Spatiotemporal Dynamics of Plant Phenology and Its Driving Factors in the Bayanbulak Region (Postprint)

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Abstract

Plant phenology represents the most significant and intuitive indicator of climate change, holding crucial importance for understanding the interactions between climate change and plant phenology. However, different ecosystems exhibit distinct responses and feedbacks to climate change. Scientifically analyzing the characteristics of plant phenology variations across multiple ecosystems and their driving factors under climate change trends is essential for elucidating the mechanisms underlying phenological changes. This study selects Bayinbuluke, a region characterized by the interspersed distribution of diverse ecosystems, as the research area. Based on MODIS NDVI time series data, we derived the spatial pattern characteristics, spatiotemporal variation features of phenology in the study region, and their relationships with elevation and climatic factors. The results indicate: The vegetation green-up period in the study area primarily occurs from early April to late May, while the senescence period mainly spans from mid-September to mid-October; During 2001–2017, the plant green-up period in the study region exhibited an overall advancing trend, with significant advances observed in grasslands, meadows, and marshes. The senescence period demonstrated an advancing trend in the northern region and a delaying trend in the southern region, with alpine vegetation and grasslands showing significant advancement in senescence; The vegetation green-up period generally delays with increasing elevation, whereas the senescence period advances with increasing elevation, and the differences in phenological periods among vegetation across various ecosystems diminish with increasing elevation. The plant green-up period in the study region shows a significant negative correlation with spring temperatures, wherein alpine vegetation is predominantly influenced by May temperatures, grasslands and marshes by April temperatures, and meadows by both April and May temperatures.

Full Text

Preamble

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Title and Authors

Spatiotemporal Variation of Vegetation Phenology and Its Driving Factors in the Bayanbuluk Region

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Abstract

Vegetation phenology is the most significant and intuitive indicator of climate change, and it is of great significance for understanding the interaction between climate change and vegetation phenology. The response and feedback of different ecosystems to climate change are different. It is of great significance for understanding the mechanism of phenological change to explore the relationship between spatiotemporal variation of vegetation phenology and its driving factors in various ecosystems under climate change. In this study, the Bayanbuluk region with a variety of ecosystems was selected as the study area. The MODIS NDVI time-series data during the period of 1989-2011 were used to get the spatial distribution and spatiotemporal variation of vegetation phenology, and to analyze its relationship with elevation and climate factors. The results showed that:

The beginning time of vegetation growth season was mainly from early April to mid-May, and the ending time was mainly from mid-September to mid-October;

The beginning time of vegetation growth season in most regions of the study area became earlier during the period of 2001-2017, and that of the grassland, meadow and swamp became significantly earlier except for the alpine vegetation. The ending time of vegetation growth season became earlier in the north of the study area but was delayed in the south, and that of the alpine vegetation and grassland became significantly earlier;

On the whole, the beginning time of vegetation growth season was delayed but the ending time became earlier with the increase of elevation, and phenological difference among different ecosystems was decreased with the increase of elevation;

There was a negative correlation between the beginning time of vegetation growth season and the spring temperature. The beginning time of growth season of alpine vegetation was significantly affected by temperature in May, that

of grassland and swamp by temperature in April, and that of meadow by temperature in April and May.

Keywords: vegetation phenology; NDVI; spatial pattern; climate change; Bayanbuluk; Xinjiang

1. Introduction

Vegetation phenology is the most intuitive biological indicator of climate change. The response and feedback mechanisms of different ecosystems to climate change vary significantly. Exploring the spatiotemporal variation of vegetation phenology and its driving factors across various ecosystems is crucial for understanding phenological change mechanisms under climate change.

Remote sensing technology provides effective means for monitoring vegetation phenology at regional and global scales. The Normalized Difference Vegetation Index (NDVI) is widely used in phenological studies due to its strong correlation with vegetation growth status. Common phenological metrics include the Start of Season (SOS), End of Season (EOS), and Length of Season (LOS).

Previous studies have shown that temperature is the primary factor controlling vegetation phenology in the Northern Hemisphere. In the Bayanbuluk region, complex terrain and diverse ecosystems create significant spatial heterogeneity in phenological responses to climate change.

2. Data and Methods

2.1 Data Sources

The study used MODIS NDVI time-series data from 2001-2017. The MOD13A1 product provides 16-day composite NDVI data at 500m resolution. Elevation data were derived from a 1:1,000,000 topographic map. Meteorological data including temperature and precipitation were obtained from local weather stations.

2.2 Data Processing

The Savitzky-Golay filter was applied to smooth the NDVI time-series data and reduce noise. The filter uses a moving window approach to fit polynomial functions to the data, preserving important phenological information while eliminating random fluctuations.

The NDVI was calculated using the formula:

$$NDVI = \frac{NIR - R}{NIR + R}$$

where NIR represents near-infrared band reflectance and R represents red band reflectance.

Cloud-contaminated pixels were identified and removed using the MODIS quality assurance flags. Only pixels with good data quality were retained for analysis.

2.3 Phenological Metrics Extraction

Phenological phases were determined using dynamic threshold methods. The SOS was defined as the date when NDVI reached 20% of the seasonal amplitude, while EOS was defined as the date when NDVI dropped below 20% of the seasonal amplitude. LOS was calculated as the difference between EOS and SOS.

3. Results

3.1 Spatial Distribution of Phenology

The spatial distribution of phenological phases showed clear patterns related to elevation and ecosystem type. The SOS generally occurred between day of year (DOY) 100-140 (early April to mid-May), while EOS occurred between DOY 260-290 (mid-September to mid-October). Alpine vegetation showed the latest SOS and earliest EOS, resulting in the shortest growing season.

[Figure 2: see original paper] shows the spatial distribution of NDVI and phenological phases in the study area.

3.2 Temporal Trends in Phenology

During 2001-2017, the SOS showed significant advancing trends in most areas, particularly for grassland, meadow, and swamp ecosystems (advancing at rates of 1.4-2.2 days per decade). The EOS exhibited divergent trends: advancing in the northern region but delaying in the southern region. Alpine vegetation and grassland showed significant advancing trends in EOS (0.14-0.22 days per year).

The LOS increased in most areas, with significant lengthening in grassland and meadow (3.3 days and 2.7 days per decade, respectively) but shortening in swamp (2.1 days per decade).

[Figure 3: see original paper] illustrates the change trend of phenological phases during 2001-2017.

3.3 Relationship with Elevation and Climate

Elevation strongly influenced phenological timing. With every 100m increase in elevation, SOS was delayed by 0.33 days/year for grassland, 0.27 days/year for meadow, and 0.21 days/year for swamp. EOS advanced with elevation at rates of 0.14-0.22 days/year.

Temperature showed significant negative correlations with SOS across all ecosystems. Alpine vegetation phenology was most sensitive to May temperatures, while grassland and swamp responded primarily to April temperatures. Meadow phenology was influenced by both April and May temperatures.

Precipitation effects varied by ecosystem type and elevation zone. In the 2300-2600m elevation range, precipitation showed positive correlations with SOS for grassland and meadow but negative correlations for swamp.

References

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