Postprint: Spatiotemporal Evolution of NDVI and Its Response to Climate in the Kashgar Delta

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Date: 2025-02-27T00:00:00+00:00

Abstract

To investigate vegetation growth trends and the degree of influence of climatic factors on vegetation growth, this study examined the spatiotemporal variation characteristics of Normalized Difference Vegetation Index (NDVI) across different seasons and its response relationships to mean temperature and precipitation in the Kashgar Delta, Xinjiang from 2000 to 2020, based on MODIS vegetation index data and concurrent monthly mean temperature and precipitation data, using methods including linear trend analysis, Pearson correlation analysis, and partial correlation analysis. The results indicate: (1) NDVI in the study area exhibited an extremely significant overall increasing trend, with the proportions of area showing significant or extremely significant increases during the growing season, spring, summer, and autumn accounting for 79.8%, 71.2%, 72.1%, and 91.3%, respectively. (2) The overall response relationship between NDVI and mean temperature and precipitation was not significant; precipitation exerted a dominant influence on NDVI, though with seasonal variations and spatially significant effects. NDVI in the growing season was negatively correlated with mean temperature and positively correlated with precipitation; NDVI in spring and summer was positively correlated with both mean temperature and precipitation; NDVI in autumn was negatively correlated with both mean temperature and precipitation. (3) The lagged response of mean temperature to NDVI was predominantly negative, while that of precipitation to NDVI was predominantly positive, indicating that increased temperature suppressed vegetation growth whereas increased precipitation promoted vegetation growth, and that precipitation exhibited a stronger lag effect on NDVI than mean temperature. The research findings can provide a reference basis for analyzing ecological environmental changes and for ecological protection and restoration in arid regions.

Full Text

Introduction and Study Significance

Previous research has primarily been conducted at larger spatial scales, focusing mainly on long-term interannual variation analysis, with less attention given to intra-annual seasonal variation trends and correlation analysis. The Kashi Delta, located in the arid and semi-arid region of southwestern Xinjiang, serves as the backbone of cotton and cash crop production in southern Xinjiang, yet its ecosystem is relatively fragile, which constrains economic development to some extent. Due to the sparse distribution of meteorological observation stations in the region, which cannot meet the needs of large-scale research, this study employs climate model data. Based on annual vegetation index data and corresponding climate data, we analyze the long-term temporal sequence and seasonal variations of NDVI and its response to climate factors in the Kashi Delta. This research helps elucidate ecological and environmental change trends in the region and provides a reference basis for regional ecological conservation, restoration, and socio-economic development.

Study Area

The study area is located in southwestern Xinjiang, on the western edge of the Tarim Basin. Its southern, western, and northern boundaries are defined by the outlets of major rivers, while its eastern boundary is marked by desert zones. The area primarily covers the plains of Kashi City, Shufu County, Shule County, Akto County, Yingjisha County, Yopurga County, and Jiashi County. Geographically, it lies between [COORDINATES], with a total area of approximately [AREA]. The width gradually increases from west to east in plan view, forming a "triangular" distribution. The overall topography features higher elevations in the west, south, and north, with lower elevations in the east. The climate is characterized as a typical warm temperate continental arid desert climate, with a multi-year average temperature of [TEMPERATURE] and multi-year average precipitation of [PRECIPITATION]. The multi-year water surface evaporation reaches [EVAPORATION]. Vegetation types in the region are mainly desert, meadow, and artificial vegetation, distributed throughout the area. Desert vegetation is primarily distributed in the north from Kashi City to Jiashi County, meadow vegetation is mainly found in the east of Akto County, north of Yingjisha County, and around Yopurga County, while artificial vegetation is predominantly in the central part of the study area, accounting for [PERCENTAGE] of the area. Desert vegetation includes temperate shrubs, temperate steppe shrubs, temperate semi-shrubs and dwarf semi-shrubs, temperate succulent halophytic dwarf semi-shrubs, etc. Meadow vegetation includes temperate halophytic grasses and forbs. Artificial vegetation mainly consists of two-year three-crop or one-year two-crop dry farming and deciduous fruit trees [CITATION] (Figure [Figure 1: see original paper]).

Data Sources

The Enhanced Vegetation Index (EVI) data were obtained from the Land Standard [PRODUCT] EVI index dataset provided by the National Aeronautics and Space Administration (NASA) website, with a temporal resolution of [TEMPORAL_{RES}] (global [COMPOSITE] vegetation) and spatial resolution of [SPATIAL_{RES}]. This study uses data spanning from [START_{YEAR}] to [END_{YEAR}]. The grid dataset was processed using [SOFTWARE] spatial analysis tools to calculate annual and seasonal means. Since the original dataset was multiplied by [FACTOR], the data were divided by [FACTOR] to obtain the true EVI values.

Temperature and precipitation data were sourced from the China monthly average temperature and monthly precipitation dataset from the National Earth System Science Data Center ([CENTER_{NAME}]), with a spatial resolution of [RESOLUTION] (approximately [DEGREE]). This dataset was generated through spatial downscaling of global climate data released by the University of East Anglia’ s Climate Research Unit (CRU) and global high-resolution climate data released by the [PLATFORM_{NAME}] platform, using a spatial downscaling scheme for China, and validated with [NUMBER] independent meteorological observation points. The validation results are reliable [CITATION]. Temperature units are [UNIT] and precipitation units are [UNIT]. This study uses data from [START_{YEAR}] to [END_{YEAR}], employing [SOFTWARE] for format conversion, band extraction, and mean calculation. Seasons were defined as: growing season [MONTHS], spring [MONTHS], summer [MONTHS], and autumn [MONTHS] [CITATION].

Methods

Descriptive Statistics

Based on the climate season characteristics and length variations in the study area, seasonal periods were defined as: growing season [MONTHS], spring [MONTHS], summer [MONTHS], and autumn [MONTHS] [CITATION]. Using monthly vegetation index, average temperature, and precipitation data from [YEARS], [SOFTWARE] tools were used to output annual and seasonal (growing season, spring, summer, autumn) averages of NDVI, average temperature, and precipitation. [SOFTWARE] was used to calculate the changing characteristics of NDVI, average temperature, and precipitation at different time scales, generating clear and intuitive line charts. [SOFTWARE] was used to input time series values of NDVI, average temperature, and precipitation at the [SCALE] scale for correlation analysis.

Linear Trend Analysis

To investigate the spatial variation patterns of NDVI and precipitation, this study employs a univariate linear regression method to calculate the changing characteristics of [NUMBER] factors [CITATION]. The specific calculation formula is as follows:

$$\text{slope} = \frac{n\sum_{i=1}^{n} i \cdot \text{NDVI}_i - \sum_{i=1}^{n} i \sum_{i=1}^{n} \text{NDVI}_i}{n\sum_{i=1}^{n} i^2 - (\sum_{i=1}^{n} i)^2}$$

Where: slope is the trend line slope; when slope > 0, it indicates an increasing trend in NDVI; when slope < 0, it indicates a decreasing trend; when slope $= 0$, it indicates no significant change. n is the number of time series years; i is the year sequence number, defined as [DEFINITION] in this study; NDVI_i is the NDVI value in year i; $\widehat{\text{NDVI}}_i$ is the linear regression value; $\overline{\text{NDVI}}$ is the average NDVI value.

The significance test for trend changes uses the F-test method [CITATION]. The calculation is completed as follows:

$$F = \frac{U/m}{Q/(n-m-1)}$$

Where: U is the error sum of squares; Q is the regression sum of squares; the regression degrees of freedom is [DF]; m is the number of variables; NDVI_i is the NDVI value in year i; $\overline{\text{NDVI}}$ is the average NDVI value.

Based on the F-test results compared with critical values, NDVI trends are divided into [NUMBER] levels: extremely significant decrease (P < [VALUE]), significant decrease (P < [VALUE]), insignificant decrease (P ≥ [VALUE]), insignificant increase (P ≥ [VALUE]), significant increase (P < [VALUE]), and extremely significant increase (P < [VALUE]).

Correlation Analysis

To analyze the relationship between NDVI and average temperature and precipitation, correlation analysis was conducted [CITATION]. The correlation between NDVI and climate factors in different seasons of the Kashi Delta was calculated using the following formula:

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

Where: r is the correlation coefficient between variable x and climate factor y; y_i is precipitation in year i; $\bar{y}$ is average precipitation; the range of r is [-1, 1]. When r > 0, it indicates positive correlation between variables; when r < 0, it indicates negative correlation; when r = 0, it indicates no correlation. The closer |r| is to 1, the stronger the correlation. The correlation analysis results are compared with r critical values to determine significance.

The correlation coefficient between x and y is calculated as:

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

Where: x_i is average temperature in year i; $\bar{x}$ is average temperature.

Partial Correlation Analysis

In complex ecosystems composed of multiple elements, changes in any element affect the entire system [CITATION]. To analyze the degree of climate influence on NDVI, partial correlation analysis is used to calculate partial correlation coefficients between NDVI and climate factors at the pixel scale [CITATION]. The calculation formula is:

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

Where: r_{xy}, r_{xz}, r_{yz} are the correlation coefficients between elements x and y, x and z, and y and z, respectively; r_{xy} · z is the partial correlation coefficient between variables x and y after controlling for z.

For partial correlation coefficient significance, the t-test is used [CITATION]. t is calculated as:

$$t = \frac{r\sqrt{n - m - 1}}{\sqrt{1 - r^2}}$$

Where: t is the significance test result for the correlation coefficient. Comparing t-test results with critical values, significance levels are divided into [NUMBER] levels: not significant (t ≤ [VALUE]), significant (t > [VALUE]), and extremely significant (t > [VALUE]).

Results

NDVI Interannual Variation in Different Seasons

As shown in Figure [Figure 2: see original paper], the growing season NDVI in the Kashi Delta shows an extremely significant increasing trend during [YEARS] (R = [VALUE], P < [VALUE]), but the interannual variation exhibits fluctuating growth rather than continuous increase. The highest growing season NDVI values occurred in [YEARS], with significant decreases compared to the previous year. From a year-over-year change perspective, [YEARS] showed an increasing trend, with [YEAR] showing positive growth compared to [YEAR]. Spring

NDVI [DESCRIPTION]. Summer NDVI [DESCRIPTION]. Autumn NDVI [DESCRIPTION].

Note: NDVI is the Normalized Difference Vegetation Index. The same below.

NDVI Trend Analysis and Significance Testing

A trend analysis and significance test were conducted for NDVI in different seasons of the Kashi Delta from 2000-2020 (Figure [Figure 3: see original paper]). The area change proportions are shown in Table . Overall, the growing season NDVI shows an increasing trend, with [PERCENTAGE] of the total area exhibiting increasing trends and localized degradation. Different seasons show varying spatial patterns of NDVI change. The growing season NDVI increase trend is [SLOPE] (P < [VALUE]). Insignificant degradation areas are distributed throughout the region, accounting for [PERCENTAGE], mainly concentrated in areas with frequent human activities. Significant degradation areas account for only [PERCENTAGE], scattered throughout the study area. Extremely significant degradation areas account for [PERCENTAGE], mainly distributed around urban areas of Kashi City, Shule County, Shufu County, and Jiashi County, with sporadic distribution in plain areas. Insignificant increase areas account for [PERCENTAGE], scattered in central, southern, and western parts of the study area. Significant increase areas are distributed in regions with concentrated human activities, accounting for [PERCENTAGE]. Extremely significant increase areas are widely distributed throughout the delta, accounting for approximately [PERCENTAGE], except in areas with frequent urban development and engineering activities (Figure [Figure 3: see original paper]).

Spring NDVI increase trend is weaker (slope = [VALUE], P < [VALUE]), with insignificant change areas accounting for [PERCENTAGE], mainly in plain areas far from cities. Degradation trend areas are small, concentrated in urban areas of Kashi City and Shule County. Most areas show significant to extremely significant increasing trends, accounting for about [PERCENTAGE], widely distributed in plains outside urban areas (Figure [Figure 3: see original paper]).

Summer NDVI shows the most obvious increasing trend among the four seasons (slope = [VALUE], P < [VALUE]). The area of insignificant change is smaller than in spring, accounting for [PERCENTAGE], mainly in relatively fixed agricultural areas. Degradation trend areas account for [PERCENTAGE], with obvious degradation in urban development concentration areas of Kashi City, Shule County, Jiashi County, Yingjisha County, and Shufu County. Extremely significant degradation areas are distributed at urban-rural junctions and in the southern piedmont plain of Yingjisha County. Significant increase areas account for only [PERCENTAGE] (Figure [Figure 3: see original paper]).

Autumn NDVI change trends differ significantly from other seasons (slope = [VALUE], P < [VALUE]), dominated by extremely significant degradation and extremely significant increase. Extremely significant degradation areas account for [PERCENTAGE], distributed north-south along the Kashi City to Yingjisha corridor. Extremely significant increase areas account for [PERCENTAGE], mainly distributed in the delta region east of Kashi City (Figure [Figure 3: see original paper]).

Interannual Variation of Climate Factors in Different Seasons

Figure [Figure 4: see original paper] shows that precipitation in the Kashi Delta exhibits an increasing trend during 2000-2020, but with obvious seasonal differences. Growing season precipitation is concentrated between [VALUES] mm, with an average of [VALUE] mm, showing fluctuating increase with maximum variation of [VALUE] mm (Figure [Figure 4: see original paper]). Spring precipitation fluctuates between [VALUES] mm, showing a weak increasing trend with variation intensity of [VALUE] and maximum variation of [VALUE] mm. Summer precipitation between [VALUES] mm shows a decreasing trend with variation intensity of [VALUE] and maximum variation of [VALUE] mm (Figure [Figure 4: see original paper]). Autumn precipitation is concentrated between [VALUES] mm, with an average of [VALUE] mm, showing a fluctuating decreasing trend with maximum variation of [VALUE] mm (Figure [Figure 4: see original paper]).

Average temperature in the growing season is between [VALUES]°C, with an average of [VALUE]°C, showing no obvious trend (R = [VALUE]) but uneven seasonal distribution with large temperature differences (Figure [Figure 4: see original paper]). Spring temperature shows a fluctuating decreasing trend with maximum variation of [VALUE]°C. Summer temperature shows a fluctuating increasing trend between [VALUES]°C. Autumn temperature shows a floating decreasing trend between [VALUES]°C with small changes, though variation exceeds [VALUE]°C in other years (Figure [Figure 4: see original paper]).

NDVI Response to Average Temperature and Precipitation

Correlation analysis between NDVI and average temperature and precipitation in different seasons of the Kashi Delta from 2000-2020 is shown in Table . Growing season NDVI shows insignificant negative correlation with precipitation, while other seasons show insignificant positive correlation with temperature and precipitation, indicating that the response relationship between NDVI and climate factors is not significant across seasons. Considering NDVI fluctuation characteristics and its lagged response to climate factors, based on NDVI fluctuation curves, statistical analysis was conducted for [NUMBER] time periods from [YEARS] to analyze correlations with previous season temperature and precipitation. The results show [NUMBER] groups of correlations: [NUMBER] groups show significant negative correlation, [NUMBER] groups show insignificant negative correlation, [NUMBER] groups show insignificant positive correlation, and [NUMBER] groups show significant positive correlation. NDVI shows mainly negative lagged response to temperature and positive lagged response to precipitation.

Spatial correlation analysis shows that temperature and precipitation effects on NDVI vary across seasons and space. Average temperature shows insignificant correlation with NDVI over [PERCENTAGE] of the area during the growing season. Significant to extremely significant positive correlation areas account for less than [PERCENTAGE], mainly in the central-western delta region, decreasing southeastward, with the rest showing insignificant correlation (Figure [Figure 5: see original paper]). Spring temperature correlation areas are distributed in the northeastern delta, decreasing from north to south, with significant positive correlation accounting for [PERCENTAGE] and extremely significant positive correlation accounting for only [PERCENTAGE] (Figure [Figure 5: see original paper]). Summer temperature correlation areas are mainly in the central-western delta, with significant to extremely significant positive correlation accounting for [PERCENTAGE] (Figure [Figure 5: see original paper]). Autumn temperature and NDVI show significant to extremely significant positive correlation areas mainly in the western delta, with small amounts in the southern piedmont plain, accounting for [PERCENTAGE] (Figure [Figure 5: see original paper]).

Precipitation effects on NDVI show overall positive correlation, accounting for [PERCENTAGE] of the area, with insignificant positive correlation accounting for [PERCENTAGE] and significant to extremely significant positive correlation accounting for [PERCENTAGE]. Negative correlation areas are very small (Figure [Figure 5: see original paper]). Growing season precipitation effects on NDVI [DESCRIPTION]. Spring precipitation correlation areas [DESCRIPTION]. Summer precipitation correlation areas [DESCRIPTION]. Autumn precipitation correlation areas [DESCRIPTION].

Note: [LEGEND DESCRIPTIONS FOR CORRELATION SIGNIFICANCE LEVELS]

Spatial Correlation Patterns

Figure 5 [Figure 5: see original paper] illustrates the seasonal correlation patterns between NDVI and precipitation/temperature in the Kashi Delta from 2000–2020. Significant positive correlations were predominantly located in the southern piedmont plain of Yingjisha County, accounting for a substantial portion of the study area. Additional positive correlation zones appeared in the southwestern piedmont plain and southeastern desert regions, decreasing from south to north and covering relatively small areas. During spring, precipitation showed significant positive correlations primarily in the central-northern delta, while spatial correlations were less pronounced in autumn. Summer precipitation exhibited the strongest influence on NDVI, with significant positive correlations concentrated in the central-northern delta region.

Temporal Trends and Driving Mechanisms

Our analysis of seasonal NDVI trends in the Kashi Delta from 2000–2020 revealed fluctuating but consistently increasing patterns across all seasons. The growth season, spring, summer, and autumn exhibited increase rates of 0.018, 0.022, 0.018, and 0.018, respectively ($P < 0.05$). Areas showing significant or extremely significant increases were primarily distributed across the extensive delta region outside urban centers, with trend magnitudes gradually intensifying from west to east and accounting for 79.8%, 71.2%, 72.1%, and 91.3% of the total area, respectively. Small-scale degradation patches were mainly concentrated in the peripheries of urban areas within the delta counties and cities.

The pronounced NDVI increase can be attributed to several factors. First, ecological protection and restoration projects implemented in the Kashi region in recent years have substantially improved the regional ecological environment. Second, the Kashgar River basin relies primarily on snow and ice melt for water replenishment, and global climate warming has enhanced river runoff, providing reliable water resources for vegetation growth. Third, short-term human activities have directly altered land use structures. While farmland vegetation cover in plain areas has increased significantly, urban expansion across various counties and cities has caused localized degradation, and the large-scale conversion of natural grassland to cultivated land has also contributed to vegetation decline in some areas.

Seasonal Climate Response Variations

The relationship between NDVI and climate factors exhibited notable seasonal and spatial heterogeneity. Overall, correlations with precipitation were generally stronger than those with temperature, though both relationships varied significantly across seasons and space. During the growing season, NDVI showed negative correlations with mean temperature but positive correlations with precipitation. In spring and summer, NDVI was positively correlated with both temperature and precipitation. In contrast, autumn NDVI displayed negative correlations with both climate variables. The spatial extent of significant climate influence also varied seasonally, with temperature effects concentrated in the central-western delta during the growing season, while precipitation effects were most pronounced in the southern piedmont plains during spring and summer.

Time-Lag Effects of Climate Factors

Considering the time-lag response of NDVI to climatic fluctuations, we examined correlations between NDVI and both concurrent and previous-season temperature and precipitation. Results demonstrated that precipitation exhibited a stronger lag effect than temperature. The time-lag response of temperature to NDVI was predominantly negative, whereas precipitation showed a mainly positive lag effect. This suggests that rising temperatures tend to inhibit vegetation growth, while increased precipitation promotes it, with precipitation effects persisting longer than temperature effects.

Conclusions

Based on our comprehensive analysis of NDVI-climate relationships in the Kashi Delta from 2000–2020, we draw the following conclusions:

1. **NDVI Trends**: The study area exhibited a highly significant upward NDVI trend, with significant increases occurring in 79.8% of the growing season area, 71.2% in spring, 72.1% in summer, and 91.3% in autumn.
2. **Climate Influence**: While overall NDVI response to mean temperature and precipitation was not statistically significant, precipitation emerged as the dominant influencing factor. Substantial seasonal and spatial variations were observed, with growing-season NDVI negatively correlated to temperature but positively correlated to precipitation; spring and summer NDVI positively correlated to both factors; and autumn NDVI negatively correlated to both.
3. **Time-Lag Responses**: Temperature showed primarily negative time-lag effects on NDVI, while precipitation demonstrated mainly positive lag effects, indicating that precipitation has a stronger and more persistent influence on vegetation dynamics than temperature.

These findings provide valuable insights for understanding ecological evolution in arid regions and can inform future ecological protection and restoration strategies.

References

1. Huang Qingyang, Cao Hongjie, Xie Lihong, et al. Species diversity and environmental interpretation of the herbaceous layer on the Wudalianchi volcanic lava plateau. *Biodiversity Science*, 2015.
2. Dai Shengpei, Zhang Bo, Wang Haijun. Spatiotemporal variation of vegetation and its influencing factors in Northwest China. *Journal of Geo-Information Science*, 2015.
3. Liu Yang, Li Chengzhi, Liu Zhihui, et al. Spatiotemporal variation of vegetation cover in Xinjiang based on MODIS data from 2000–2010. *Acta Ecologica Sinica*, 2015.
4. Chen Jinlin. Landscape resources, environmental assessment and sustainable development of Qinghai Lake National Geopark and its adjacent areas. Beijing: China University of Geosciences, 2015.
5. Zhang Yin, Gulixian · Tuerxunbai, Su Litan. Spatiotemporal characteristics of climate change at different altitudes in Xinjiang in recent 50 years. *Arid Land Geography*, 2015.

6. Ma Quanlin, Zhang Dekui, Yuan Hongbo, et al. Quantitative classification and environmental interpretation of vegetation in the Ulan Buh Desert. *Journal of Arid Land Resources and Environment*, 2015.
7. Sui Yue, Lu Linlin, Zhang Xi, et al. Multi-scale remote sensing analysis of vegetation cover change in Xinjiang from 2000–2010. *Meteorological and Environmental Sciences*, 2015.
8. He Hang. Spatiotemporal characteristics of NDVI in Xinjiang and its response to climate change. *Journal of Geo-Information Science*, 2015.
9. Ci Hui, Zhang Qiang, Zhang Bo, et al. Variation characteristics of NDVI in Northern China and its response to climate change. *Rural Eco-Environment*, 2015.
10. Pang Chaoyue, Liu Yuting, Zhang Qifei, et al. Impact of climate factors on net primary productivity in three southern Xinjiang prefectures. *Journal of Northeast Forestry University*, 2015.
11. Liu Shasha. Response of vegetation cover change to climate in Xinjiang. Shandong Agricultural University, 2015.
12. Hu Renjie, Chen Xuanli, Chen Jin, et al. Saturation effects of NDVI on remote sensing estimation of alpine meadow biomass: A case study of the eastern Qinghai-Tibet Plateau. *Acta Ecologica Sinica*, 2015.
13. Zhang Handong, Li Chongbo, Meng Liqi, et al. Evolutionary characteristics of NDVI in the Kashi Delta and its response to the climate. *Energy Science*, 2015.
14. Alim・Yiming, Zhu Min, Muhtar・Aimaiti. Spatiotemporal variation and influencing factors of vegetation cover in Kashi region in recent two decades. *Northern Horticulture*, 2015.
15. Du Jiaqiang, Gao Yun, Jiaerheng・Ahati, et al. Spatiotemporal variation and driving factors of vegetation growth anomalies in Xinjiang from 2000–2017. *Acta Ecologica Sinica*, 2015.
16. Liu Jing, Wen Zhongming, Gang Chengcheng. Response of different vegetation types to climate change on the Loess Plateau. *Acta Ecologica Sinica*, 2015.
17. Xu Yufeng, Yang Jing, Li Weihong, et al. Spatiotemporal variation of vegetation growth and its response to multi-timescale drought in Xinjiang. *Desert and Oasis Meteorology*, 2015.
18. Xu Liping. Impact of vegetation restoration on climate and its interaction effects in the Loess Plateau region. Xianyang: Northwest A&F University, 2015.
19. Zhang Hanyu, Fang Nufang, Shi Zhihua. Spatiotemporal variation of vegetation cover on the Loess Plateau and its response to climate factors.

Acta Ecologica Sinica, 2015.

20. Yang Yanping, Chen Jianjun, Qin Qiaoting, et al. Spatiotemporal variation of vegetation in Guangxi and its response to topography, climate, and land use. *Transactions of the Chinese Society of Agricultural Engineering*, 2015.
21. Zhang Yuandong, Xu Yingtao, Gu Fengxue, et al. Correlation analysis between desert oasis vegetation and climatic/hydrological factors. *Chinese Journal of Plant Ecology*, 2015.
22. Su Hongjun, Xu Zhonglin. Spatiotemporal dynamic analysis of vegetation index in Xinjiang. *Hubei Agricultural Sciences*, 2015.
23. Zheng Chunyan, Liang Junhong, Wang Jian. Spatiotemporal variation and influencing factors of NDVI in the China-Pakistan Economic Corridor. *Journal of Rural Eco-Environment*, 2015.
24. A Duo, Zhao Wenji, Gong Zhaoning, et al. Spatiotemporal variation of climate in the North China Plain and its impact on vegetation cover. *Acta Ecologica Sinica*, 2015.
25. Wang Na, Niu Ting, Wen Fang, et al. Analysis of driving factors of vegetation change in Xinjiang. *Environmental Protection of Xinjiang*, 2015.
26. Yang Guanghua, Bao Anming, Chen Xi, et al. Analysis of vegetation cover change and its driving factors in Xinjiang from 2000–2010. *Journal of Glaciology and Geocryology*, 2015.
27. Sun Yuxiang, Maimaitituxun · Maimaiti, Mahemujiang · Aihemaiti, et al. Spatiotemporal dynamic change of vegetation cover in Kashi City. *China Rural Water and Hydropower*, 2015.
28. Du Jiaqiang, Zhao Chenxi, Jiaerheng · Ahati, et al. Dynamic change of vegetation in Xinjiang and its response to climate change and human activities. *Acta Ecologica Sinica*, 2015.
29. Dong Lu, Zhao Jie, Liu Xuejia, et al. Response of vegetation growth to temperature in Xinjiang. *Chinese Journal of Applied Ecology*, 2015.
30. Maimaitituxun · Maimaiti, Mahemujiang · Aihemaiti, Tao Hongfei, et al. Spatiotemporal variation of oasis vegetation cover in the Kashgar River Basin. *Water Resources and Hydropower Engineering*, 2015.

Abstract: The impact of climatic factors on vegetation growth was examined using MODIS vegetation index data, monthly average temperature, and precipitation data for the period 2000–2020. Linear trend analysis, Pearson correlation analysis, and partial correlation analysis were applied to study the temporal and spatial variations in normalized difference vegetation index (NDVI) across different seasons and its response to mean temperature and precipitation in the Kashi

Delta of Xinjiang, China. The findings revealed the following trends: (1) NDVI in the study area showed a highly significant upward trend, with significant increases in the affected area during the growing season, spring, summer, and autumn, at 79.8%, 71.2%, 72.1%, and 91.3%, respectively. (2) Overall, NDVI showed no significant response to mean temperature and precipitation, though precipitation had a dominant influence on NDVI. Seasonal and spatial variations were observed. During the growing season, NDVI was negatively correlated with temperature and positively correlated with precipitation. In spring and summer, NDVI was positively correlated with both temperature and precipitation, while in autumn, it was negatively correlated with both. (3) The time-lag response of temperature to NDVI was mainly negative, whereas precipitation showed a mainly positive lag effect on NDVI. This suggests that increasing temperatures inhibit vegetation growth, while increased precipitation promotes it. Precipitation has a stronger lag effect on NDVI than temperature. These findings provide valuable insights for future analysis of ecological evolution in arid regions and can guide ecological protection and restoration efforts.

Keywords: NDVI; spatiotemporal variation; climate factors; Kashi Delta