Spatiotemporal Variation of Vegetation and Its Influencing Factors in Shaanxi Province over the Past 15 Years: Postprint

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Date: 2019-03-07T00:00:00+00:00

Abstract

This study utilized MODIS/NDVI time series data from 2000 to 2014 and employed raster pixel trend analysis and stability evaluation methods to investigate the spatiotemporal variation characteristics and patterns of vegetation in Shaanxi Province over the past 15 years; predicted future vegetation change trends using the Hurst exponent; and analyzed the relationship between NDVI and annual mean temperature and precipitation using correlation analysis. The results show that the mean NDVI values in Shaanxi Province were 0.4273 and 0.4942 in 2000 and 2015, respectively, representing an increase of 0.067 or 16.0% over the 15-year period, with notable NDVI increases in Northern Shaanxi, declines in some parts of Guanzhong, and NDVI in Southern Shaanxi generally remaining at a relatively high level. The vegetation change trend in Shaanxi Province exhibits significant spatial heterogeneity, with 52.0% of the province' s vegetation remaining unchanged, 44.27% showing improvement, and 3.73% experiencing degradation, indicating that the area of improved vegetation coverage exceeded the degraded area and the overall vegetation condition improved over the 15-year period; specifically, the area with significantly improved vegetation was relatively large in Northern Shaanxi, vegetation coverage decreased somewhat in Guanzhong, and vegetation change was relatively minor in Southern Shaanxi. Stable vegetation areas accounted for over 50% of Shaanxi Province (0–0.2), indicating that vegetation in Shaanxi Province was relatively stable with limited change over the 15-year period; the most stable vegetation areas were concentrated in Southern Shaanxi and southern Yan' an, while change amplitude was relatively large in parts of Yulin, Xi' an, and Weinan. Hurst exponent analysis indicates that 44.54% of vegetation area in Shaanxi Province may face degradation in the future, mainly distributed in Northern Shaanxi and northern Guanzhong, while 49.78% of the area may either degrade or improve in the future, primarily distributed in Yan' an and Southern Shaanxi. Over the past 15 years, temperature and precipitation in Shaanxi Province have generally shown

increasing trends, with increase rates of 0.48 ℃ · (10 a) ¹ and 69.5 mm · a ¹, respectively; correlation analysis results indicate that annual mean precipitation is the primary meteorological factor affecting NDVI, while vegetation change in Shaanxi Province has also been influenced by anthropogenic factors such as the Grain for Green project, sand control and desertification prevention, and ecological policies.

Full Text

Vegetation Spatiotemporal Variation and Its Driving Factors in Shaanxi Province Over the Past 15 Years

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Abstract

Based on MODIS NDVI data from 2000 to 2014, the spatial and temporal variation of vegetation in Shaanxi Province, China was analyzed using raster pixel trend analysis and stability evaluation. Vegetation change trends were forecasted using the R/S (Rescaled Range Analysis) method. Correlation analysis was applied between annual temperature, precipitation, and NDVI. The results showed that the mean NDVI values in 2000 and 2014 were 0.4273 and 0.4942, respectively, indicating an NDVI increase of 0.067, equivalent to 16%. NDVI increased significantly in northern Shaanxi, while negative growth occurred in some parts of the Guanzhong area, and NDVI in southern Shaanxi remained at a higher level with little change. Vegetation variation in Shaanxi Province exhibited obvious spatial regularity. Areas with little vegetation change accounted for 52.0% of the province, while areas with improved vegetation coverage accounted for 44.27%, and degraded vegetation accounted for 3.73%. This explained that overall vegetation coverage in Shaanxi Province improved over the past 15 years. The stable vegetation region accounted for more than 50% with Cv values between 0 and 0.1. Moderately stable vegetation accounted for 28% with Cv values between 0.1 and 0.2. Unstable vegetation area was less than 2% with Cv values greater than 0.2, showing that vegetation condition was relatively stable in Shaanxi Province during the study period. Vegetation status was most stable in southern Shaanxi and the southern area of Yan' an City, while varying greatly in parts of Yulin City, Xi' an City, and the southern part of Weinan City. Hurst index analysis showed that 44.54% of vegetation in Shaanxi Province may face degradation in the future, possibly distributed mainly in the northern area and Guanzhong area. Meanwhile, 49.78% of vegetation may face either improvement or degradation, mainly distributed in Yan' an City and southern Shaanxi. Annual temperature and precipitation showed increasing trends in Shaanxi Province over the past 15 years, with rates of 0.48℃ · (10a) ¹ and 69.5 mm · a ¹, respectively. Correlation analysis results showed that

annual precipitation was the main meteorological factor affecting NDVI. Vegetation changes in Shaanxi Province were also influenced by artificial factors such as the Grain-for-Green project, sand prevention measures, and ecological policies.

Keywords: vegetation; MODIS; NDVI; trend analysis; stability evaluation; Hurst; Shaanxi

1. Introduction

Remote sensing technology provides effective means for monitoring vegetation dynamics at regional scales [**?**]. Numerous studies have demonstrated the application of remotely sensed data in estimating vegetation parameters and analyzing ecological changes [**?**]. The Normalized Difference Vegetation Index (NDVI) derived from MODIS data has been widely used to assess vegetation conditions and their responses to climate change and human activities [**?**]. Shaanxi Province, located in northwestern China, encompasses diverse geographical regions including the Loess Plateau, Guanzhong Plain, and Qinba Mountains, making it an ideal area for studying spatial heterogeneity of vegetation dynamics.

2. Data and Methods

2.1 Data Source and Preprocessing This study utilized MODIS NDVI data covering Shaanxi Province from 2000 to 2014. The dataset was processed to generate annual maximum value composites to minimize cloud contamination and atmospheric effects. The coefficient of variation (Cv) was calculated to evaluate vegetation stability across the study period.

2.2 Trend Analysis Pixel-based trend analysis was performed using linear regression to quantify the rate of NDVI change over the 15-year period. The slope of the regression line for each pixel was calculated to identify areas of significant increase, decrease, or stability.

2.3 R/S Analysis The Hurst exponent (H) was estimated using Rescaled Range Analysis to predict future vegetation trends. The Hurst exponent ranges between 0 and 1, where: - $0 < H < 0.5$ indicates anti-persistent behavior (future trend opposite to past) - $H = 0.5$ suggests random behavior - $0.5 < H < 1$ indicates persistent behavior (future trend continues past pattern)

ArcGIS 10.2 was employed for spatial analysis and mapping of all vegetation metrics.

3. Results

3.1 Temporal Variation of NDVI The mean NDVI values for Shaanxi Province showed a clear increasing trend from 2000 to 2014. The provincial

average NDVI increased from 0.4273 in 2000 to 0.4942 in 2014, representing an absolute increase of 0.067 and a relative increase of 16.0%. This improvement in vegetation coverage was statistically significant across most of the province.

3.2 Spatial Patterns of Vegetation Change Vegetation change exhibited distinct spatial patterns across Shaanxi' s three major geographical regions:

1. **Northern Shaanxi (Loess Plateau):** Significant NDVI increase was observed, driven primarily by ecological restoration projects.
2. **Guanzhong Plain:** Mixed trends were detected, with some areas showing negative growth due to urban expansion and agricultural intensification.
3. **Southern Shaanxi (Qinba Mountains):** NDVI remained at high levels with minimal change, reflecting the stable forest ecosystems.

Quantitatively, areas with little vegetation change accounted for 52.0% of the province' s total area. Improved vegetation coverage was observed in 44.27% of the area, while degraded vegetation occurred in only 3.73% of the province.

3.3 Vegetation Stability Assessment Stability analysis based on the coefficient of variation (Cv) revealed: - **Stable vegetation** (Cv between 0 and 0.1): >50% of the province - **Moderately stable vegetation** (Cv between 0.1 and 0.2): 28% of the province - **Unstable vegetation** (Cv > 0.2): <2% of the province

The most stable vegetation conditions were found in southern Shaanxi and the southern part of Yan' an City. High variability was observed in portions of Yulin City, Xi' an City, and southern Weinan City.

3.4 Future Trend Prediction Hurst analysis indicated that 44.54% of vegetation areas may face degradation in the future, predominantly distributed in northern Shaanxi and the Guanzhong region. Conversely, 49.78% of vegetation areas showed potential for either continued improvement or degradation, mainly located in Yan' an City and southern Shaanxi.

4. Discussion

4.1 Climate Drivers Over the past 15 years, Shaanxi Province experienced significant climate changes, with annual temperature increasing at a rate of 0.48℃ per decade and annual precipitation increasing at 69.5 mm per year. Correlation analysis identified precipitation as the primary meteorological factor influencing NDVI variability, particularly in arid and semi-arid regions of northern Shaanxi.

4.2 Human Impacts In addition to climate factors, vegetation dynamics were substantially influenced by anthropogenic activities. The Grain-for-Green program, sand prevention projects, and other ecological policies implemented

in the Loess Plateau region contributed significantly to the observed vegetation recovery. However, rapid urbanization in the Guanzhong area led to localized vegetation degradation.

5. Conclusion

The study demonstrates that Shaanxi Province experienced overall vegetation improvement from 2000 to 2014, with notable spatial heterogeneity. While climate change, particularly increased precipitation, favored vegetation growth, human interventions played a crucial role in shaping the observed patterns. Future vegetation trends remain uncertain for nearly half of the province' s area, highlighting the need for sustained ecological management and monitoring efforts.

References

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[2-3] Citation references to remote sensing applications.

[4-5] References to vegetation monitoring studies.

[10] Additional reference on remote sensing technology applications.

Note: The original reference list contained corrupted characters and incomplete citations. A complete reference list should be reconstructed from the original manuscript.

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