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Analysis on the Change of Grassland Coverage in the Source Region of Three Rivers during 2000-2012

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Abstract. The Source Region of Three Rivers (SRTR) has very important ecological functions which form an ecological security barrier for China's Qinghai-Tibet plateau. As the biggest nationally occuring nature reserve region in China, the ecological environment here is very fragile. In SRTR the grassland coverage is an effective detector to reflect the ecological environment condition, because it records the changing process of climatic and environmental sensitively. In recent years SRTR has been suffering pressures from both nature and social pressures. With MODIS data the study monitored the grassland coverage continuously in SRTR from 2000 to 2012. The density-model was adapted to estimate grassland coverage degree firstly. Then the degree of change and the change intensity, change type were used to judge the grassland coverage change trend comprehensively. For grassland coverage there was natural change annual or within the year, and the degree of change was used to judge if there was change or not. The grassland has another important characteristic, annual fluctuation, and it can be differed from sustained changes with change type. For grassland coverage, such continuous change, like improvement or degradation, and to what extent, has more guidance sense on specific production practice. On the base of change type and degree of change, change intensity was used to identify the change trend of the grassland coverage. The analysis results from our study show that steady state and fluctuation are two main change trends for the vegetation coverage in SRTR from 2000 to 2012. The conclusion of this paper can provide references in response to environment change research and in the regional ecological environmental protection project in SRTR.

1. Introduction

As the source area of the Yangtze River, Yellow River and Lancang River, the SRTR has an important strategic status and plays a key role [1]. There are Sanjiangyuan National Nature Reserve and Hoh Xil National Nature Reserve in SRTR. The Qinghai-Tibet Railway crosses through this region. Its ecological function is also significant. The SRTR is not only the ecological barrier of the sustainable development for middle and lower reaches of the three rivers, but also the treasure of biodiversity resources for the civilization of human in life restricted zone and the Humanity’s common natural wealth. This area has the unique and typical alpine ecosystem [2], and the grassland, meadow accounts for nearly 80% of the whole area. The grassland is one of the most important elements of the ecological environment in SRTR. The grassland coverage fraction (GCF) is a comprehensive

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quantitative indicator for grassland. And the changes in ecological environment can be reflected from the side by monitoring the indicator continuously.

With the development of remote sensing technology, now it is possible to measure or monitor GCF in regional, national and global region without relying on field survey data. MODIS image data has been widely applied to monitor continuously macroscopic vegetation in large region [3-6]. The validity of the empirical model, based on the vegetation index conversion to estimate vegetation coverage, has been proved by many studies [7-11]. To monitor the change of vegetation in long time sequence, there are many methods such as principal component analysis [12], regression method [13], change vector analysis [14], trend line analysis [15] etc. The last two methods play important roles in qualitative and quantitative analysis and they were continuously used widely in macroscopic monitoring in recent years [3, 16-17].

With MODIS normalized difference vegetation index (NDVI) data during the period from 2000 to 2012, the study adopted non-density model to estimate the GCF in SRTR first. Then the dynamic change of GCF and its trend during the period were analyzed. The results of this study may provide the basic data for ecological construction and protection, reasonable utilization of grassland resources, sustainable development of the regional economy in SRTR.

2. Data and Methods

2.1. Study Area

The SRTR is the hinterland and main body of the Qinghai-Tibet Plateau, located in western China, southern Qinghai Province, latitude31°39 'to 36°12'N, latitude 89°45 'to 102°23'. The eastern and southeastern regions are adjacent to Gansu and Sichuan Province, and the southern and western adjacent to the Tibet autonomous region. The north is connected with the Zhiduo county and the Hoh Xil Nature Reserve region. The total area is 346500 km^2, accounting for about 43% of the total area of Qinghai province. The mountain landscape is dominant here with the average elevation about 4400m and the landform is complex. The climate belongs to Tibetan Plateau climate system. Because of the high elevation, there is thin air in most regions, and vegetation growth cycle here is short. The main vegetation types are meadow complying with obvious horizontal distribution and vertical distribution rules. The main grasslands here are alpine meadow and alpine steppe grassland [18] and there is transition between the two types from southeast to northwest. The alpine meadow presents generally in the region of 3500-4500 m above sea level, with Kobresia as the dominant species. The Alpine grasslands present in the region of 4000-4500 m above sea level, with Cold and xerophytic perennial dense grass and sedge as dominant species, like Stipa, the Qinghai-Tibet Carex, Festuca rubra, Festuca, psammophytic Artemisia[19].

2.2. Data and Pre-processing

The data source is MODIS, including vegetation index product MOD13Q1, leaf area index product MOD15A2 and land cover product MOD12Q1, in the growing season every year, from 2000 to 2012, with growing season every year from May to October. There are 59 field points, collected in August 2011. And the auxiliary reference data includes two grassland degradation thematic data (the main objects are alpine meadow and alpine steppe grassland) which are interpreted from TM / ETM data around 2009 and 2004.

The month maximum values of MOD13Q1 and MOD15A2 were made with maximum value composite (MVC) method, which eliminates the noise impacts of the clouds, atmosphere, and sun elevation angle [20]. But there are still many abnormal values among the data. The S-G filtering algorithm [21] was adopted to further improve the data quality. There are 68 long time consecutive series data in 13 years through the noise reduction processing.

2.3. Research Methods

2.3.1. GCF Estimation. The GCF is the percentage of grassland vertical projection area to the surface area within the observation area. Here vegetation index is the most suitable remote sensing data to estimate the GCF with empirical model [22]. Using non-density model [10, 23] to estimate the GCF, the key formulas and parameters can be found in reference [24]. To verify the accuracy of estimated GCF with the 59 field measured points in August 2011, the accuracy is 87.13% calculated by the root mean square error.

2.3.2. Change Analysis for GCF.

2.3.2.1 Change Vector Analysis. Change vector analysis techniques were used to analyze the change of the target object during many years. And it is used widely to monitor the change trend in many continuous yeas of biophysical parameters from low-resolution remote sensing data. With each value in the target timing as a point in the timing space, the points in several consecutive years can be connected into a change vector. Here the direction of the vector determines the tendency of changes, and the size of the vector characterizes the intensity of the change [25, 26]. This change can be described with change vector as follows:

$$\Delta P(i) = P(i,y) - P(i,x) = \begin{Bmatrix} y_1 - x_1 \\ y_2 - x_2 \\ \cdots\cdots \\ y_n - x_n \end{Bmatrix} \quad (3)$$

Here $\Delta P(i)$ is the change vector of pixel i from year x to y. $\Delta P(i)$ includes change information of i in each time dimension from year x to y. The norm of the change vector $\|\Delta P(i)\|$, determined by the Euclidean distance, indicates the change strength of the indicator.

$$\|\Delta P\| = \sqrt{(y_1 - x_1)^2 + (y_2 - x_2)^2 + \cdots + (y_n - x_n)^2} \quad (4)$$

The type of vector change can be determined by the strength of change and the rate of cumulative annual value . The cumulative rate of change can be defined as following:

$$V_{fg} = \frac{(\sum_{i=1}^{n} y(t_i) - \sum_{i=1}^{n} x(t_i))}{\sum_{i=1}^{n} x(t_i)} \times 100\ \% \quad (5)$$

The qualitative change occurs when $\|\Delta P(i)\|$ is more than the threshold. Here the threshold can be used as the criterion to determine if there is any change. Then the change can be further divided into increased type, fluctuation, degraded type based on the cumulative rate.

Change vector analysis compares information of the pixel directly and gets specific strength and type of change in the time dimension. In 2002 Chen YH [27] studied the change of Chinese terrestrial vegetation NDVI conditions from 1983 to 1992. However with that method, in any target timing period the change tendency can only be expressed qualitatively for no change, improved continually, degraded continually, fluctuation, mutation. When it comes to quantitative subtle change the method is not effective.

2.3.2.2 Change Trend Line Analysis. The degree of change for GCF can be analyzed with change tendency line, which can be expressed with minimum power of the linear regression equation slope of the GCF within a period of time as following:

$$\Theta_{slope} = \frac{n \times \sum_{i=1}^{n} i \times M_{fc,i} - \sum_{i=1}^{n} i \sum_{i=1}^{n} M_{fc,i}}{n \times \sum_{i=1}^{n} i^2 - (\sum_{i=1}^{n} i)^2} \quad (6)$$

Here i is number of the year in the corresponding period of time. $M_{fc,i}$ is the GCF value in the i year. The tendency line of the pixel is a simulated general change of the GCF for the object pixel in a long time. But the line is not a simple connection between the last year and the first year. Here the positive or negative result value indicates that the grassland coverage was improved or degraded, and the absolute value embodies the degree of change.

2.3.2.3 Change Trend Judgment for GCF. It is natural for grassland with inner-annual and inter-annual change. This change belongs to normal natural change, which is regarded as naturally smooth change (no change). The change can be used to judge whether there has natural change or not.

For grassland the inter-annual fluctuations is also a very important feature. There are close correlations between grassland conditions and precipitation. Generally the climate change cycle is long, therefore the fluctuations of the grassland cannot be ignored during the period of more than 10 years. It is too simple if we take the change like this as improved or degraded change. The fluctuations are more frequent and they have the overall improved or degraded trend in the target time period. Here fluctuations and continuing change also can be defined with the change type.

For grassland coverage, improvement or degradation, and to what extent of the change, are the most concerned issues to define the tendency. For specific production practices, such ongoing changes have the most significant guidance. To judge the types of changes with the formula (4), the degree of change has to be determined with equation (5).

To define the change tendency of grassland condition, the process combined with intensity, type, degree can be used as following:

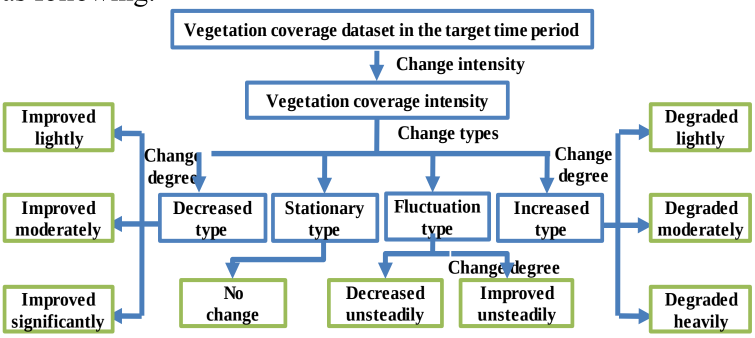


Figure 1. The flow chart to judge the changes trend of grassland coverage

This method takes three parameters to determine the final trend at the same time. Finally there are 9 trend categories. The distinction between categories may be set according to the actual situation of the study area and reference materials.

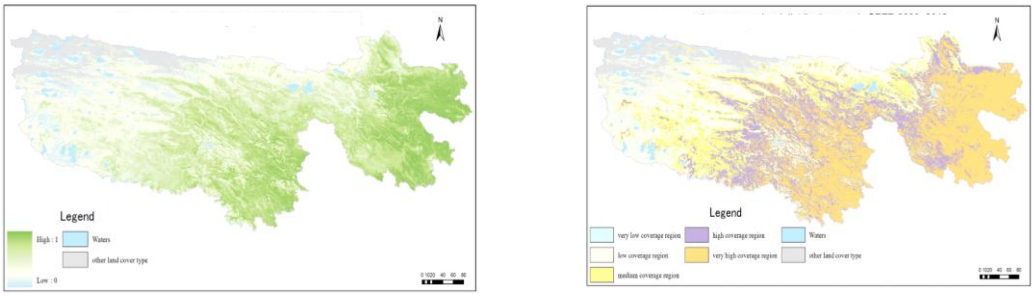
3. The grassland coverage during the period from 2000 to 2012 in SRTR

The average of annual maximum GCF can reflect the average condition of vegetation biomass. During the period from 2000 to 2012, the spatial distribution of GCF in SRTR can be found in figure 2(a), and the special distribution is high in east and low in west. In order to give an intuitive and convenient map, we referred to the professional standard, "The main technical regulations for national desertification monitoring" and "Technical specification for investigation of grassland resources", and divided the vegetation coverage into 5 types. The figure 2(b) and table 1 show the distribution of different levels and area ratio clearly. And average value in northwest is below 0.3, which belongs to the low coverage area; average value in middle area between 0.55~0.75, which belongs medium and high coverage area; average value in eastern and southeastern above 0.75, which belongs to very high coverage area.

In 2012 the grassland coverage in SRTR was in good condition. High and very high grassland coverage area are about 47%. Moreover, in 2012 the percentage of very high coverage region is 4% more than the average level in the last13 years, and the difference is larger than other types', which shows that the grassland condition in SRTR has been improving during the last 13 years.

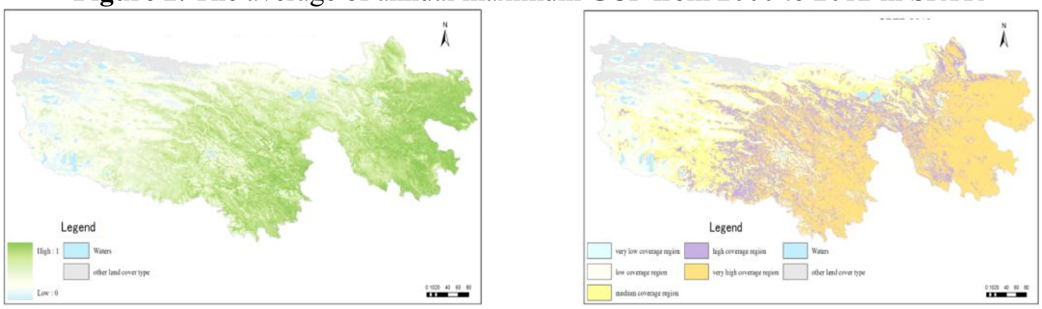
Table 1. The grade standard of Grassland coverage in SRTR

Level	GCF	Types	Area Ratio(%)	
			2000～2012	*2012*
I	<10%	very low coverage region	0.84	0.81
II	10%～35%	low coverage region	26.29	23.17
III	35%～55%	medium coverage region	21.10	20.74
IV	55%～75%	high coverage region	22.17	21.73
V	>75%	very high coverage region	29.60	33.55



(a)spatial distribution of GCF (b)spatial distribution of grassland coverage grades

Figure 2. The average of annual maximum GCF from 2000 to 2012 in SRTR



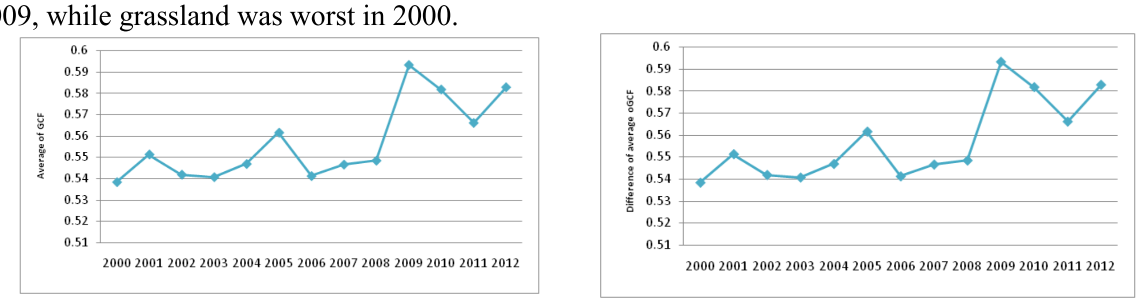
(a)spatial distribution of GCF (b)spatial distribution of grassland coverage grades

Figure 3. The average of annual maximum GCF in 2012 in SRTR

4. The grassland coverage change during the period from 2000 to 2012 in SRTR

4.1. Inter-annual variation analysis

During the period from 2000 to 2012, the change of average of annual maximum GCF is showed as in figure 4. The GCF had been changing fluctuantly and it presented the general amelioration in the last 13 years. From the curve, it can be found that the peaks appear in 2001, 2005 and 2009, and the trough appear in 2003, 2006 and 2011; the largest maximum grassland coverage was presented in 2009, while grassland was worst in 2000.



(a)the change of average of GCF (b)the change of average difference of GCF

Figure 4. The change of average of annual maximum GCF from 2000 to 2012 in SRTR

4.2. Analysis of variation within the year

Figure 5 shows the comparison of average of month maximum GCF in growing season during the period from 2000 to 2012 in SRTR. Overall, there has also an improving grassland condition in the last 13 years. The crest and trough characteristics of curve for the month maximum GCF is consistent with that of the annual maximum GCF curve. There is highest GCF and relatively small change amplitude in August and July, with lowest GCF and relatively large change amplitude in May and October.

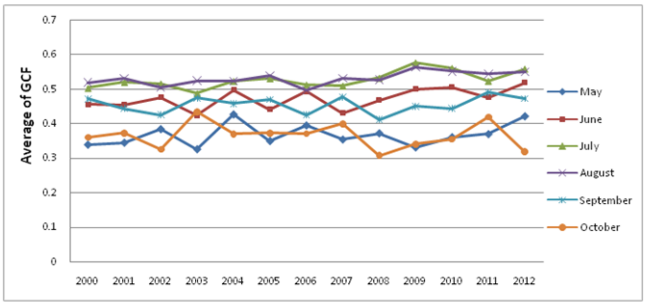


Figure 5. The comparison of average of month maximum GCF in from 2000 to 2012 in SRTR

4.3. Change Trend Analysis

The spatial distribution of the change tendency of GCF during the period from 2000 to 2012 in SRTR is showed in figure 6. The grassland was improved significantly in northwest, while it is degraded heavily in small areas in middle north. The grassland was improved unsteadily and lightly, which occurred mainly in the northern part, while the grassland degraded unsteadily and lightly, which occurred mainly in the southern part.

Overall the grassland condition has been becoming better during the last 13 years in SRTR. and the improved area accounts for 63.03% of the total area, while the degradation area occupies 17.68%; the main improvement type is unsteady improvement, about 29.77% The main degradation type is unsteady degradation, about 12.38%.

Table 2. The change trend statistics of grassland coverage 2000 to 2012 in SRTR

The parameters for change trends judgment	**Change Type**	**area/km^2**	**Percent/%**
$\|\Delta P\|<0.343647$	No change	60935.25	19.28
$\|\Delta P\|>0.343647$; $V_{fg}>0.1$; $\theta_{Slope} \le 0.011393$	improved lightly	81932	25.93
$\|\Delta P\|>0.343647$; $V_{fg}<0.1$; $\theta_{Slope} > 0$	improved unsteadily	92526.63	29.28
$\|\Delta P\|>0.343647$; $V_{fg}<0.1$; $\theta_{Slope} < 0$	degraded unsteadily	40678.38	12.87
$\|\Delta P\|>0.343647$; $V_{fg}>0.1$; $0.011393 \le \theta_{Slope} \le 0.018629$	improved moderately	8768.88	2.77
$\|\Delta P\|>0.343647$; $V_{fg}>0.1$; $\theta_{Slope} \ge 0.018629$	Improved significantly	1013.75	0.32
$\|\Delta P\|>0.343647$; $V_{fg}<-0.1$; $\theta_{Slope} \ge -0.000055$	degraded lightly	21474.13	6.79
$\|\Delta P\|>0.343647$; $V_{fg}<-0.1$; $-0.009352 \le \theta_{Slope} \le -0.000055$	degraded moderately	7806.88	2.47
$\|\Delta P\|>0.343647$; $V_{fg}<-0.1$; $\theta_{Slope} \le -0.009352$	degraded heavily	895.44	0.28

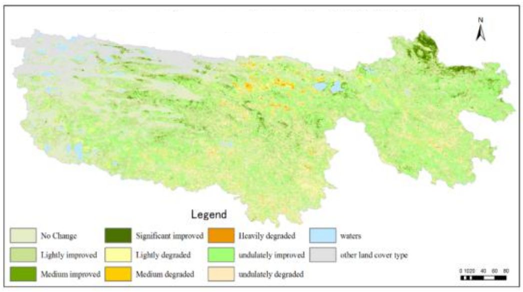


Figure 6. The spatial distribution of the change trends of GCF from 2000 to 2012 in SRTR

5. Discussion and conclusion

- The change analysis method proposed in the study, which is combined with change vector and tendency, can make fine categorization for the grassland coverage change tendency in a long time period. By setting the threshold the natural change can be recognized. Here the threshold is a key factor which currently cannot be set automatically. In the study, the thresholds are based on monitoring results from high resolution image and the accumulation of experience.
- Grassland is the material basis for the development of animal husbandry in SRTR. Because of the sensitive and fragile grassland ecosystem, it is very necessary to monitor the grassland condition continuously from the macroscopic view. The results of this study show that the estimation accuracy of GCF with MODIS NDVI is above 80%. It is feasible to monitor the grassland change tendency combined with the advantage of continuous observation from MODIS and the analysis method proposed in the study.
- According to the monitoring results of this study, the grassland coverage condition deteriorated heavily in some small areas in northern part of the central region. More attentions should be paid here; fine monitoring should be taken using remote sensing data with higher resolution. In recent years, mild degeneration and fluctuation degradation mainly occurred in southern SRTR. It is suggested that when making the relevant policies and regulations or implementing environmental protection project, government decision-making departments should pay more attention to the southern region.

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