Vegetation Coverage Change Trend in Inner Mongolia of China during 1998-2008

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Abstract. Vegetation is sensitive to reflect the change of ecological environment, so it is significant to study the vegetation dynamics for ecological environment protection and ecological early warning. Based on the time series of the SPOT/VEGETATION NDVI dataset, this paper has obtained the spatial distribution of NDVI in Inner Mongolia (IM), analyzed the characteristics of NDVI change trend in the period of 1998-2008 by Maximum Value Composites (MVC) and Mann-Kendall test. The main findings are as follows: (1) NDVI time series in most regions of IM has tendency in the recent 10 years. (2) The significant increased areas of vegetation cover are mostly distributed in the area of severe desertification, and the significant decreased areas of vegetation cover are mainly located in the typical steppes.

Keywords: Vegetation coverage, NDVI; Tendency, Mann-Kendall Test.

1 Introduction

Vegetation is the main part of the terrestrial ecosystem, and is considered as a sensitive indicator for environmental change by reflecting the land cover change to a certain extent [1]. As one of the core issues for Land Use/Land Cover Change (LUCC), related studies about vegetation-covered change have been the important part for the research of global change [2]. scientists have recognized the value of evaluating spatial ecosystem patterns and temporal processes using data archives [3, 4].

Among the surface parameters extracted from the remote sensing data, NDVI (Normalized Difference Vegetation Index) is an extensive used indicator for vegetation condition [5]. NDVI is closely related to the vegetation coverage, phytomass, leaf area index and net primary productivity, and it can reflect the coverage information objectively in a large spatial and temporal scale, which is a fine index to the condition of vegetation growth and the density of vegetation spatial distribution [6, 7]. In this research, the data of NDVI time series, which was obtained from the Environmental and Ecological Science Data Center for West China, National Natural Science Foundation of China (http://westdc.westgis.ac.cn), covering the

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period from April 1998 to July 2008, consists of 372 SPOT/VEGETATION scenes. The dataset, which has made atmospheric correction, radiometric correction and geometric correction by Vegetation Image Processing Center. The 1 km spatial resolution was nearly constant across the whole 2,250 km swath covered, which meant that there was almost no distortion at the image edge [8]. To display conveniently, every pixel's gray value of 372 scenes applied in this paper has taken linear stretch by i_{ndv}=DN×0.004－0.1, converting the data range to between 0 and 1.

The study area we selected is the Inner Mongolia Autonomous Region (IM). It lies between the latitudes as 37°24′～53°23′ N and longitudes as 97°12′～126°04′ E, and traverses the northern frontier of China from northeast to west, which is totally up to 1,183,000 km^2. In IM, flat plateau is its major terrain, with an average altitude of 1000～1500m, and the area of grassland is up to 880,000 km2, accounting for 21.7 % of the total nation and taking as the leader of five largest grasslands in China.IM is the typical temperate grassland in the world with mid-latitudinal & semiarid ecological type. Owing to the droughty climate and excessive reclamation & grazing, the vegetation ecosystem in IM has been very fragile and the condition for land desertification and vegetation degradation is very severe. Simultaneously, there is an obvious contradiction between high-insensitive land development and vegetation protection. Therefore, it is necessary to evaluate the characteristics of vegetation dynamic, what is offer decision making for sustainable development.

This paper has analyzed the spatial distribution condition of NDVI in the past 10 years, in the basis of the IM remote sensing data of NDVI from 1998 to 2008. Here, Maximum Value Composites and Mann-Kendall Test was alculated from NDVI time series of each pixel, and every pixel's NDVI variation trend was determined. It can reveal the inherent regularity of vegetation change in IM, by the further analysis for the results.

2 Maximum Value Composites

In the present study, the Maximum Value Composites (MVC) method was applied to generate the NDVI representative value every year, i.e., to obtain a maximum NDVI value in a year for each pixel. The algorithm is as follows:

$$NDVI_i = \mathrm{Max}\{\, ndvi_{i,j} \,\} \tag{1}$$

where, i= 1, 2,…, 11, j=1, 2,…, 37, and $NDVI_i$ is the i^{th} year's composite value, as well as $ndvi_{i,j}$ is the j^{th} period's actual value in the i^{th} year. Then, compute the annual mean value for the maximum NDVI in the years of 1998-2008 for every pixel, and obtain the synthesized data of MNDVI.

Here, the MVC method was selected for the reason that the influences of clouds, atmosphere and solar altitude will weaken in case the real NDVI value is underestimated.

3 Mann-Kendall Test

With the MK test for NDVI trend testing, the paper treat 10-days NDVI for each pixel as one time series, and MK test statistic Z_c and Kendall gradient β as the NDVI

attenuation indexes for unit pixel. The statistic of the Mann-Kendall statistical test, Z_c is expressed as:

$$z_c = \begin{cases} \dfrac{S-1}{\sqrt{\mathrm{var}(S)}}, & S > 0 \\ 0, & S = 0 \\ \dfrac{S+1}{\sqrt{\mathrm{var}(S)}}, & S < 0 \end{cases} \tag{2}$$

where, the expressions of S and var(S) can be find in literature [9], and will no be elaborated.

The Mann-Kendall test can be used in the following manner, for the null hypothesis H_0, if $|Z_c|>Z_{(1-\alpha)/2}$, then refuse the null hypothesis, where, $Z_{(1-\alpha)/2}$ is the standard normal variance, and α is the significance level for the test. When $|Z_c|>Z_{(1-0.05)/2}=1.96$, it means that the confidence level of this time series is less than 0.05, and the trend variation is significant. Conversely, when $|Z_c|<1.96$, the trend variation is not significant.

4 Result and Discussion

Distribution of NDVI. Figure 1 is the grid map of the NDVI distribution in the period of 1998-2008 in IM by calculated the mean inter-annual maximum composite value of NDVI time series for every pixel. It can be found that the spatial distribution of IM vegetation cover has the obvious characteristic of gradually decaying from northeast to southwest. In the eastern, the Greater Higgnan Mountains is the high NDVI value region, where has a better vegetation cover from forest and forest steppe. In the western, Central Gobi, Badain Jaran Desert, Tenger Desert and Ulanbuh Desert are the low NDVI value regions displayed from west to east, where filled with desert and desert steppe. In the midlands, NDVI is relatively concentrated, and high value region and low value region are distributed alternately, with high value in the Hetao Plain and Xilingol Grassland, and low value in Ortos Plateau and Otindag Sandy Land, what is consistent with the alternate distribution of the topographic pattern of Plateau Mountain in IM.

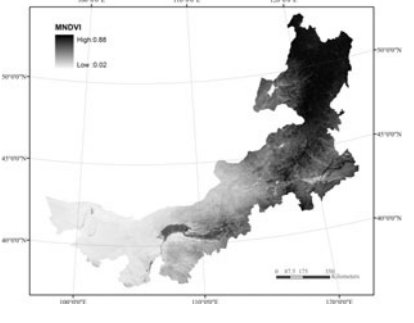

Fig. 1. NDVI distribution in IM in the period of 1998-2008 based on the MVC

NDVI Change Trend. Based on the MK test, NDVI change trend distribution in IM in the period of 1998-2008 (Figure 2) was obtained by calculating statistic Z_c of NDVI time series for each pixel. Taking significance level as 0.05 and critical threshold as $|Z_c| = Z_{(1-0.05)/2} = 1.96$, vegetation change trend was divided into 4 types.

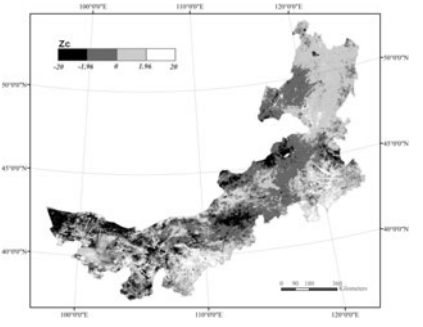

Fig. 2. NDVI change trend in IM in the period of 1998-2008

As for the space distribution, vegetation that of significantly increased and decreased all showed out concentrated distribution. Specifically, most regions that have vegetation significantly improved are desert regions, which are concentrated in Keerqin Sandy Land and Ortos Plateau, as well as the scattered regions distributed in the middle section of the Greater Higgnan Mountains, the Otindag Sandy Land and in the south rim of the Alxa Plateau. Obviously, desert control project has achieved remarkable results in the desert region of IM since 1998. On the other hand, there are serious crises in some steppe regions. For instance, regions with significantly decreased vegetation are mainly concentrated in typical steppe regions excepting for the Gobi and desert areas in the west. Especially, the Xilingol Grassland and Ulanqab Grassland have appeared obviously reduced vegetation in large area. As is known to all, the ecosystem of these typical steppe regions is very sensitive and fragile, and irrational animal husbandry production, sharply increased population and rapid urbanization have brought great pressures to ecological environment.

As for the proportion of area, there is 10.16% of the total area having attenuated trend, and 7.53% of the total area showing increased trend (Table 1). Where, the two are less than one-fifth of the total area, for the reason that many regions have the increased or attenuated trend in vegetation cover, but did not pass the test of significance level on 0.05. Generally speaking, the pixels have increased trend are a little more than the pixels have attenuated trend, which can be said that the overall condition of vegetation in IM is taking a favorable turn in the recent 10 years.

Table 1. Occupied area and proportion of different types vegetation variation trend

Vegetation variation trend		Area(km^2)	Proportion
attenuation	significant	120189.4	10.16%
	not significant	464716.4	39.28%
enhancement	significant	89115.5	7.53%
	not significant	506584.2	42.82%

5 Conclusions

Based on the calculation of the mean inter-annual maximum composite value and statistic Zc in MK test for each pixel's NDVI time series, this paper has drawn the spatial distribution maps and analyzed the temporal evolution characters of the IM vegetation change trend in the period of 1998-2008. According to the analytic results, we may come to the following conclusions:

In the recent 10 years, the vegetation cover in IM is improved in the whole, but there are still 10.16% of IM presenting significant attenuation trend. However, it cannot ignore deterioration of vegetation in some areas, and it needs to strength the ecological monitoring in the areas with vegetation significantly decreased. According to further analysis on the spatial distribution of the vegetation areas which are obviously increased and attenuated, they are concentrated in space. Where, the significant increased areas of vegetation cover are mostly distributed in the area of severe desertification, and the significant decreased areas of vegetation cover are mainly located in the typical steppes.

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