Spatiotemporal Variation of Fractional Vegetation Cover and Its Relationship with Environmental Factors in the Qaidam Basin from 2000 to 2015: Postprint

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Abstract

Based on MODIS-NDVI, DEM, and meteorological data, the spatiotemporal variation characteristics of Fractional Vegetation Cover (FVC) in the Qaidam Basin from 2000 to 2015 were analyzed, and correlation, partial correlation, or overlay analysis was conducted with precipitation, temperature, sunshine duration, relative humidity, evapotranspiration, and elevation to explore the relationship between FVC and various environmental factors. The results show that: FVC generally decreases in a semi-ring pattern from southeast to northwest inland, is concentrated below 20%, and human activities and runoff break the zonal pattern of vegetation; from 2000 to 2015, FVC improved significantly and was widely distributed in the central and western regions of the basin, with the most significant interannual variation occurring during 2001-2002; FVC is mainly positively correlated with precipitation and relative humidity, shows no significant relationship with temperature, is mainly negatively correlated with sunshine duration and evapotranspiration, precipitation contributes the most to FVC, temperature indirectly affects FVC by influencing evapotranspiration, and soil evaporation has a greater impact on evapotranspiration than plant transpiration; FVC spatial distribution aligns well with contour lines, exhibits two peaks at 2,800-2,900 m and 4,600-4,700 m, and decreases rapidly above 4,700 m.

Full Text

Preamble

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Abstract

The relationship between fractional vegetation cover (FVC) and environmental factors constitutes a critical research focus for ecosystem studies in arid regions. This paper analyzes the spatiotemporal variation characteristics of FVC in the Qaidam Basin, Qinghai Province, China, from 2000 to 2015 using MODIS-NDVI data. Combined with DEM data and meteorological observations from the basin, we conducted correlation analysis, partial correlation analysis, and overlay analysis between FVC and precipitation, temperature, sunshine duration, relative humidity, evapotranspiration, and altitude to explore the response characteristics of vegetation to major environmental factors.

The results demonstrate that FVC in the Qaidam Basin exhibited a semi-annular decreasing trend from southeast to northwest, with overall coverage below 20%. Human activities and runoff distribution disrupted the regularity of zonal vegetation patterns, significantly affecting FVC. Against the backdrop of global warming, FVC increased significantly during 2000–2015, with improvements most widely distributed in the central, western, and eastern mountainous regions of the basin. The most pronounced inter-annual variation occurred between 2001 and 2002, particularly for forest, grassland, and meadow vegetation.

The relationships between FVC and different meteorological elements varied. FVC showed positive correlations with precipitation and relative humidity, and negative correlations with sunshine hours and evapotranspiration. The relationship between FVC and temperature was not significant. Among these factors, precipitation contributed most to FVC and represented the primary limiting factor for vegetation growth in the basin. Temperature indirectly affected FVC by influencing evapotranspiration, contributing more to evapotranspiration than precipitation did. Meanwhile, soil evaporation's influence on evapotranspiration substantially exceeded that of vegetation transpiration.

The spatial distribution of FVC demonstrated consistency with altitude, showing good alignment with contour patterns and evident vertical differentiation. Two peak values occurred at 2800–2900 m and 4600–4700 m, respectively, due to water source and temperature influences, while FVC decreased rapidly above 4700 m. This study clarifies the relationship between multiple environmental factors and FVC, elucidating vegetation response characteristics to major en-

vironmental drivers under global warming and drying conditions, which holds significant implications for ecological environment and climate change research in arid regions.

Keywords: fractional vegetation cover; inter-annual variation; environmental factor; correlation analysis

2. Study Area and Methods

The Qaidam Basin, located in northwestern Qinghai Province, represents a typical arid inland basin characterized by sparse vegetation cover. Previous studies have extensively analyzed FVC spatial distribution patterns in this region [4, 8–10, 14]. Human activities and runoff distribution substantially influence FVC dynamics, disrupting the regularity of zonal vegetation distribution. This study employed MODIS-NDVI data from 2000–2015, DEM data with 35 m spatial resolution, and meteorological observations to investigate FVC variation and its driving mechanisms.

2.1 Data Sources

Remote Sensing Data: We obtained MODIS-NDVI products (MOD13Q1) from NASA for the period 2000–2015, covering the growing season (May–September). The data feature 250 m spatial resolution and 16-day temporal resolution, with preprocessing including mosaicking, projection transformation, and format conversion using MRT tools. The MODIS Reprojection Tool (MRT) was used for batch processing of NDVI data from 2000–2015.

Meteorological Data: Daily observations of precipitation, temperature, sunshine duration, relative humidity, and wind speed from 2000–2015 were acquired from the China Meteorological Data Service Centre (data.cma.cn). The dataset includes 35 meteorological stations within and surrounding the basin. Data underwent quality control and were interpolated to 16-day intervals using Matlab R2011b to match the NDVI temporal resolution. ArcGIS 10.2 was employed for Kriging interpolation of precipitation, temperature, evapotranspiration, and other variables.

Auxiliary Data: A 1:1,000,000 vegetation type map of the Qaidam Basin was obtained from the WestDC database (westdc.westgis.ac.cn). Land use data were derived from remote sensing interpretation. The SRTM 90 m DEM was resampled to 250 m resolution to match the NDVI data for elevation analysis.

2.2 Methods

2.2.1 FVC Calculation FVC was calculated using the dimidiate pixel model based on NDVI values:

$$FVC = \frac{NDVI - NDVI_{soil}}{NDVI_{veg} - NDVI_{soil}}$$

where $NDVI_{soil}$ and $NDVI_{veg}$ represent bare soil and full vegetation cover values, respectively. Following established practices [10, 14-15], we used the 5% and 95% percentiles of NDVI frequency accumulation as $NDVI_{soil}$ and $NDVI_{veg}$ thresholds.

2.2.3 Evapotranspiration Calculation Reference evapotranspiration (ET_0) was calculated using the FAO Penman-Monteith equation:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

where Δ is the slope of the saturation vapor pressure curve (kPa·°C ^{1}), R_n is net radiation (MJ·m ^{2}·d ^{1}), G is soil heat flux (MJ·m ^{2}·d ^{1}), γ is the psychrometric constant (kPa·°C ^{1}), T is mean temperature (°C), u_2 is wind speed at 2 m height (m·s ^{1}), e_s is saturation vapor pressure (kPa), and e_a is actual vapor pressure (kPa). Parameters a and b in the net radiation calculation were set to 0.198 and 0.787, respectively [19].

2.2.4 Correlation Analysis We performed correlation analysis, partial correlation analysis, and overlay analysis to quantify relationships between FVC and environmental factors (precipitation, temperature, sunshine duration, relative humidity, evapotranspiration, and altitude). Statistical significance was tested at the 95% confidence level.

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3. Results

3.2 Temporal Variation Characteristics

FVC in the Qaidam Basin showed significant inter-annual variation during 2000-2015, with an overall increasing trend. The most dramatic changes occurred between 2001-2002, when FVC increased substantially across the basin. The period 2002-2006 exhibited relatively stable FVC values, with a slight decreasing trend.

From 2000-2015, areas with FVC improvement accounted for 21.25% of the basin, predominantly distributed in central and western regions and eastern mountainous areas. Regions with decreasing FVC comprised only 0.73% of the area, mainly scattered in the northwestern basin. The coefficient of variation for FVC was 0.15, indicating moderate inter-annual variability.

3.3 Correlation Analysis Between FVC and Environmental Factors

3.3.1 Relationship with Precipitation FVC demonstrated a significant positive correlation with precipitation across most of the basin (correlation coefficient: 0.35). Areas with strong positive correlations covered 18.87% of the basin, primarily distributed in mountainous regions with elevations between 3500–4600 m. The correlation was particularly strong in forest and grassland zones, where precipitation serves as the primary limiting factor. Partial correlation analysis revealed that after controlling for temperature effects, the positive correlation between FVC and precipitation remained significant, confirming precipitation as the dominant driver of vegetation growth.

3.3.3 Relationship with Altitude FVC exhibited distinct vertical distribution patterns, showing consistency with elevation contours. Two peak zones occurred at 2800–2900 m and 4600–4700 m, with FVC values of 37.3% and 49.2%, respectively. These peaks correspond to areas with favorable water availability and temperature conditions. Above 4700 m, FVC decreased rapidly due to low temperature and harsh environmental conditions. The vertical differentiation was most evident in the 3500–4000 m range, where FVC varied between 10–20% depending on aspect and slope.

The correlation between FVC and elevation was complex, showing positive correlations in lower elevation zones (2800–3500 m) where increasing elevation brought more precipitation, and negative correlations above 4700 m where temperature constraints dominated. This vertical pattern reflects the combined influences of orographic precipitation, temperature gradients, and water availability on vegetation distribution in the arid basin environment.

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