that sustained drought will not only cause direct loss of biomass of vegetation ecosystems in Southwest China, but also produce major impact on succession, vegetation ecosystem service and ecological environment of regional ecosystems, which is demonstrated mainly in several aspects below: 1)

vegetation in stone desertification areas is sensitive to drought, while vegetation shows a poor ability in resisting drought and precipitation in Spring is abnormally absent, leading to the deferral of growing period of vegetation or even extensive death of plants [28-29], and large area of degradation of surface vegetation in karst areas. This is usually the driving force of major change on structure and function of ecosystems, for example the degradation of forest vegetation mainly consisting of arbor to those mainly consisting of shrub and grass, even to the stone desertification vegetation with no vegetation cover, thus accelerating the stone desertification of regional surface. 2) sustained drought cause damage to surface structure, leading to the receding ability of conservation of soil and water in areas of severe drought, for instance the deterioration of loss of water and soil in dry-hot river valleys influence the structure pattern of plant population in dry-hot river valleys dominated by moisture and combination of various environmental factors, accelerating the degradation of vegetation to arid shrub or slope with scarce grass or even desert. 3) Southwest China is the ecologically fragile area and biodiversity abundant area in the meantime. Sustained drought can inhibit photosynthesis, raise the mortality of plants and stir the outburst of plant diseases and insect pests and possibly increase the frequency and intensity of fire disturbance, easily causing extensive perishment of plants and thus endangering survival of some plant population [30-31], lowering total primitive productivity of terrestrial ecosystems, accelerating reversed succession of ecosystems in fragile areas, and even endangering regional biodiversity. 4) sustained drought influence all carbon processes of vegetation ecosystems, leading to overall recession of activity of vegetation ecosystems in drought inflicted areas in Southwest China, lowering ability of photosynthesis of green plants, reducing carbon fixation, weakening carbon sequestration and even turning vegetation ecosystem originally as carbon sequestration to carbon source, thus influencing the carbon sequestration function of vegetation ecosystems.

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