Analysis of Spatiotemporal Variation and Driving Forces of Terrestrial Vegetation Coverage in China from 2001 to 2015: Postprint

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Abstract

Based on MODIS-NDVI remote sensing data, this study retrieved and calculated the spatial distribution of land surface vegetation coverage across China from 2001 to 2015, discussed the spatiotemporal variation patterns of vegetation coverage, and analyzed the main driving factors influencing its dynamic changes over the past decade. The results indicate that vegetation coverage across China' s landmass exhibited an overall increasing trend from 2001 to 2015, with particularly significant increases in the Huai River Basin, the North China Plain, and the Loess Plateau region. According to the temporal variation characteristics of vegetation coverage, the change patterns can be categorized into six types, including continuous growth and decrease-then-increase patterns; agricultural planting areas generally exhibited continuous growth, while major forest-covered regions, particularly in southwestern China, showed fluctuating variation characteristics during the study period. Precipitation is a crucial factor driving the dynamic changes in vegetation coverage in the northern North China Plain, Inner Mongolia, and most areas of northwestern China; vegetation coverage in northeastern China and the Qinghai-Tibet Plateau is significantly influenced by temperature, whereas in China' s southeastern coastal regions, sunlight conditions constitute the primary factor affecting vegetation coverage.

Full Text

Preamble

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Abstract:
Vegetation coverage is a quantitative index that reflects the surface condition of plant communities and can indicate regional environmental change, which has important significance for regional hydrological, ecological conditions and the regional response of global change. In this study, based on the MODIS-NDVI data during the period from 2001 to 2015, the mean values of vegetation coverage were firstly calculated every three years, and the differences of distribution during each period were investigated. Secondly, the variation rate of vegetation coverage was computed at the national scale during the study period, and six variation types were defined and the distribution of different types was analyzed in order to understand the variation characteristics. Finally, the drivers of the vegetation coverage change in different areas were analyzed by computing the correlation between vegetation coverage and typical climatic factors, such as annual mean temperature, annual precipitation and annual average sunshine percentage. The results were summarized as follows: (1) The spatial distribution of vegetation coverage in China is gradually reduced from the southeast coast to the northwest inland. From 2001 to 2015, there were regional variations of the vegetation coverage which caused little difference in terms of the overall distribution trend. (2) Over the past 15 years, the vegetation coverage in China had shown an increasing trend, in particular, in the Huaihe River Basin, the North China Plain area and the Loess Plateau region it was increased significantly. While the vegetation coverage of Qinghai-Tibet Plateau and Inner Mongolia plateau had little change. (3) According to the time series analysis of the vegetation coverage, the variation type can be divided into six categories, such as continuous growth, reduced-after-initially-increase, and so on. The vegetation coverage in most plain areas showed a continuous growth, while most of the forest-covered area, especially in the southwest, the vegetation coverage showed the variation characteristics of volatility during the study period. (4) By calculating the correlation coefficient between vegetation coverage and the selected climatic factors, it can be found that the vegetation coverage and precipitation were significantly and positively correlated in the Northern China Plain, Inner Mongolia, and most of the northwest area, which indicated that precipitation is the main climatic factor that affects vegetation coverage in those areas. Climate factors such as temperature, sunshine have a significant positive correlation with vegetation coverage in humid climate region, while there is a significant negative correlation in arid climate region.

Keywords: vegetation coverage; spatial-temporal variations; rate of change; driving force

1 Introduction

1.1 Data and Methods

The slope method was used to calculate the variation rate of vegetation coverage. The slope (_slope) represents the trend of vegetation coverage change over time, where n is the number of years and *C_i* is the vegetation coverage in year i. A positive slope indicates increasing vegetation coverage, while a negative slope indicates decreasing coverage.

Vegetation coverage was calculated using a linear spectral mixture model based on NDVI values. The model assumes that each pixel' s NDVI value is a linear combination of vegetation and soil components:

$$NDVI = f_{veg} \times NDVI_{veg} + (1 - f_{veg}) \times NDVI_{soil}$$

where *NDVI* is the pixel value, *NDVI_veg* is the pure vegetation endmember, *NDVI_soil* is the pure soil endmember, and *f_veg* is the vegetation fraction.

Vegetation coverage levels were classified into five categories based on vegetation fraction (*f_g*): very low coverage (*f_g* 0.2), low coverage (0.2 < *f_g* 0.4), medium coverage (0.4 < *f_g* 0.6), high coverage (0.6 < *f_g* 0.8), and very high coverage (*f_g* > 0.8). These five levels were used to analyze the spatial distribution patterns during 2001-2015.

Time series analysis was performed using three-year intervals to calculate the mean vegetation coverage for each period. The variation types were determined based on the trend analysis results, with classification criteria including: continuous increase (*C_avg_i* < *C_avg_i+1*), stable (*C_avg_i* *C_avg_i+1*), and other patterns.

1.2 Data Sources

MODIS-NDVI data with 500m spatial resolution were obtained from the National Tibetan Plateau Data Center (http://www.gscloud.cn). The dataset covered the period 2001-2015 with a temporal resolution of 16 days. Maximum value compositing (MVC) was applied to generate monthly NDVI data, which were then used to calculate annual vegetation coverage.

Meteorological data including annual mean temperature, annual precipitation, and annual sunshine percentage were obtained from the China Meteorological Data Service Center (http://data.cma.cn/) for the period 2001-2010.

1.3 Data Processing

The NDVI data were preprocessed using the following steps: (1) Radiometric calibration and geometric correction; (2) Atmospheric correction using the

MODIS reprojection tool; (3) Extraction of NDVI values using the MODIS land product quality assurance information; (4) Application of the Savitzky-Golay filter to remove noise and fill gaps in the time series.

Vegetation coverage was calculated for each pixel using the linear spectral mixture model. The pure endmember values were determined from the NDVI histogram: *NDVI_soil* was set at the 5th percentile and *NDVI_veg* at the 95th percentile of the NDVI distribution.

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2 Methods

2.1 Temporal Variation Analysis

The variation rate of vegetation coverage during 2001–2015 was calculated using the slope method. The 15-year period was divided into five 3-year intervals to analyze the temporal trends. The slope was calculated for each pixel to identify areas with significant changes.

The significance of trends was tested using the F-test at the 95% confidence level. Areas with significant positive slopes were classified as "significant increase," while those with significant negative slopes were classified as "significant decrease."

2.2 Spatial Pattern Analysis

Spatial distribution patterns of vegetation coverage and its variation types were analyzed using GIS techniques. The spatial autocorrelation of vegetation coverage changes was examined using Moran' s I index.

The relationship between vegetation coverage and climate factors was quantified using Pearson correlation coefficients. The correlation analysis was performed at the pixel level to identify regional differences in climate-vegetation relationships. Six variation types were defined based on the temporal trajectory of vegetation coverage: (1) continuous growth, (2) reduced after initial increase, (3) increased after initial decrease, (4) continuous decline, (5) fluctuating, and (6) stable.

The driving factors of vegetation change were analyzed by comparing the correlation coefficients between vegetation coverage and different climate variables. Areas with correlation coefficients significant at $p < 0.05$ were identified as having strong climate-vegetation coupling.

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3 Results

3.1 Spatial Distribution Characteristics

The spatial distribution of vegetation coverage in China shows a clear gradient decreasing from the southeast coast to the northwest inland. From 2001 to 2015, this overall pattern remained relatively stable, though regional variations occurred. High vegetation coverage areas (>0.6) are primarily concentrated in the humid and semi-humid regions of eastern and southern China, while low coverage areas (<0.2) dominate the arid and semi-arid regions of northwestern China.

[Figure 4: see original paper] Land use classification map in China

3.2 Temporal Variation Trends

Over the past 15 years, vegetation coverage in China has shown an overall increasing trend. The national average vegetation coverage increased by approximately 0.03 (or 5%) during 2001–2015. Significant increases occurred in the Huaihe River Basin, North China Plain, and Loess Plateau regions, where vegetation coverage increased by 8–15%. In contrast, the Qinghai-Tibet Plateau and Inner Mongolia plateau regions showed minimal change (<2%).

[Figure 5: see original paper] Spatial distribution of variation types of vegetation coverage

3.3 Variation Type Patterns

Based on time series analysis, six variation types were identified across China. The majority of plain areas exhibited continuous growth patterns, particularly in agricultural regions where improved management practices contributed to steady increases. Forest-covered areas, especially in southwestern China, showed fluctuating patterns characterized by high inter-annual variability. Approximately 60% of the study area exhibited stable or continuously increasing vegetation coverage, while 25% showed fluctuating patterns.

3.4 Driving Factor Analysis

Correlation analysis between vegetation coverage and climate factors revealed distinct regional patterns:

(1) **Precipitation**: Strong positive correlations ($r > 0.6$, $p < 0.01$) were found in the North China Plain, Inner Mongolia, and most northwestern regions, indicating precipitation is the primary limiting factor for vegetation growth in these arid and semi-arid areas.

(2) **Temperature**: Positive correlations dominated in humid climate regions (e.g., southeastern China), while negative correlations were observed in some arid regions where higher temperatures may increase evapotranspiration stress.

(3) **Sunshine percentage**: Showed significant positive correlations in humid subtropical regions but negative correlations in arid regions, suggesting complex interactions with vegetation physiology and water availability.

The combined effects of climate factors explained 45-65% of vegetation coverage variation in most regions, with human activities (e.g., ecological restoration projects) accounting for additional variation, particularly in the Loess Plateau where the "Grain for Green" program has significantly increased vegetation coverage since 2000.

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Note: Figure translations are in progress. See original paper for figures.