

Tempo-spatial changes of vegetation coverage using remote sensing in Altay, China

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Abstract. Vegetation dynamics are very sensitive to climate change, especially in arid and semi-arid regions. In this paper, the Moderate Resolution Imaging Spectroradiometer (MODIS) data were used to evaluate vegetation coverage area in Altay Prefecture during the 2000 to 2015. Furthermore, the patterns of tempo-spatial variations in vegetation coverage were analysed. The vegetation coverage area significantly changed in the past 16 years and the average percentage of vegetation was 35.72%. The results also indicated that the trend of vegetation cover had obvious discrepancy in various altitude ranges.

1. Introduction

The Altay Mountain, located on the northern Altay Prefecture, is a trans-country mountain range among China, Russia, Mongolia and Kazakhstan in Central Asia. It is the source of rivers including the Irtysh and Ulungur River, these rivers play an extremely important role in the ecological environment of Central Asia. However, the ecosystem of Altay Prefecture is fragile because of the semi-arid climate. Monitoring and assessing the environment changes in this region is crucial to understand the global change, ecological security and sustainable development.

Vegetation is one of the primary indicators for ecosystem. Changes of vegetation coverage can reflect dynamic variations of regional energy balance, biochemistry cycle, atmospheric cycle and water cycle [1,2]. Meanwhile, it can also indicate the positive and negative impacts of human activities on ecological environment [3,4]. Therefore, aside from evaluating the inter-annual changes of vegetation coverage, we should also monitor the spatial characteristics of changing areas.

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Considering the broad spatial coverage and long time span in this study, we used MODIS data, which have high spatial and spectral resolutions, to extract vegetation coverage area. In the field of remote sensing, vegetation indexes have been widely used for monitoring vegetation changes [5,6]. EVI (enhanced vegetation index) is more sensitive in high biomass areas and more stable under high aerosols compared to NDVI (normalized difference vegetation index) [6,7]. Therefore, this paper utilized EVI to evaluate vegetation coverage area. Furthermore, Digital Elevation Model (DEM) data from Shuttle Radar Topography Mission (SRTM) were used to analyse the spatial characteristics of vegetation change.

2. Study area and data source

2.1. Study area

The study area is Altay Prefecture, which is located on northern Xinjiang Province. It has a geographic coverage of 45°00'- 49°11'N, 85°31'- 91°04'E (figure 1). The west and north of Altay Prefecture is mountainous area, the middle part is valley and the south-eastern part is desert. Altay Prefecture has a cold temperate continental climate with less precipitation and great range of mean annual temperature. Its average temperature is 4.5°C, and annual precipitation is 256.6 mm. Altay Mountain lies in the northern Altay Prefecture, it is nearly 500 km long and 1000-3000 m high. In Altay Mountain, the monthly mean temperature ranges from 24°C to 40°C in July and -14°C to -60°C in January.

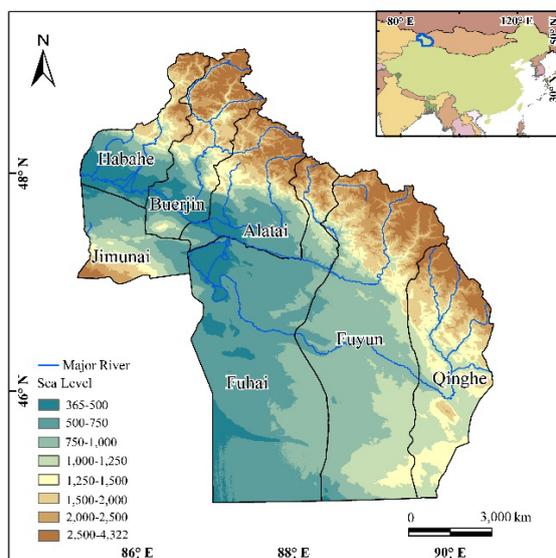


Figure 1. Location map of study area.

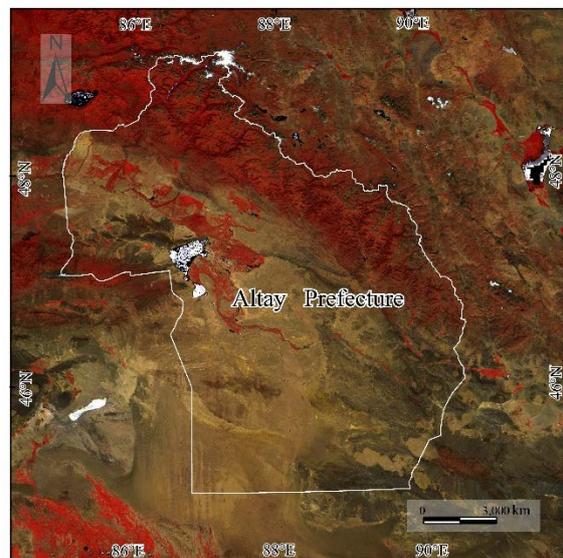


Figure 2. MODIS image of study area.

2.2. Data source

The data used in this paper are MODIS MOD13Q1 images with tracks of h23v4 and h24v4. MOD13Q1 data, which were acquired from the Land Processes Distributed Active Archive Center (LP DAAC), are MODIS level 3 product. These data are provided every 16 days at 250 m spatial resolution and in the Integerized Sinusoidal (ISIN) projection. This paper utilized MOD13Q1 EVI bands to extract vegetation coverage area and analyse temporal and spatial changes.

EVI is calculated using surface reflectance values from the red, NIR (near-infrared) and blue bands:

$$EVI = G \times \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + C_1 \times \rho_{red} - C_2 \times \rho_{blue} + L} \quad (1)$$

where ρ_{NIR} , ρ_{red} and ρ_{blue} are MODIS surface reflectance of the NIR, red and blue bands, L is the background (soil) adjustment coefficient, and C_1 , C_2 are the fitting coefficients. This equation utilizes the blue band to correct aerosol influence in red band. In the EVI equation, values of these coefficients are, $L=1$, $C_1=6$, $C_2=7.5$, and G (gain) =2.5 [7].

3. Results and Discussion

3.1. Temporal changes of vegetation area

The main contents of pre-processing MODIS EVI data were mosaicking every two images and reprojecting mosaicked images to UTM WGS84 coordinate system. Then we chose 1500 as the optimised EVI threshold to extract vegetation coverage area (table 1). Vegetation area in Altay Prefecture changed significantly during 2000-2015, the average vegetation coverage area was 41,999.87 km², and average percentage was 35.72%.

Table 1. Vegetation area in Altay Prefecture

year	Vegetation area (km ²)	Percentage (%)	year	Vegetation area (km ²)	Percentage (%)	year	Vegetation area (km ²)	Percentage (%)
2000	38,224.964	32.512	2006	41,979.343	35.705	2012	42,463.273	36.116
2001	47,022.201	39.994	2007	41,968.468	35.696	2013	46,559.333	39.600
2002	39,846.876	33.891	2008	37,555.412	31.942	2014	40,168.058	34.164
2003	43,338.634	36.861	2009	38,123.653	32.425	2015	40,143.621	34.143
2004	42,117.778	35.823	2010	43,681.754	37.153			
2005	45,148.418	38.400	2011	41,789.033	35.543			

3.2. Spatial changes of vegetation area

There are a variety of geomorphological types in Altay Prefecture, which lead to evident altitude discrepancy in different regions. The great discrepancy in elevation results in an obvious characteristic of vertical distribution in hydrothermal conditions and human activities, and these will potentially influence the vegetation growth [8]. This paper divided the study region into three districts according to altitude: high altitude regions (above 1500 m), middle altitude regions (640-1500 m) and low altitude regions (below 640 m) and extracted vegetation area respectively (figure 3). Figure 3(a) shows: there are more than half of vegetation distribute in high altitude regions. These districts are covered with ice and snow all year round, and thus the vegetation can get adequate meltwater. Figure 3(b) shows: the inter-annual changing trend in these three districts have great differences, there are conspicuous changes in middle and low altitude regions, while small changes in high altitude regions. These results implied that the changes of vegetation coverage area mostly take place in middle altitude regions, low altitude regions will be the next, but rarely in high altitude regions.

In order to validate the above results, the vegetation images of 2001 and 2013 with the largest vegetation area are used to subtract the vegetation image of 2008 with the smallest vegetation area, then we can get figures 4 and 5. In these figures, green pixels stand for increased vegetation area and

red pixels are decreased vegetation area. The main vegetation changes from 2001 to 2008 are reduction of area and they mostly distributed in the low altitude regions. And the major changes in vegetation from 2008 to 2013 are area increasing and they mainly distributed in the low to middle

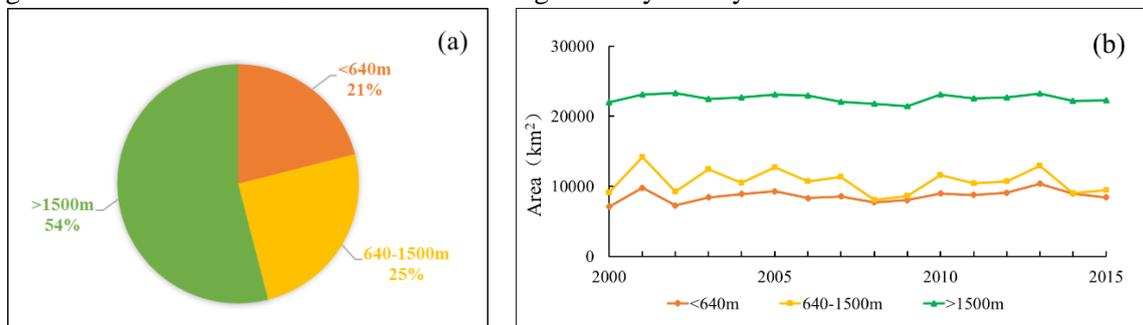


Figure 3. Vegetation area percentages(a) and changes(b) in three districts.

altitude regions. The amount of vegetation area in the high altitude regions are almost stable from 2000 to 2015 as shown in figure 3(b).

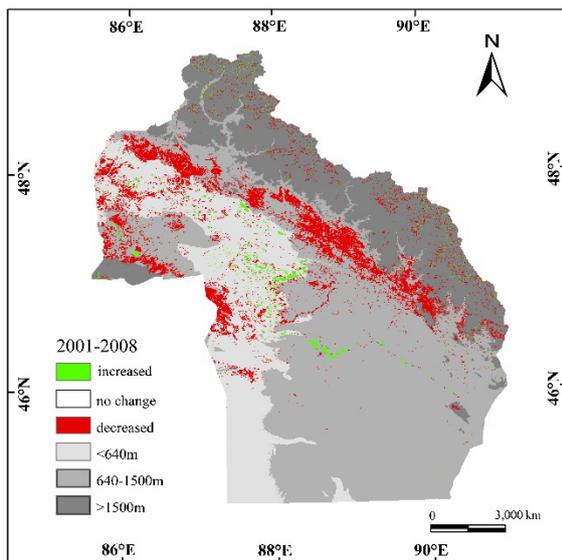


Figure 4. Vegetation changes from 2001 to 2008.

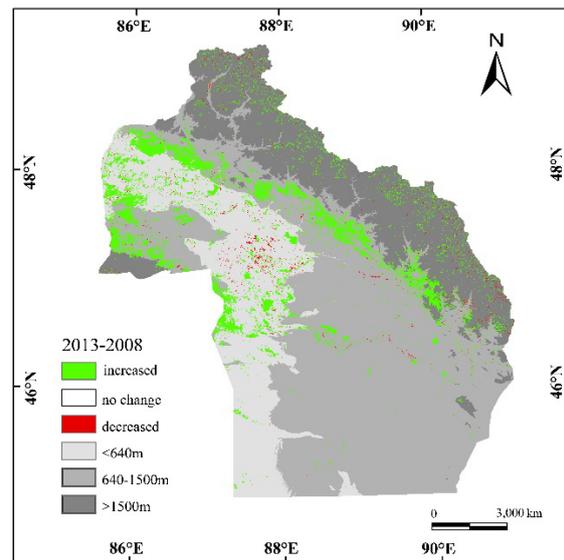


Figure 5. Vegetation changes from 2008 to 2013

3.3. Climate control factors on vegetation dynamics

Previous study showed that both the temperature and precipitation have increased significantly (0.35 °C /10y, 11.2 mm/10y) in northern Xinjiang during the period 1960-2011 under global warming [9]. As a sensitive indicator of ecosystem, the vegetation cover has changed. Many studies have documented that both the temperature and precipitation are major control factors on the growth of arid and semi-arid vegetation in northwestern China [1], but the precipitation is the dominant one [10,11].

4. Conclusions

In this study, the tempo-spatial features of vegetation change in Altay Prefecture from 2000-2015 are extracted using the MODIS EVI images, and we got the following conclusions:

- (1) There are extremely significant variations of vegetation coverage in the Altay Prefecture during 2000-2015.

(2) The percentages of vegetation distribution in high, middle and low altitude regions are 54%, 25%, 21%, respectively.

(3) The inter-annual changes of vegetation coverage area had great discrepancies during different altitude regions.

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