

Spatiotemporal Variation Characteristics of Vegetation Cover in the Ili River Valley, 2000-2015: Postprint

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Abstract

Using EOS/MODIS data from 2000-2015, this study employs trend analysis, Hurst exponent, and coefficient of variation methods to analyze the spatiotemporal variation and future trends of vegetation in the Ili River Valley. The results show that: spatially, vegetation coverage exhibits a distribution pattern with higher values in the north, south, and east, and lower values in the west and center; temporally, from 2000 to 2015, vegetation coverage showed a fluctuating decrease at a rate of $6.25\% \cdot (10 \text{ a})^{-1}$; in terms of regional distribution, vegetation displayed low fluctuation changes, with areas of moderate or lower fluctuation accounting for 73.16%, and areas of high fluctuation accounting for 26.84%. Future predictions indicate that vegetation coverage is projected to show a degrading trend, with continuously degrading areas accounting for 57.55% and continuously improving areas accounting for 13.51%.

Full Text

Spatial-Temporal Characteristics of Vegetation Cover Change in the Ili River Valley from 2000 to 2015

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Abstract: Based on MODIS data from 2000 to 2015, this study analyzes the degree of vegetation coverage and its spatial change characteristics in the Ili River

Valley. Trend analysis, the Hurst index, and coefficient of variation methods were employed to examine vegetation cover change and predict future trends. Results show: (1) The spatial distribution pattern exhibits high vegetation coverage in the north, south, and east, while low coverage occurs in the west and middle. The ratios of vegetation area in poor, medium, and good condition account for 12.75%, 16.11%, and 71.14% of the total area, respectively. (2) Affected by natural factors such as rising temperatures and decreasing precipitation, along with human factors like overgrazing, the average NDVI fluctuated between 0.58 and 0.68, showing a decreasing trend of $6.25\% \cdot (10 \text{ a})^{-1}$. (3) Overall, the Ili River Valley experienced relatively low vegetation change. Regions with low fluctuation degree accounted for 73.16%, mainly distributed in mountainous areas with mountain meadow, alpine meadow, and primitive forest vegetation types. Regions with high fluctuation degree accounted for 26.84%, primarily located in areas 0–1,500 m altitude around the Tekes, Künes, and Ili Rivers, and on sunny mountain slopes. (4) Vegetation coverage shows a future decreasing trend. Degraded vegetation accounts for 76.90%, mainly in high-altitude areas of Huocheng, Yining, Gongliu, Xinyuan, Tekes, and Zhaosu Counties. Improved vegetation accounts for 23.10%, primarily on gentle slopes in Qapqal County, Yining County, and Yining City. (5) The change trend is complex, with continuous degradation and improvement areas showing clear spatial distribution. Continuous degradation occupies 57.55%, mainly in high-altitude regions of the North, Middle, and South Tianshan Mountains. Continuous improvement occupies 13.51%, mainly in newly reclaimed valley areas. These results provide scientific support for understanding ecological conditions and formulating protection strategies.

Keywords: Ili River Valley; spatiotemporal variation; vegetation cover; trend analysis

1 Study Area Overview

The Ili River Valley ($42^{\circ}14'16''$ – $44^{\circ}50'30''$ N, $80^{\circ}09'42''$ – $84^{\circ}56'56''$ E) is located in the western Tianshan Mountains of China. It borders Tacheng Prefecture and Bayingolin Mongol Autonomous Prefecture to the east, neighbors Aksu to the south, adjoins the Republic of Kazakhstan to the west, and is adjacent to Bortala Mongol Autonomous Prefecture to the north. The valley extends approximately 360 km east-west and 275 km north-south, covering a land area of 5.53×10^4 km². The region has a mean annual temperature of 9.8 °C and mean annual precipitation ranging from 200–300 mm to 600–800 mm or more. The valley comprises nine administrative units: Zhaosu, Tekes, Xinyuan, Gongliu, Nilka, Qapqal Xibe Autonomous County, Yining County, Huocheng County, and Yining City. The natural grassland area is approximately 3.71×10^6 hm², accounting for 6.38% of Xinjiang's grassland area. Grassland types include mountain meadow, alpine meadow, temperate steppe, temperate meadow steppe, temperate desert steppe, temperate desert, and tropical shrub grassland.

2.1 Data Sources

Remote sensing data were obtained from NASA's MODIS MOD13A1 product, with spatial and temporal resolutions of 500 m and 16 days, respectively. The dataset covers the period 2000–2015, comprising 23 periods per year and 368 total periods. The data were batch-processed using the MODIS Reprojection Tool for mosaicking, projection (Albers Equal Area Conic Projection), and format conversion. Using the Ili River Valley administrative boundary map, the dataset was clipped in ArcGIS 10.0. Maximum Value Compositing (MVC) was applied to extract monthly maximum NDVI values, which represent annual peak vegetation conditions.

2.2.1 Interannual Trend Analysis of Vegetation Cover

The slope method was used to analyze NDVI trends. The slope value indicates the change rate of NDVI over the study period. When slope > 0 , NDVI shows an increasing trend (vegetation improvement); when slope < 0 , NDVI shows a decreasing trend (vegetation degradation).

2.2.2 Hurst Analysis Method

The Hurst exponent is a long-term memory analysis method based on rescaled range analysis, first proposed by hydrologist H.E. Hurst in 1951. It reflects the persistence of future states relative to current conditions and is widely applied in hydrology, climatology, and geology.

For a given time series $\{x(t), t = 1, 2, \dots, n\}$, for any positive integer τ , the mean sequence is defined as:

$$\bar{x}(\tau) = (1/\tau) \sum_{t=1}^{\tau} x(t)$$

where $x(t)$ is the NDVI value in year t , and τ is the time period.

The cumulative deviation is:

$$X(t, \tau) = \sum_{u=1}^t [x(u) - \bar{x}(\tau)], t = 1, 2, \dots, \tau$$

The range $R(\tau)$ is:

$$R(\tau) = \max_{1 \leq t \leq \tau} X(t, \tau) - \min_{1 \leq t \leq \tau} X(t, \tau)$$

The standard deviation $S(\tau)$ is:

$$S(\tau) = \sqrt{[(1/\tau) \sum_{t=1}^{\tau} [x(t) - \bar{x}(\tau)]^2]}$$

The Hurst exponent H is obtained through the relationship:

$$R(\tau)/S(\tau) \sim \tau^H$$

Taking logarithms and using least squares fitting yields the H value. Different H values indicate different trend characteristics: $-0 < H < 0.5$: Antipersistence (future trend opposite to past). H approaching 0 indicates stronger

anti-persistence. - $H = 0.5$: Random sequence (future trend independent of past). - $0.5 < H < 1$: Persistence (future trend consistent with past). H approaching 1 indicates stronger persistence.

2.2.3 Spatial Variation Analysis of NDVI Interannual Changes

The coefficient of variation (CV) measures the degree of spatial dispersion:

$$CV = (1/n) \times \sqrt{[\sum_{i=1}^n (\bar{x}_i - \bar{x})^2 / (n-1)]}$$

where \bar{x}_i is the NDVI value in year i , \bar{x} is the mean NDVI, and $n = 16$. A larger CV indicates more discrete spatial distribution and greater fluctuation instability, while a smaller CV indicates more concentrated distribution and temporal stability.

3 Results and Discussion

3.1 Spatial Distribution Characteristics of Vegetation Cover in the Ili River Valley

Based on the 2000–2015 mean NDVI and classification standards from Zhang et al. and Zhang Hongbin et al., NDVI values were divided into three classes: 0.0–0.4 (poor vegetation), 0.4–0.6 (moderate vegetation), and 0.6–1.0 (good vegetation). The spatial distribution shows clear patterns: poor vegetation covers 6,382.44 km² (12.75%), mainly in temperate desert steppe zones at altitudes above 3,500 m in the North, Middle, and South Tianshan Mountains. Moderate vegetation covers 8,065.37 km² (16.11%), primarily in temperate steppe zones. Good vegetation covers 34,606.49 km² (71.14%), mainly in Zhaosu, Tekes, Gongliu, Xinyuan, Nilka, Yining, and Huocheng counties at 2,000–2,500 m altitude.

The spatial pattern shows higher coverage in the north, south, and east, and lower coverage in the west and middle. The valley is surrounded by high mountains on three sides, forming a trumpet shape opening westward. Influenced by westerly circulation from the Atlantic and Arctic Oceans, orographic precipitation increases from west to east with altitude. Low-altitude central-western areas receive 200–300 mm precipitation with sparse vegetation, while higher-altitude northern, eastern, and southern valleys receive 600–800 mm with abundant vegetation.

3.2.1 Temporal Variation Characteristics of NDVI in the Ili River Valley

From 2000 to 2015, NDVI showed a fluctuating decreasing trend. Annual mean NDVI varied between 0.58 and 0.68, with a decreasing rate of $6.25\% \cdot (10 \text{ a})^{-1}$. The minimum NDVI occurred in 2008 and the maximum in 2002. The change

can be divided into three increasing stages and three decreasing stages, with peaks in 2002 and 2005 and troughs in 2008 and 2012.

Interannual variation in hydrothermal conditions significantly affects NDVI. Precipitation fluctuations align closely with NDVI fluctuations—lower precipitation corresponds to lower vegetation coverage. In arid regions, water is the primary limiting factor for vegetation growth, making NDVI highly sensitive to precipitation variability. Temperature fluctuations show opposite patterns to NDVI. Rising temperatures accelerate potential evapotranspiration and soil water loss, creating stress that restricts vegetation growth. Human factors also contribute significantly to NDVI decline. Overgrazing has accelerated grassland degradation, with livestock inventories increasing by 19.43% during the study period. Land use changes show substantial conversion: cropland and construction land increased while forest, grassland, and unused land decreased, with cropland expanding by 59.30% (104.69 km²).

3.2.2 Regional Differentiation Characteristics of NDVI in the Ili River Valley

Based on Liu Yang et al.'s CV classification standards, NDVI variability was divided into five levels. Overall, the Ili River Valley showed low fluctuation trends. Areas with medium or lower fluctuation account for 73.16%, mainly in mountainous regions with mountain meadow, alpine meadow, and primitive forest vegetation that experience minimal human disturbance. High-fluctuation areas account for 26.84%, distributed at 0–1,500 m altitude around the Tekes, Künes, and Ili Rivers and on sunny slopes. These areas experienced large-scale land reclamation since 2000, causing high variability. Sunny slopes also show unstable vegetation due to precipitation variability.

3.2.3 Trend Analysis of Vegetation Cover Change in the Ili River Valley

At the pixel scale, NDVI trends were analyzed using slope and significance testing. Vegetation shows overall degradation, with decreasing areas accounting for 76.90% and increasing areas for 23.10%. Significant increases ($P < 0.01$) account for 3.28%, mainly in newly reclaimed areas of the Ili River Valley where artificial vegetation establishment has improved coverage. Significant decreases ($P < 0.01$) account for 22.31%, primarily in high-altitude areas of Huocheng, Yining, Gongliu, Xinyuan, Tekes, and Zhaosu counties. Reduced precipitation and rising temperatures strongly inhibit forest and grassland growth in these regions.

The Hurst exponent was used to predict future persistence. By overlaying Hurst and slope indices, future trends were classified: areas with Hurst > 0.5 (persistent trend) and Hurst < 0.5 (anti-persistent trend). Results show 71.10% of the valley will maintain current trends, while 28.90% will show opposite trends. Continuous degradation accounts for 57.55%, mainly in high-altitude North,

Middle, and South Tianshan regions. Continuous improvement accounts for 13.51%, primarily in newly reclaimed areas of the Ili River Valley where agricultural development has increased vegetation cover.

4 Conclusions

Based on 500 m resolution MODIS data from 2000–2015 and MVC processing, the main conclusions are:

1. Vegetation coverage shows higher values in the north, south, and east, and lower values in the west and middle. Poor vegetation covers 6,382.44 km² (12.75%), while good vegetation covers 34,606.49 km² (71.14%).
2. NDVI shows a fluctuating decreasing trend at $6.25\% \cdot (10 \text{ a})^{-1}$, with annual means varying between 0.58 and 0.68.
3. Overall low fluctuation characterizes the region, with 73.16% showing medium or lower variability and 26.84% showing high variability.
4. Degradation dominates, with 76.90% of area decreasing (22.31% significantly) and 23.10% increasing (3.28% significantly).
5. Hurst analysis indicates 71.10% of vegetation will maintain current trends. Continuous degradation occupies 57.55% and continuous improvement 13.51% of the area.

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