MONITORING VEGETATION DYNAMICS IN XILINGUOLE LEAGUE, INNER MONGOLIA, CHINA BY USING SPOT/VEGETATION DATA

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KEY WORDS: SPOT/VEGETATION, vegetation dynamics monitoring, Xilinguole League

ABSTRACT: A new method for grassland vegetation dynamics monitoring was developed based on the linear time trends (LTT) estimation and change vector analysis (CVA) using SPOT-VGT imagery. Firstly, seasonally integrated normalized difference vegetation index (SINDVI) was calculated by using 10-day NDVI. Then by evaluating spatially averaged SINDVI of vegetated areas, the apparent change periods were identified. Thirdly, the areas where SINDVI changed significantly were extracted during the apparent periods. And finally, the magnitude of NDVI change in the above regions was calculated with CVA. The method was used in the grassland dynamics detection in Xilinguole League (Inner Mongolia, China) to verify its performance. The results indicated that the new method is effective for long-term vegetation dynamics monitoring. There are two periods with obvious decrease of NDVI: 1998-2001 and 2003-2007. From 1998 to 2001, the area where SINDVI showed significant decrease trend (ASSDT) accounts for 82.29% of the whole vegetated area; and in this area obviously decreased region was mainly located in the middle part of the study area. From 2003 to 2007, ASSDT accounts for 48.73% of the whole vegetated area; and the obviously decreased region was mainly located in the northeast of the study area.

1. INTRODUCTION

Understanding grassland vegetation dynamic is an underlying tenet of plant ecology and has important significance in grassland biomass estimation, grazing capacity prediction and grassland ecosystem protection. The progress of satellite remote sensing technology makes the grassland vegetation monitoring at regional and global scale possible. The generation and development of long time series data has made the remote sensing technology the main tool in vegetation monitor.

Linear time trends (LTT) was used to characterize interannual variability of vegetation activity in the northern high latitudes from 1981 to 1991 by Myneni (Myneni et al., 1997). Tucker extended this work by adding data from 1992 to 1999 (Tucker et al., 2001). The above studies showed that the LTT can make full use of the time series data and detect the change trend of vegetation index. This method is simple but effective for trend monitoring. It's useful to retrieve the interannual change trend from the time series data by linear regression, but the accuracy may be affected by extreme situation and not satisfactory due to straight line fit, in addition, it uses
annual integrated vegetation index data to document the change, and can not detect subtle or abrupt change in seasonality and can not indicate the magnitude of the change. Change vector analysis (CVA) is a robust method for land use/cover change detection and it is good at change magnitude detection. In one NDVI change detection study using CVA carried by Lambin and Strahler (1994), the NDVI in one year is defined as a 12-dimension vector; the magnitude of the change vector is calculated by the Euclidean distance. In grassland vegetation dynamic monitoring, CVA is more sensitive to subtle changes in seasonality, vegetation phenology and ecosystem dynamic. But the approach only compare time series data of two separate years, it is necessary to bridge the gap to detect the change trend for a long term. The objective of the study was to develop a new method based on LTT & CVA using SPOT/VGT imagery. And as a case study, the method was used in Xilinguole League (Inner Mongolia, China) for verifying its performance in grassland dynamics monitoring.

2. METHODOLOGY

The seasonally integrated normalized difference vegetation index (SINDVI) was calculated by using the 10-day NDVI time series data. With the SINDVI data set, the periods and regions with a significantly changing trend were identified, and the change magnitude was calculated on that region with CVA. The 10-day NDVI time series data was defined as $X$, and

$$X = [x_{ij}] = \begin{pmatrix} x_{i1} & \cdots & x_{in} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix} \quad i = 1,2,\ldots,m \\
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of the fitting line between $c$ and $d$ is larger than $r_{0.05}$, then the period $[c, d]$ could be defined as the apparent change period.

(3) Extraction of the SINDVI significantly changed areas
During the period $[c, d]$, the change trend was estimated for each pixel by the slope of the fitting line between SINDVI and time. The slope is calculated as follows:

$$a = \frac{l \times \sum_{i=1}^{l} i \times x_i - \sum_{i=1}^{l} i \sum_{i=1}^{l} x_i}{l \times \sum_{i=1}^{l} i^2 - (\sum_{i=1}^{l} i)^2}$$

where $l$ is the length of the time series, $l=d-c+1$. $x_i$ is the SINDVI of year $i$. The test of significance was performed. When $a>0$ and at an acceptable confidence level, the SINDVI increased with time significantly, while when $a<0$ and at an acceptable confidence level, the SINDVI decreased significantly. If the fitting is bad, the SINDVI fluctuated during the period.

(4) Calculation of magnitude of SINDVI change
In the significantly changed area obtained in the last step, the magnitude of NDVI change was calculated in the period $[c, d]$ with CVA. An m-dimension temporal space was defined by a vector. Based on the definition of temporal vector, it was observed that any NDVI change between $c$ and $d$ can be described by a change vector in m-dimension space as the equation 4:

$$\Delta x(i) = x(i, d) - x(i, c) = \begin{bmatrix} x_{d1} - x_{c1} \\ x_{d2} - x_{c2} \\ \vdots \\ x_{dm} - x_{cm} \end{bmatrix}$$

where $\Delta x(i)$, the change vector for pixel $i$ from year $c$ to $d$, contains all of changes of pixel $i$ in every temporal-dimension. The magnitude of the change vector, $||\Delta x||$, calculated by the Euclidean distance between the two vector, measures the intensity of the change in NDVI.

$$||\Delta x|| = \sqrt{(x_{d1} - x_{c1})^2 + (x_{d2} - x_{c2})^2 + \cdots + (x_{dm} - x_{cm})^2}$$

When $||\Delta x||$ is over a threshold, obvious change has taken place. The threshold in CVA is often determined according to empirical strategies, or from manual trial-and-error procedures. In this paper, the break points were produced based on the location and shape of their histogram peaks. The change magnitude was classified into three levels based on the histogram.

3. CASE STUDY

Xilinguole League, Inner Mongolia, China (Figure 1), geographically situated between 42° and 47° North latitude and between 111° and 119° East longitude. The climate is typical of the temperate steppe region, with an annual average temperature between -2°C and 2°C, and an annual total precipitation between 200mm and 400mm. The grassland covers about 97.2% of the
study area, which are meadow steppe, typical steppe and desert steppe from the east to west.

3.1 Data and Pre-processing

The original dataset used in the study were SPOT/VGT NDVI S10 and Landsat TM. The former are available free of charge at the Vlaamse Instelling voor Technologisch Onderzoek Image Processing centre http://www.vgt.vito.be. The temporal series span from Apr. 1998 to Dec. 2007. Two Landsat TM images were selected, which are available free of charge at the United States Geological Survey/ Earth Resources Observation and Science Center http://glovis.usgs.gov. The dates are Aug. 15th, 2003 and Aug. 15th, 2007. The location is shown in Figure 1.

In the pre-processing procedures, the 10-day NDVI products were reconstructed by the method based on the Savitzky-Golay filter developed by Chen et al. (2004). The average yearly NDVI from 1998 to 2007, \( Y_{DN} \) \((0\sim255)\) was transferred into real value \((-1\sim1)\) with the equation \( I_{NDVI} = Y_{DN} \times 0.004 - 0.1 \). A pixel is considered vegetated if averaged \( I_{NDVI} \) is larger than 0.1.

<table>
<thead>
<tr>
<th>(a) Study Area</th>
<th>(b) TM Aug., 15th, 2003</th>
<th>(c) TM Aug., 15th, 2007</th>
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<tr>
<td>4, 3, 2 RGB</td>
<td>4, 3, 2 RGB</td>
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Figure 1 The Study Area and the Location of Landsat TM

3.2 The Detection of the Grassland Vegetation Dynamics in the Study Area

According to the methods mentioned in the section 2, the SINDVI was calculated by using the SPOT/VGT 10-day NDVI from 1998 to 2007, in which the growing season is from May to September. Then with the equation 2, taking the spatially averaged SINDVI as the dependent variable, and the time as the independent variable, two apparent decrease periods were identified: 1998-2001 and 2003-2007 (Figure 2). Thirdly, with the equation 3, using the SINDVI data of the apparent periods, the slope of the fitting line was calculated for each pixel, and the test significance was taken. When \( \alpha < 0.3 \) and \( \alpha < 0 \), it is significantly decreased. Finally, we defined a 15-demensional vector for NDVI in the growing season. With the equation 4 and 5, the decrease magnitude was calculated in the two periods. And the threshold was 145.6 and 101.5 (Figure 3).

4. RESULTS

Two periods when NDVI decreased with time were apparent: 1998-2001 and 2003-2007,
separated by a marked increase in SINDVI from 2001 to 2003. From 1998 to 2001, the SINDVI in most area showed a significant decrease trend except the southwest and west of the study area, where fluctuating changes took place. The area of decreased trend accounts for 82.29% of the vegetated area. And the area of slight, moderate and obvious decrease were $3.9 \times 10^4 \text{km}^2$, $2.3 \times 10^4 \text{km}^2$ and $1.1 \times 10^4 \text{km}^2$ respectively; the percentage is 19.13%, 11.27% and 5.27% respectively. The obviously decreased area was located in the middle part of the study area. From 2003 to 2007, the area where SINDVI showed a significant decrease trend accounts for 48.73% of the vegetated area, and the area of slight, moderate and obvious decrease were $2.6 \times 10^4 \text{km}^2$, $2.4 \times 10^4 \text{km}^2$ and $1.1 \times 10^4 \text{km}^2$ respectively; the percentage is 13.09%, 11.72% and 5.41% respectively. The obviously decreased area was located in the northeast of the study area.

![Figure 2](image1)

**Figure 2** The Temporal Variation of SINDVI and the Apparently Decreased Periods

![Figure 3](image2)

**Figure 3** The Change Magnitude of NDVI during 1998-2001 and during 2003-2007

### 5. ACCURACY ASSESSMENT

In order to evaluate the performance of the method, the accuracy of change detection was estimated. The Landsat TM data was used for accuracy assessment. The hypothesis that the monitor result based on Landsat TM data was the most similar to the truth was given because the resolution of Landsat TM is 30m, much higher than that of SPOT/VGT.

The validation included three parts: (1) The decreased patterns derived from SPOT/VGT were compared with that derived from Landsat TM, and the results showed that it was similar. (2) Resample the result based on the Landsat TM to 1km, construct an error matrix, and calculate the total accuracy. A Kappa coefficient of 0.60 and an overall accuracy of 80.84% were achieved. (3) In each 10km×10km block, the proportion of the block covered by SINDVI decreased area derived from 1 km spatial resolution data were compared with that derived from 30m spatial resolution maps, through linear regression analysis. The agreement between VGT and TM
estimates was good, as evidenced by the high value of $R^2 (0.90)$ at a 99.99% confidence level. The y-intercept is close to 0 and the slope is high (0.91) (Figure 4).

![Figure 4 Linear regression between the decreased area proportion estimates derived from the Landsat TM data and the VGT data. The number of observation is 115. The regression of is significant at 99.99% confidence level.](image)

**6. CONCLUSIONS**

The conclusions are as follows: (1) The new method is effective for long-term vegetation dynamic monitoring. The total accuracy is 80.84%. The NDVI change maps derived from 1km spatial resolution were compared with that derived from 30m spatial resolution obtained with Landsat TM scenes through linear regression analysis; and good correspondence was observed. (2) There are two periods with apparent NDVI decreased: 1998-2001 and 2003-2007. From 1998 to 2001, the area where SINDVI showed significant decrease trend (ASSDT) accounts for 82.29% of the whole vegetated area. The area of obvious decrease accounted for 5.27% and located in the middle part of the study area. From 2003 to 2007, ASSDT accounts for 48.73% of the whole vegetated area. The area of obvious decrease accounts for 5.41% and located in the northeast of the study area.

**ACKNOWLEDGEMENT**

The research is supported by the natural scientific foundation of China (Grant No. 40971059).

**References**


