

Relationship Between Growing Season Precipitation Characteristics and Normalized Difference Vegetation Index in Typical Desert Regions of Northern China: Postprint

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Abstract

Precipitation variation during the plant growing season is a crucial factor inducing interannual variability in plant growth, with precipitation amount, distribution pattern, concentration degree, and timing representing key characteristics of precipitation variation. Using MODIS normalized vegetation dataset from 2000–2017 and daily precipitation data from four sample sites during the plant growing season (May–September), we analyzed the correlation between NDVImax and precipitation characteristics in the study area. The results indicate that: NDVImax at the four sample sites in the study area all exhibited upward trends from 2000–2017; growing season precipitation displayed a pattern of increasing precipitation on both flanks and decreasing precipitation in the central region; Precipitation Concentration Degree (PCD) increased in the west and decreased in the east; Precipitation Concentration Period (PCP) throughout the study area showed a delayed trend. Except for Yulin, the effects of PCD and PCP on NDVImax in the other three locations were greater than that of growing season precipitation, suggesting that interannual variation in NDVImax values at these three sites was primarily determined by changes in PCD and PCP, with both exhibiting positive correlations, i.e., more concentrated precipitation was more conducive to NDVImax increase. In the Yulin region, partial correlation analysis revealed a positive correlation between NDVImax and growing season precipitation and a negative correlation with PCD, with the strongest correlation observed with growing season precipitation, indicating that vegetation in this region was more sensitive to growing season precipitation and that more uniform precipitation was more favorable for plant growth in this area.

Full Text

Correlation between Precipitation and NDVI in Vegetation Growing Season in a Typical Desert in North China

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Abstract: Precipitation change during the vegetation growing season is an important factor causing inter-annual fluctuation of vegetation growth. The correlation between NDVI and precipitation in the vegetation growing season in a typical desert in northern China was analyzed using the MODIS normalized vegetation dataset and daily precipitation data from May to September during 2000–2017. The results indicated that the values of NDVI in four sample plots in the study area showed an increasing trend from 2000 to 2017. Precipitation in the study area during the vegetation growing season exhibited an increase-decrease-increase trend. The precipitation concentration degree (PCD) was high in the west but low in the east, and it became later in the study area. In addition to Yulin, the effects of PCD and PCP on NDVI in the other three sample plots were higher than that of precipitation, which revealed that the inter-annual fluctuation of NDVI values in these sample plots was mainly affected by the changes of PCD and PCP, and there were positive correlations among them. In Yulin, however, NDVI had a positive correlation with precipitation in the vegetation growing season, but a negative one with PCD, and its correlation with precipitation in the vegetation growing season was the highest, indicating that vegetation growth was more sensitive to precipitation in the vegetation growing season.

Keywords: NDVI; vegetation growing season; precipitation variation; precipitation concentration degree; precipitation concentration period; desert

1 Study Area and Data

1.1 Study Area

The study area is located in the desert region of northern China, encompassing four representative sample plots. The geographic coordinates and elevations of these plots are shown in [TABLE:N]. The region is characterized by typical desert vegetation including *Haloxylon ammodendron*, *Seriphidium*, and *Artemisia* communities, with sparse coverage and sensitive responses to precipitation changes.

1.2 Data Sources

The NDVI data were obtained from MODIS 13Q1 products (2000–2017) with a spatial resolution of 250 m and a temporal resolution of 16 days, downloaded from NASA's Land Processes Distributed Active Archive Center (<https://lpdaac.usgs.gov>). Precipitation data were derived from daily observations at meteorological stations within the study region for the period 2000–2017, obtained from the China Meteorological Data Service Center (<http://data.cma.cn>). The vegetation growing season was defined as May to September.

2 Methods

2.1 Data Processing

MODIS NDVI data were processed using the MODIS Reprojection Tool (MRT) to convert HDF format to GeoTIFF, with projection transformation and format conversion performed in ArcGIS. The maximum value composite (MVC) method was applied to generate monthly NDVI values, and the maximum NDVI (NDVI_{max}) for each growing season was extracted. Precipitation data were aggregated to monthly and growing season totals. A 50 km buffer zone was established around each sample plot to analyze regional precipitation patterns.

2.2 Calculation of Precipitation Metrics

The precipitation concentration degree (PCD) and precipitation concentration period (PCP) were calculated using the following formulas:

$$PCD = \frac{\sum_{i=1}^n p_i \sin(\theta_i)}{\sum_{i=1}^n p_i}$$

$$PCP = \frac{\sum_{i=1}^n p_i \cos(\theta_i)}{\sum_{i=1}^n p_i}$$

where p_i is monthly precipitation and θ_i is the corresponding monthly angle (15°, 45°, 75°, etc.). These metrics quantify the temporal distribution and peak timing of precipitation during the growing season.

3 Results

3.1 Temporal Variation of NDVI

From 2000 to 2017, NDVI_{max} in all four sample plots showed significant increasing trends ([FIGURE:N]). The average NDVI_{max} values ranged from 0.139 to 0.453,

with the highest value recorded in 2016 and the lowest in 2001. The linear trend rates varied among plots, with the highest increase observed in the westernmost plot at 0.0836 per decade.

3.2 Temporal Variation of Precipitation

Precipitation during the growing season exhibited an increase-decrease-increase pattern over the study period ([FIGURE:N]). The PCD showed spatial variation, being higher in western plots (0.424–0.513) and lower in eastern plots (0.221–0.287). The PCP demonstrated a delayed trend across the region, indicating that peak precipitation occurred later in the growing season in recent years.

3.3 Correlation Analysis

Correlation and partial correlation analyses between NDVI and precipitation metrics revealed distinct patterns ([TABLE:N]):

- In three of the four plots (excluding Yulin), both PCD and PCP showed stronger correlations with NDVI than total precipitation, with correlation coefficients of 0.421–0.676 ($p < 0.05$).
- In Yulin, NDVI was most strongly correlated with total precipitation ($r = 0.549$, $p < 0.05$) but negatively correlated with PCD ($r = -0.334$, $p < 0.05$).
- Partial correlations controlling for other variables confirmed that PCD and PCP were the primary drivers of NDVI variation in most plots.

4 Discussion

4.1 Effects of Precipitation Patterns on Vegetation

The positive correlation between NDVI and PCD/PCP in most sample plots indicates that vegetation growth in these desert ecosystems is highly sensitive to the timing and concentration of precipitation events. Higher PCD values suggest that concentrated precipitation pulses can more effectively support vegetation growth in water-limited environments. The delayed PCP trend may affect phenological processes, potentially extending the effective growing season.

In Yulin, the negative correlation with PCD suggests that overly concentrated precipitation may be detrimental, possibly due to increased runoff and reduced infiltration in this specific geomorphological setting. The stronger positive correlation with total precipitation indicates that cumulative water availability remains the dominant control factor.

4.2 Comparison with Previous Studies

These findings align with previous research on precipitation-vegetation relationships in arid regions [cite{2,23-24}]. Studies in the Gurbantunggut Desert

[cite{4}] and northwestern China [cite{5}] have similarly reported that NDVI is more sensitive to precipitation distribution than total amount. The spatial heterogeneity observed in our study highlights the importance of local environmental factors, including soil properties and topography, in modulating vegetation responses to precipitation changes [cite{26-27}].

The increasing NDVI trend across all plots from 2000–2017 is consistent with regional greening reported in other studies [cite{6-7}], suggesting improved vegetation conditions despite variable precipitation patterns. This may reflect combined effects of climate change and ecological restoration efforts in desert regions.

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