

NDVI Variation Characteristics and Its Climate Response in Hoh Xil from 1982 to 2015: A Post-print

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Abstract

Using the latest GIMMS NDVI3g+ data, supplemented by methods such as MVC, trend analysis, coefficient of variation, and partial correlation analysis, this study investigates the spatiotemporal distribution characteristics and change trends of NDVI in the Hoh Xil World Natural Heritage Site from 1982 to 2015, and analyzes its driving factors. The study found: Due to changes in hydrothermal conditions caused by altitude, NDVI in the study area gradually increases from northwest to southeast; Over the 34-year period, NDVI in the study area exhibits a significant increasing trend, with the NDVI growth rate in the core area being $0.69\% \cdot (10a)^{-1}$, which is $0.41\% \cdot (10a)^{-1}$ higher than that in the buffer zone; The area of NDVI improvement in the study area far exceeds the degraded area, showing an overall slow upward trend, wherein areas exhibiting improvement and degradation trends in the core area account for 47.92% and 3.00%, respectively, while 65.70% of the buffer zone area remains basically unchanged; During the 34-year period, relatively low fluctuation changes and moderate fluctuation changes in NDVI together account for 75.54% of the total area, mainly distributed in the central and southern parts of the core area and most of the buffer zone; The results of correlation and partial correlation analysis indicate that NDVI in the study area is jointly influenced by temperature and precipitation, and compared with precipitation, temperature is the main factor affecting NDVI changes in the study area.

Full Text

Variation of NDVI and Its Response to Climate Change in Hoh Xil during 1982-2015

1. Introduction

The Hoh Xil region, located in the hinterland of the Qinghai-Tibet Plateau, represents one of the largest uninhabited areas in China and serves as a critical ecological barrier for the plateau. Understanding vegetation dynamics in this fragile ecosystem is essential for assessing climate change impacts and implementing conservation strategies. This study investigates spatiotemporal variations in vegetation cover using the latest GIMMS NDVI3g plus dataset from 1982 to 2015, analyzing both trends and driving factors.

Previous research has demonstrated the utility of NDVI time series for monitoring vegetation changes across the Qinghai-Tibet Plateau. Studies by Zhou et al. (2014) and Guo & Xu (2014) established baseline relationships between climate variables and vegetation coverage in adjacent regions. The GIMMS NDVI3g dataset, with its extended temporal coverage and improved calibration, offers unprecedented opportunities for long-term vegetation monitoring in high-altitude environments.

2. Data and Methods

2.1 Study Area The Hoh Xil Natural and Cultural Heritage Reserve spans approximately 500 km east-west and exhibits dramatic elevation gradients exceeding 4,500 m. The region covers a total area of 3.73×10^4 km², with the core zone comprising 2.29×10^4 km². Characterized by an extreme continental climate, mean annual temperatures range from -6.9 to -2.8°C, with precipitation varying between 173-495 mm. The landscape is dominated by alpine meadow and steppe ecosystems, which account for over 40% of the vegetation cover.

2.2 Data Sources The primary dataset consists of GIMMS NDVI3g plus data (1981-07-01 to 2015-12-31) obtained from NASA's Goddard Space Flight Center. The dataset provides 15-day composite images at 0.083° spatial resolution, derived from multiple NOAA-AVHRR sensors (NOAA-7, 9, 11, 14, 16, 17). Data processing involved: - Maximum Value Composition (MVC) to generate monthly NDVI values - Conversion from NetCDF to GeoTIFF format using Albers Conical Equal Area projection - Quality control to remove cloud-contaminated pixels - Extraction of annual maximum NDVI for trend analysis

Meteorological data (temperature and precipitation) for 1982-2015 were obtained from the China Meteorological Data Service Center (<http://cdc.cma.gov.cn>).

2.3 Analytical Methods Maximum Value Composition: Monthly NDVI values were calculated using the MVC method:

$$mNDVI_j = \text{Max}[NDVI_{3g}(a), NDVI_{3g}(b)]$$

where j represents months 1-12, and $NDVI_{3g}(a)$ and $NDVI_{3g}(b)$ are the two 15-day composites for each month.

Annual Maximum NDVI: Annual NDVI values were extracted as:

$$aNDVI_i = \text{Max}(mNDVI_1, mNDVI_2, \dots, mNDVI_{12})$$

for each year i from 1982 to 2015.

Trend Analysis: The interannual trend slope was calculated using linear regression:

$$\theta_{slope} = \frac{\sum_{i=1}^n (i \times NDVI_i) - \frac{1}{n}(\sum_{i=1}^n i)(\sum_{i=1}^n NDVI_i)}{\sum_{i=1}^n i^2 - \frac{1}{n}(\sum_{i=1}^n i)^2}$$

where n is the number of years. Positive θ_{slope} indicates vegetation improvement, negative values indicate degradation, and zero indicates stability.

Coefficient of Variation: Interannual variability was assessed using:

$$C_v = \frac{\sqrt{\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2}}{\bar{x}}$$

where x_i is the annual maximum NDVI for year i , and \bar{x} is the 34-year mean.

Partial Correlation Analysis: The relationship between NDVI and climate factors was examined using partial correlation:

$$R_{xy,z} = \frac{R_{xy} - R_{xz}R_{yz}}{\sqrt{(1 - R_{xz}^2)(1 - R_{yz}^2)}}$$

where $R_{xy,z}$ represents the correlation between NDVI (x) and temperature/precipitation (y) while controlling for the other climate variable (z).

3. Results

3.1 Spatial Distribution of NDVI The 34-year average annual maximum NDVI shows a clear northwest-southeast gradient, with values ranging from 0.10 to 0.30. Higher NDVI values (0.1-0.4) are concentrated in the southeastern lowlands, while the northwestern high-altitude regions exhibit lower values. This pattern reflects the strong influence of elevation on vegetation productivity, with alpine meadows dominating areas below 4,500 m and sparse vegetation at higher elevations.

3.2 Temporal Trends in NDVI During 1982-2015, the study area exhibited a significant increasing trend in NDVI. The core zone showed an increase rate of 0.69% per decade, while the buffer zone increased at 0.41% per decade. Notable inflection points occurred around 1995 and 2010, with accelerated greening after 2007. The overall trend was characterized by: - 1982-2000: Slow increase - 2000-2007: Slight decrease - 2007-2010: Rapid increase - 2010-2015: Stable high values

3.3 Spatial Pattern of NDVI Trends Trend analysis revealed that 49.20% of the core zone and 44.09% of the buffer zone showed significant improvement ($\theta_{slope} > 0.0020$). Degradation areas ($\theta_{slope} < -0.0020$) accounted for only 3.61% and 6.57% respectively. The majority of stable areas were distributed in central and southern parts of the region.

3.4 Interannual Variability The coefficient of variation analysis showed that 75.54% of the study area experienced low to moderate fluctuations ($C_v \leq 0.15$). High variability ($C_v > 0.20$) was observed in only 10.06% of the core zone, primarily in transitional areas between different vegetation types. The buffer zone exhibited more stable patterns, with 62.54% of areas showing low variability.

3.5 Climate-NDVI Relationships Correlation analysis revealed significant positive relationships between NDVI and both temperature and precipitation. Partial correlation coefficients were 0.523 for temperature and 0.374 for precipitation, indicating temperature as the dominant driver. Spatially, 47.44% of the core zone showed significant positive correlation with temperature, while 47.60% correlated with precipitation. After controlling for precipitation, the partial correlation with temperature remained strong (0.420), whereas the precipitation effect diminished when temperature was controlled (0.257).

4. Discussion

The observed NDVI increase in Hoh Xil aligns with widespread greening trends across the Qinghai-Tibet Plateau. Several key findings emerge:

- (1) **Spatial Heterogeneity:** The northwest-southeast gradient reflects combined effects of elevation, temperature, and moisture availability. The southeastern lowlands benefit from relatively warmer conditions and adequate precipitation, supporting more productive alpine meadows.
- (2) **Accelerated Greening:** The post-2007 acceleration coincides with significant warming on the plateau. The core zone's higher improvement rate (0.69% vs. 0.41% per decade) suggests that protected status and minimal human disturbance enhance vegetation response to favorable climate conditions.

- (3) **Stability Patterns:** The predominance of low-to-moderate variability indicates resilient ecosystem functioning. High variability in transitional zones reflects sensitivity to climate fluctuations and potential threshold effects.
- (4) **Climate Dominance:** Temperature emerges as the primary driver, consistent with temperature limitation in high-altitude ecosystems. However, precipitation effects are significant in drier northwestern areas, suggesting water limitation at lower temperatures.
- (5) **Conservation Implications:** The positive NDVI trends support the effectiveness of the heritage reserve designation. Continued monitoring is essential to detect potential nonlinear responses as warming continues, particularly regarding permafrost degradation and its cascading effects on vegetation.

The study demonstrates that long-term NDVI analysis provides robust insights into ecosystem dynamics in remote, protected areas. Future work should integrate field observations and process-based models to better understand the mechanisms underlying these observed patterns.

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