

# Temporal and Spatial Variations of Vegetation Cover in Xinjiang from 2002 to 2015 and Their Response to Climate

S S Liu<sup>1</sup>, Q Zhang<sup>1\*</sup>, X C Li<sup>2</sup>, W J Song<sup>1</sup>, J N Yang<sup>1</sup> and X J Liu<sup>2</sup>

<sup>1</sup> Institute of Remote Sensing and Digital Earth Chinese Academy of Sciences, Beijing 100094, China;

<sup>2</sup> College of Information Science and Engineering, Shandong Agricultural University, Taian 271018, China

E-mail: zhangqing01@radi.ac.cn

**Abstract.** In this paper, the dataset of normalized difference vegetation indexes (NDVIs) in the arid region in Xinjiang from 2002 to 2015 as well as the climate data from 52 meteorological stations are utilized and the temporal and spatial variations of NDVI in recent years and their response to temperature and precipitation are analyzed in combination with various methods such as the maximum value analysis, correlation analysis and spatial analysis. It is concluded that in the past 14 years, the annual maximum NDVIs of Xinjiang presented a moderate rising tendency; Under the influence of the global background, the temperature and precipitation also showed different degrees of increase, which showed a significant increase in temperature. The annual maximum NDVI had a significant correlation with the annual precipitation (correlation coefficient: 0.634), but no obvious correlation was identified between the annual maximum NDVI and the annual average temperature (correlation coefficient: 0.279). To this end, regarding to the climatic factors, the influence of precipitation on the vegetation cover is higher than that of temperature.

## 1. Introduction

Located in the arid and semi-arid climatic zone of Eurasia, Xinjiang is an area with scarce vegetation, severe water and soil losses as well as extremely-fragile ecological environment. The climatic factors are principal elements leading to vegetation changes. In particular, temperature and precipitation have significant influence on the growth, distribution and carbon budget function of the vegetation [1]. Valuable explorations have been made by researchers on how to study land cover/vegetation dynamics with NDVI coupling with climatic factors. Gao and Liu(2016) [2] found that the vegetation index of the arid region of northwest China had little correlation with the precipitation and temperature, while Yan and Dai (2013) [3] pointed out that different types of vegetation had distinct responses to climatic factors, but the NDVIs of all vegetation did have significant positive correlation with the temperature and precipitation. Due to different temporal and spatial scales and analytical methods adopted for the study areas, previous studies drew distinct opinions and conclusions, and most of the study and analytical methods are simplex. In this paper, the temporal and spatial variations of NDVIs of the arid region in Xinjiang in the past 14 years as well as their response characteristics and sensibility to precipitation and temperature are analyzed, and the occurrence of extreme climatic events in Xinjiang in recent years as well as their influences on NDVI in allusion to the interannual variation of climatic factors are explored, so as to reveal the sensitivity of vegetation cover variations in the arid region in Xinjiang in the past 14 years to major climatic factors in the context of global warming and to provide scientific basis for guiding the oasis development and ecological environment construction in the arid region in Xinjiang with specific pertinence.

## 2. Data and study areas

\* Corresponding author.



### 2.1. Overview of the study areas

Xinjiang (73°20' ~ 96°25'E, 34°15' ~ 49°10'N) is located in the border area of northwest China with a total area of  $1.66 \times 10^6$  km<sup>2</sup>. It contains several major topographic units, such as the Altai Mountains, the mountainous region in the west of Dzungaria, Dzungarian Basin, Tianshan Mountains, Tarim Basin and Southern Mountain Area, which endows Xinjiang with a regional structure of "two basins embedded in three mountains". With scarce forests and low vegetation coverage (1.68%), the large area of desert, Gobi and open ground as well as the intensified land desertification year by year, Xinjiang has an extremely fragile ecological environment [4].

### 2.2. Data preparation

2.2.1. *Acquisition of MODIS data.* The NDVI data used in this paper are collected from the data product on monthly vegetation index of MODIS MOD13A from 2002 to 2015 from the official website of NASA (resolution ratio: 1 KM  $\times$  1 KM), and the annual maximum NDVI is calculated by Maximum Value Composite(MVC).

2.2.2. *Meteorological data.* The data of the temperature and precipitation from 2002 to 2015 are collected from the annual average temperature and precipitation data from 2002 to 2013 and the monthly average temperature and precipitation data from 2014 to 2015 from 52 basic meteorological stations, which are provided by the Meteorological Information Center of Xinjiang Uygur Autonomous Region; the annual average temperature and precipitation data are obtained by processing the aforesaid data.

## 3. Study methods

### 3.1. Spatial interpolation method

Inverse distance interpolation: the formula for inverse distance interpolation for the attribute  $z=z(x, y)$  of an arbitrary point  $(x, y)$  in the space is defined as follows:

$$\hat{z} = \sum_{i=0}^n \frac{1}{d_{\alpha}} z_i \quad (1)$$

Where:  $d_{\alpha}$  is the distance between the interpolated point and the first point in the field.

Kriging interpolation: the formula for Kriging interpolation for the attribute  $z=z(x, y)$  of an arbitrary point  $(x, y)$  in the space is defined as follows:

$$\hat{z}(s_0) = \sum_{i=1}^n \lambda_i z(s_i) \quad (2)$$

Where:  $z(s_i)$  is the measured value at position  $i$ ;  $\lambda_i$  is the unknown weight of the measured value at the  $i$  position;  $s_0$  is the mredicted position;  $N$  is the measured value.

### 3.2. Correlation analysis method

In this paper, the sensitivity of NDVI to corresponding climatic factors (including temperature and precipitation) is analyzed through correlation analysis. The formula for correlation analysis and calculation is provided as follows:

$$R_{xy,z} = \frac{R_{xy} - R_{xz}R_{yz}}{\sqrt{(1 - R_{xz}^2)(1 - R_{yz}^2)}} \quad (3)$$

Where:  $n$  is the cumulative number of years in the monitoring period,  $X$  and  $Y$  are the 2 variables of the correlation analysis; and  $\bar{x}$ ,  $\bar{y}$  are The average value of the sample values

## 4. Results and discussion

4.1. Analysis on interannual variation characteristics of vegetation cover

The annual maximum NDVI represents the NDVI value in the period when the vegetation is the most exuberant. Changes in NDVI may reflect the interannual vegetation variation caused by climatic and human factors. In this paper, analysis is made on the interannual variation of the annual maximum of NDVI from 2002 to 2015 through Excel.

(1) The annual maximum NDVIs of Xinjiang from 2002 to 2015 fluctuated between 0.1638 and 0.1853, At 2008, the maximum of NDVI reach the minimum.

(2) Interannual variation tendency: phase of rapid growth (2009-2010; 2014-2015), phase of rapid decrease (2002-2004; 2007-2009; 2013-2014) and phase of moderate growth (2004-2006; 2010-2013).

(3) In the past 14 years, an overall rising tendency was found in the annual maximum NDVIs of the arid region in Xinjiang. As a symbol of vegetation cover variations, it indicates that the overall ecological environment of the arid region in Xinjiang has been improved.

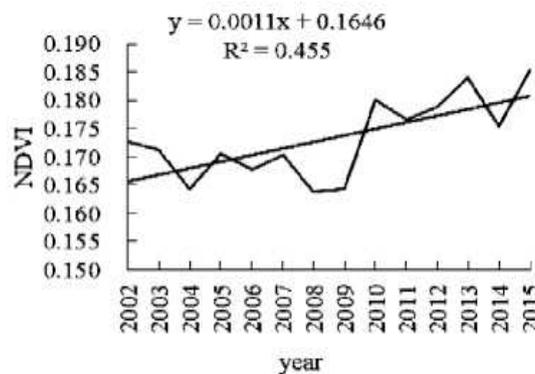


Figure 1. interannual Variation of Annual Maximum NDVI of Xinjiang from 2002 to 2015

4.2. Temporal variation of climatic factors and the influence of extreme climatic events on vegetation

(1) The curve of interannual variation of annual precipitation in Xinjiang (figure 2) showed a slight upward tendency of the annual precipitation in the arid region in Xinjiang from 2002 to 2015.

(2) The minimum precipitation occurred in 2008, when the second severe drought disaster in the history of meteorological record happened. The disaster caused significant damages to the vegetation cover as well as human production and living activities in Xinjiang. It was also the reason for the obvious and rapid decrease tendency of annual maximum NDVI of Xinjiang to occur in 2008 and 2009.

(3) Embraced a rapid growth in 2009-2010, the precipitation in Xinjiang reached 185 mm in 2010. The curve (figure 3) shows an obvious increasing tendency (including a periodic decreasing tendency from 2007 to 2012) of the annual average temperature of Xinjiang. The lowest annual mean temperature (6.18°C) occurred in 2012. The annual mean temperature rose again in 2012-2015, and then the highest annual average temperature occurred in 2015.

(4) As for the growth rate, the annual precipitation increased 0.407 mm/year from 2002 to 2015 (figure 2), while the annual temperature increased 0.079°C/year during the same period (figure 3). This indicates that in the context of global warming, the tendency towards warm and wet climate has been relatively obvious since the 21st century in the arid region in Xinjiang.

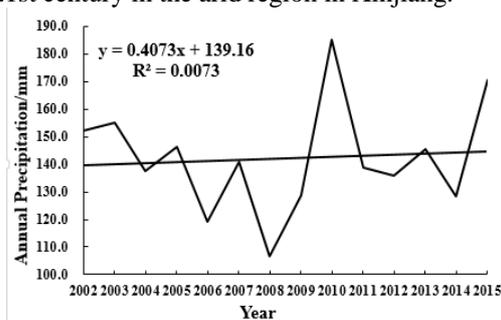


Figure 2. Interannual Variation of Annual

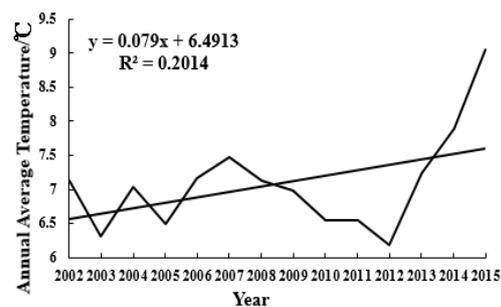


Figure 3. Interannual Variation of Annual

Precipitation from 2002 to 2015.

Average Temperature from 2002 to 2015.

4.3. Spatial pattern of temperature and precipitation

- (1) The precipitation showed a decreasing trend from northwest to southeast (figure 4), the middle of the Tarim Basin had a lowest annual precipitation of 50 mm/year.
- (2) The spatial distribution of regional annual average temperature showed a decreasing trend character from south to north (figure 5), where the lowest annual average temperature was -3.5°C and the highest was 15.7°C.

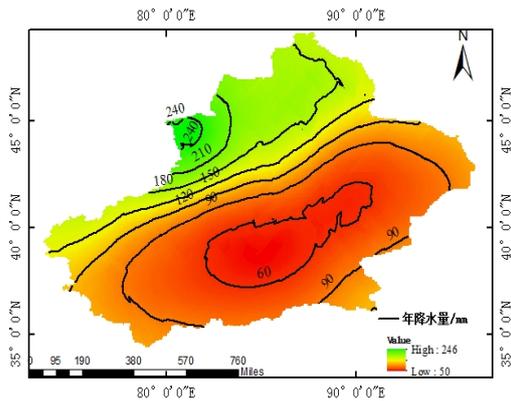


Figure 4. Spatial Distribution of Annual Average precipitation from 2002 to 2015

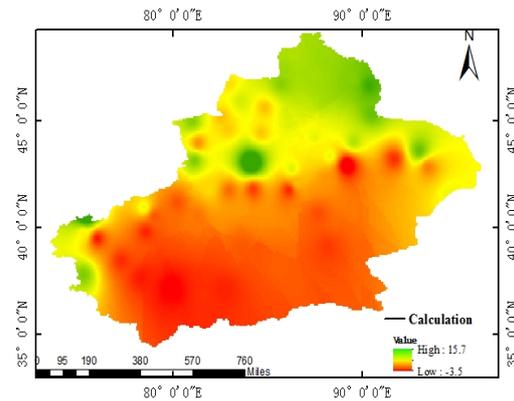
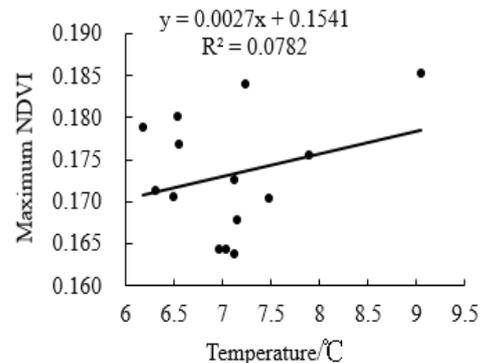
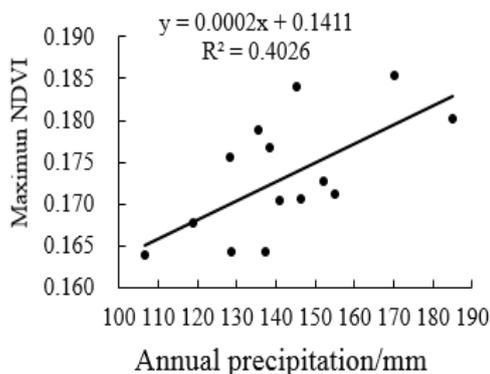


Figure 5. Spatial Distribution of Annual Average Temperature from 2002 to 2015

(1) Solar radiation and monsoon and other factors have influence on the temperature, precipitation and the growth of vegetation [5]. It is found that the correlation coefficients between annual maximum NDVI and annual precipitation and annual average temperature of 52 stations in the study areas are 0.634 ( $P < 0.05$ ) and 0.279 (table 1) respectively, which indicates that the annual maximum NDVIs of vegetation have a higher positive correlation with annual precipitation and annual average temperature.

(2) Figure 6 is the scatter diagram between the annual maximum NDVI and annual precipitation. The annual average NDVI is of a significant positive correlation with the annual average precipitation. When the annual precipitation ranges from 100 to 150 mm, the distribution of the point is denser, which indicates that in this period of time, the vegetation is of good growth conditions with high vegetation coverage. This is the sensitive range of annual Maximum NDVI to annual average precipitation (figure 6).

(3) Figure 7 is the scatter diagram between the annual maximum NDVI and annual average temperature. The annual average NDVI is of a positive correlation with the annual average temperature. With the increase of the annual average temperature, the annual average NDVI increases, therefore the vegetation coverage increases gradually. When the annual average temperature is 7°C, the vegetation is of the best growth conditions; when the annual average temperature ranges from 6 to 7.5°C, the vegetation is exuberant. This is the sensitive range of annual Maximum NDVI to annual average temperature (figure7).



**Figure 6.** Correlation Analysis of Annual Maximum NDVI and Annual Precipitation

**Figure 7.** Correlation Analysis of Annual Maximum NDVI and Annual Average Temperature

**Table 1.** Correlation of Average Annual Maximum NDVI with Temperature and Precipitation of Xinjiang from 2002 to 2015

NDVI	Climatic Factors	Correlation Coefficients	P
Annual maximum NDVI	Precipitation	0.634*	0.015
	Temperature	0.279	0.334

Note: “\*” means significant correlation

## 5. Conclusion

(1) The annual maximum NDVI of Xinjiang has a low sensitivity to annual average temperature, while it has a high sensitivity to precipitation. In general, it has a significant correlation with climate, and extreme climatic events have a significant influence on the NDVI in the arid region of Xinjiang.

(2) Climate change is an important factor influencing the temporal and spatial variations of vegetation in the arid region of Xinjiang. In this study, only two climatic factors, temperature and precipitation, are studied, while the influence of other climatic factors including illumination intensity and sunshine duration on the vegetation coverage will be the emphasis in next study.

(3) Climatic factors as well as other driving factors, including urbanized life and human activities that increased rapidly as well as society and economy factors, will influence the vegetation. In human life, the development of oasis agriculture in Xinjiang, the change of plantation structure and the cultivated area of main crop (cotton) will influence the change of vegetation cover in Xinjiang to some degree. The guidance and analysis on the oasis agriculture and the ecological environment construction in Xinjiang will be more comprehensive if we try to use other geo-statistic methods to explore and quantify the interactive intensities of these factors, and carry out study for a longer time series.

## References

- [1] Zhang Q, Yuan X L, Chen X, Luo G P and Li L H 2016 Vegetation Change and Its Response to Climate Change in Central Asia from 1982 to 2012 *Chinese Journal of Plant Ecology* **40** 13-23 (In Chinese with English Abstract)
- [2] Gao Z Q and Liu H Y 2000 The Study on Driving Factors and Models of NDVI Change Based on Remote Sensing and GIS in China *Climatic and Environmental Research* **5** 155-64 (In Chinese with English Abstract)
- [3] Yan X X and Dai C X 2013 Change Characteristics of the Vegetation Index in the North of the Tianshan Mountains and the Relation with the Temperature and Precipitation *Meteorological and Environmental Sciences* **36** 42-46 (In Chinese with English Abstract)
- [4] Li J, Liu H B, Li L and Li C Y 2016 Vegetation Dynamic Changes in Northwest China based on Multi-source Remote Sensing Datasets in Recent 30 years *Arid Land Geography* **39** 387-94 (In Chinese with English Abstract)
- [5] Dai S P, Zhang B and Wang H J 2010 Spatio-temporal Change of Vegetation Index NDVI in Northwest China and Its Influencing Factors *Journal of Geo-Information* **12** 315-21 (In Chinese with English Abstract)
- [6] Liu X F, Zhou X F, Pan Y Z, Li Y Z and Zhao A Z 2015 Spatiotemporal Changes in Vegetation Coverage in China During 1982-2012 *Acta Ecologica Sinica* **35** 5331-42 (In Chinese with English Abstract)
- [7] Shen X J, Zhou D W, Li F and Zhang H Y 2015 Vegetation Change and Its Response to Climate Change in Grassland Region of China *Scientia Geographica Sinica* **35** 622-29 (In Chinese with English Abstract)