Spatiotemporal Variations in Vegetation NDVI on the Northern Slope of the Tianshan Mountains and Their Relationship with Climatic Factors: Postprint

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Abstract

Using MODIS NDVI data products combined with corresponding climate data, and employing simple linear regression trend analysis and correlation analysis, this study investigates the spatiotemporal variations of annual and monthly average NDVI and their relationships with climate factors on the northern slope of the Tianshan Mountains from 2000 to 2015. The results indicate: Over the past 16 years, annual average NDVI values on the northern slope of the Tianshan Mountains have fluctuated and increased within the range of 0.27–0.31, showing a generally significant increasing trend; monthly average NDVI values demonstrate that vegetation coverage increases rapidly beginning in April each year, reaches its maximum in July, and then begins to decline in August, with monthly average NDVI variations exhibiting a unimodal pattern. Vegetation indices across different seasons on the northern slope of the Tianshan Mountains all display an upward trend. Spatially, vegetation coverage on the northern slope of the Tianshan Mountains shows a distribution pattern characterized by high values in the west and low values in the east, and high values in the south and low values in the north. Changes in both growing season NDVI values and annual average NDVI values exhibit significant spatial heterogeneity, manifested as increased vegetation coverage in the central region and decreased vegetation coverage in the northeastern, western, and southern regions. Annual average temperature and average precipitation on the northern slope of the Tianshan Mountains have gradually increased, with the trend showing a rising-falling-rising pattern. Spatially, the southern mountainous region of the northern slope of the Tianshan Mountains features low temperatures and high precipitation, while the northern plain area features high temperatures but low precipitation. Vegetation NDVI values show certain correlations with temperature and precipitation. Both temperature and precipitation affect vegetation

growth, wherein spring vegetation NDVI values are closely related to temperature, and summer vegetation NDVI values are closely related to precipitation. Comprehensive analysis reveals that precipitation exerts a greater influence on vegetation coverage than temperature. There exists a certain lag effect between growing season (May–September) vegetation NDVI values and temperature and precipitation.

Full Text

1 Data and Methods

1.1 Study Area

The northern slope of the Tianshan Mountains serves as a critical ecological barrier in Xinjiang, with elevations ranging from 200 m to over 5000 m. The region exhibits a typical temperate continental climate, characterized by mean annual precipitation of 200 mm and mean annual temperature of 2–8°C. Precipitation increases with altitude while temperature decreases, creating distinct vertical vegetation zones [**?**].

1.2 Data Sources

NDVI Data: The study utilized MODIS NDVI data from 2000–2015, specifically the MOD13A3 product at 1 km spatial resolution. The dataset underwent rigorous quality control, including format conversion, projection transformation, and clipping. Monthly maximum value composites (MVC) were generated to minimize cloud contamination and atmospheric effects, resulting in a 16-year monthly NDVI time series.

Meteorological Data: Corresponding temperature and precipitation data were obtained from the China Meteorological Data Sharing Service System. The dataset included monthly records from 37 meteorological stations distributed across the study area, which were interpolated to 0.1° × 0.1° grid cells using kriging to match the NDVI resolution.

1.3 Methods

Trend Analysis: The monadic regression method was employed to analyze temporal trends in NDVI, temperature, and precipitation. The slope of the regression line indicates the magnitude of change, with positive values representing increasing trends and negative values representing decreasing trends. The formula is given as:

$$slope = \frac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{n\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2}$$

where x_i represents the year, y_i represents the NDVI value, and n is the number of years.

Correlation Analysis: Pearson correlation coefficients were calculated between NDVI and climate factors (temperature and precipitation) at both pixel and regional scales. The correlation strength was classified as: weak ($|r| < 0.3$), moderate ($0.3 < |r| < 0.5$), strong ($0.5 < |r| < 0.8$), and very strong ($0.8 < |r| < 1$) [**?**].

Hysteresis Analysis: The study examined the time-lag effects of vegetation response to climate factors by computing correlation coefficients between monthly NDVI and climate variables from the previous 1-2 months.

[Figure 1: see original paper] Sketch map of the study area

[Figure 5: see original paper] Variation trend of average annual precipitation on the northern slope of the Tianshan Mountains during 2000–2015

[Figure 6: see original paper] Spatial distribution of annual mean temperature and precipitation on the northern slope of the Tianshan Mountains

Interannual variation trend of average annual NDVI and average NDVI in growing season on the northern slope of the Tianshan Mountains from 2000 to 2015

Hysteresis of NDVI, precipitation and temperature in each month on the northern slope of the Tianshan Mountains in growing season

2 Results

2.1 Temporal Variation of NDVI

From 2000 to 2015, the average annual NDVI on the northern slope of the Tianshan Mountains fluctuated between 0.27 and 0.31, showing a significant increasing trend. The monthly NDVI exhibited a unimodal pattern, beginning rapid increase in April, peaking in July, and declining from August onward. The growing season (May–September) NDVI showed stronger correlation with climate factors than annual NDVI.

2.2 Spatial Variation of NDVI

Spatially, vegetation coverage was higher in the western and southern parts of the region but lower in the eastern and northern areas. The central region showed increasing trends, while the northeast, west, and south exhibited decreasing trends. Areas with significant NDVI increase accounted for 48.99% of the total region, primarily distributed in mid-altitude zones (1500–3000 m), while significant decrease occupied 8.80%, mainly in high-altitude areas above 3500 m.

2.3 Climate Factor Variations

Temperature and precipitation both showed increasing trends from 2000 to 2015, with precipitation increasing from 218 mm in 2000 to 340 mm in 2015. Spatially, the southern mountainous areas were warmer and wetter, while the northern plains were cooler and drier. The correlation between NDVI and precipitation (r = 0.478–0.553) was generally stronger than with temperature (r = 0.060–0.294) during the growing season.

2.4 Hysteresis Effects

The vegetation response to climate factors showed distinct time-lag effects. NDVI in spring was more closely correlated with temperature, while summer NDVI showed stronger correlation with precipitation. The hysteresis analysis revealed that precipitation from the previous 1–2 months had the greatest impact on current month NDVI, particularly in the peak growing season (June-August).

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Abstract: In this paper, the monadic regression analysis was employed to investigate the annual and monthly as well as spatial variations of vegetation NDVI on the northern slope of the Tianshan Mountains from 2000 to 2015 based on the MODIS NDVI data and the corresponding climate data. The results are as follows: In recent 16 years, the average annual NDVI on the northern slope of the Tianshan Mountains fluctuated between 0.27 and 0.31 and in a significant increase trend. The average monthly NDVI value began to increase rapidly in April, reached its maximum in July, and then began to decrease in August. The curve of average monthly NDVI was unimodal. The increase of vegetation index on the northern slope of the Tianshan Mountains was different from different seasons. Spatially, the vegetation coverage was high in the west and south but low in the east and north. There was a significant spatial difference of average annual vegetation NDVI and NDVI in growing season, and the vegetation coverage was increased in the central area but decreased in the northeast, west and south; The average temperature and precipitation on the northern slope of the Tianshan Mountains in the past years were gradually increased and in an increase-decrease-increase fluctuation trend. Spatially, the temperature was low but the precipitation was high in the southern mountainous region, the situation in the northern plain, however, was opposite; There was a certain correlation between the vegetation NDVI and the temperature and precipitation, especially in growing season. The vegetation NDVI in spring was more closely related to the temperature, but in summer was more closely related to the precipitation. Comprehensively, and the effect of precipitation on the vegetation coverage was higher than that of temperature; There was a hysteresis of vegetation NDVI than the temperature and precipitation in growing season from May to September.

Keywords: NDVI; spatiotemporal variation; climatic factor; northern slope of the Tianshan Mountains

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