Temporal and Spatial Pattern Characteristics of Vegetation in Qaidam Basin and Its Response to Climate Change

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Abstract: vegetation is a sensitive indicator of climate change. The spatial-temporal dynamic changes of vegetation cover and aboveground biomass and their relationship with climate factors in Qaidam Basin in recent 13 years were studied by using vegetation index. The results are as follows: (1) the total area of vegetation in Qaidam Basin increased from 2002 to 2015, with a growth rate of 644.11km²/a ($R^2 = 0.4919$). In recent 14 years, the change of vegetation area has been increasing → decreasing → increasing → decreasing, among which the vegetation area has been increasing continuously from 2009 to 2012; (2) During the period of 2002-2015, the vegetation area of each level of vegetation coverage showed an increasing trend, and the increasing rates were 300.2km²/a, 242.8km²/a and 101.2km²/a, respectively, which indicated that the vegetation ecology in Qaidam Basin was developing to a benign trend; (3) the aboveground biomass of vegetation was mainly low-yield vegetation less than 1500kg/hm², followed by vegetation of 1500-3000kg/hm², accounting for the total area of vegetation The proportion is less than 10%, and the vegetation area of other grades is very small, only scattered, while the high-yield vegetation larger than 6000kg/hm² is distributed in the southeast of the basin and the alpine mountains around the basin; (4) there is a certain coupling relationship between the climate and vegetation change in Qaidam basin, which is reflected in the positive correlation between the total vegetation area and the annual precipitation, the precipitation from May to September and the precipitation in summer, and the correlation significance of summer precipitation > may September precipitation>annual precipitation. However, it was negatively correlated with winter precipitation, but not with autumn precipitation and annual average temperature ($P > 0.5$).

1. Introduction
As one of the most important members of terrestrial ecosystem, vegetation is an indicator of climate change. Vegetation coverage is the result of the interaction of environment, climate and human activities, and the most direct factor is the impact of climate on vegetation.Normalized vegetation index (NDVI) is a dimensionless ratio parameter, which can be calculated by using near-infrared and red bands of satellite image data. It is widely used to evaluate the growth and development of vegetation. It is closely related to vegetation coverage, aboveground biomass and net primary
productivity (NPP). It is widely used in the study of regional vegetation dynamic changes at large and medium scales, and is an important data source of great value in vegetation research\(^1,2\). The traditional vegetation monitoring method usually uses the field sampling method, which needs a lot of manpower and material resources, and is limited by many objective and subjective factors, so it is impossible to carry out a large range of vegetation growth monitoring in a short time. In addition, with the traditional sampling method, the number of ground observations is limited, so it is difficult to comprehensively analyze the spatiotemporal change of vegetation in the region\(^3\). Remote sensing technology has a wide range of application, is convenient and efficient, and is an effective means of large-area vegetation monitoring. Since the application of satellite remote sensing data in 1960s, various satellite remote sensing data have been used in vegetation monitoring and evaluation\(^4-6\). Many foreign scholars have done a lot of research on the dynamic changes of vegetation growth, aboveground biomass and vegetation coverage by using the historical sequence data of vegetation index. In the 1980s and 1990s, NOAA-AVHRR data was mainly used. In 1999, with MODIS With the launch of Terra satellite, more and more scholars began to use MODIS data with higher spatial resolution for remote sensing estimation of vegetation classification, vegetation coverage, land use/land cover, aboveground biomass and leaf area index. Tucker et al.\(^7\) used NOAA satellite vegetation index data to monitor vegetation dynamic change in Sahel region of Africa, and analyzed vegetation coverage and drought change; Chen Yanli et al.\(^8\) used MODIS from 2000 to 2005 NDVI data is used to monitor the vegetation change of typical steppe in Xilinguole League. On this basis, the precipitation, water vapour pressure, average temperature, maximum temperature, minimum temperature and sunshine hours are taken as climate indexes to analyze the correlation between MODIS NDVI of typical steppe and desert steppe in Xilinguole League and climate factors in the same period and earlier period, and the climate driving factors of grassland vegetation change are discussed.

Remote sensing research on grassland vegetation in China started in 1980s, mainly including vegetation coverage, aboveground biomass estimation, grassland resource evaluation and grassland net primary productivity (NPP) estimation\(^9-12\). Sun Hongyu et al.\(^13\) used NOAA-AVHRR NDVI data from 1985 to 1990 to analyze the temporal and spatial changes of vegetation in China, and concluded meteorological data during the contract period to analyze the relationship between vegetation coverage change and climate factors. With the continuous development of science and technology, Landsat 8 Compared with other early land satellites, the oli data has been greatly improved\(^14\). However, compared with the high-resolution domestic satellites launched in recent years, there are narrow breadth, long transit period, large impact by clouds, less clear sky data, and it is difficult to build a remote sensing inversion model of vegetation historical sequence yield and coverage. Therefore, it is of great significance to analyze the response of vegetation to climate change in Qaidam Basin by using MODIS enhanced vegetation index (EVI) or NDVI historical sequence data and corresponding climate data.

In recent years, Chinese scholars have also made a lot of research on vegetation index, but NOAA-AVHRR/NDVI is the main one in the early stage. Park Shilong and Fang Jingyun\(^15\) used NOAA-AVHRR data to analyze the spatiotemporal dynamics of vegetation coverage in China in the past 18 years; Chen Jiang et al.\(^16\) used noaa-ndvi data and GIS technology to quantitatively analyze the spatiotemporal dynamics of vegetation coverage in the Qinghai Tibet Plateau during 1982-2002; Ma Junfei et al.\(^17\), and Wang Xiaolin et al.\(^18\) In the process of land cover classification of Qaidam Basin by using the shape matching method of NDVI time series change curve, Jin Xiaomei et al.\(^19\) calculated the vegetation coverage of Qaidam Basin by using MODIS NDVI data from 2000 to 2013, and analyzed its dynamic change law. The results show that the area of bare soil and low coverage vegetation in the basin decreases gradually, while the area of medium coverage, high coverage and high coverage vegetation increases year by year, and meteorological factors, elevation, groundwater table depth and groundwater salinity are the main influencing factors of vegetation change.
2. Data Processing and Methods

2.1 Overview of the Study Area
Qaidam Basin is located in the west of Qinghai Province, between 35°00′ - 39°20′N and 90°16′ - 99°16′E, with an area of 257768 km². The administrative area includes four counties and cities in Qinghai Province, namely Ulan, Dulan, Delingha, Golmud (excluding Tanggula area), and three towns of Dachaidan, Lenghu and Mangya. Qaidam Basin is located in the interior of Eurasian continent, surrounded by huge mountains, Kunlun Mountains in the south, Qilian Mountains in the north, Altun Mountains in the northwest, sun and moon mountains in the East, which is a closed inland basin. The vegetation in Qaidam Basin is sparse and simple, with less than 200 species in total. Most of them are shrubs, subshrubs and herbs with high drought resistance, and there are many halophytes.

2.2 Data Source
MODIS Vegetation Index (NDVI) data comes from mod13q1 products on NASA website, with a spatial resolution of 250m, a time resolution of 16d (the first day to 353rd day of each year), a product orbit number of h25v05 and h26v05 in Qaidam Basin, and a total of 84 scenes of 16d synthetic products corresponding to June, July and August of 2002-2015.

2.3 Data Processing and Methods
The data preprocessing of MODIS NDVI 16d synthesis product (MOD13Q1) includes the following steps: 1) Data mosaic and projection conversion. Use the MODIS special data processing tool MRT software, ENVI software or IDL program development language provided by NASA website for programming and processing. The output data can be in Img or Geotiff format. The projection method is converted to Albers projection. The ellipsoid is selected as Beijing 54 and the nearest neighbor method is selected as the resampling method. 2) Monthly vegetation index synthesis. Using BAND MATH in the ENVI software, the MOD13Q1 data was recombined with the maximum composite NDVI of 2 scenes and 16 days per month according to the maximum method, and finally the maximum monthly NDVI was obtained; 3) image cropping. Overlay the vector boundaries of the Qaidam Basin on the largest NDVI image map of the month, then turn the vector boundaries of the watershed into regions of interest, and finally use the SUBSET BY ROI under the BASIC TOOLS menu bar in ENVI software to crop the NDVI grid of the Qaidam Basin Illustration.

Correlation coefficient method: The trend line of the interannual time series only reflects the overall change trend of the Qaidam Basin. It does not reflect the spatial differences of vegetation changes in the watershed. Due to the complex and diverse topography of the Qaidam Basin and the large spatial differences in elevation, the types of surface coverage in the basin are diverse. Therefore, based on the pixel scale, first calculate the average NDVI in the river basin from 2002 to 2015, and then subtract the multi-year average value from the NDVI value of the current year (the NDVI value of the current year minus the average NDVI value of the previous year). The result is the NDVI anomaly value of the current year. Finally, according to the NDVI anomaly value of the current year, the pasture growth situation of the current year is positive. A positive value indicates that the grassland vegetation growth is better than the average of the past year. A negative value indicates that the grass development is worse than the average of the previous year.

Grassland biomass remote sensing monitoring: Select the grid data of the largest synthetic vegetation index in the peak seasons of June, July, and August, and then measure the maximum value of the corresponding month with the ground meteorological station. The above-ground biomass of the grassland was statistically analyzed to construct the most suitable grassland biomass model in the Qaidam Basin (y = 1237 * X2-527.2X + 95.011). This model has been initially applied to the pasture monitoring in Qinghai Province, and then estimated and studied. Aboveground biomass of grassland in the past 14 years (2002 ~ 2015).

The above-ground grassland biomass is divided into 8 grades, and the fresh grass yield> 9000kg / hm² is grade 1; 7500~9000kg / hm² is grade 2; 6000~7500kg / hm² is grade 3; 4500~6000kg / hm² is
grade 4; 3000~4500 kg/hm² is grade 5; 1500~3000 kg/hm² is grade 6; 750~1500 kg/hm² is grade 7; <750 kg/hm² is grade 8 [20] (Yu E Du, 2018).

Grassland coverage model: The following models were used to study the spatial and temporal distribution of grassland vegetation coverage in the Qaidam Basin.

\[
F_c = \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}
\]

Among them, NDVI vegetation index NDVI corresponds to 5% coverage, and NDVI corresponds to 90% coverage.

The grading criteria are: when 0 ≤ Fc < 0.20, grass coverage is defined as low coverage; when 0.20 ≤ Fc < 0.50 and Fc ≥ 0.50, grass coverage is defined as medium coverage and high coverage, respectively.

High-coverage grassland: Coverage of natural grassland, improved grassland, and mowed grassland is greater than 50%. This kind of grassland requires dense growth and good hydrothermal conditions. Medium-coverage grassland refers to natural grassland and improved grassland with sparse grassland growth and insufficient water. The coverage of this kind of grassland is generally between 20% and 50%. Low-coverage grassland refers to grassland with sparse growth, lack of water, and poor availability. The coverage of such natural grasslands is between 5% and 20% [21].

3. Vegetation Dynamics in Qaidam Basin

3.1 Vegetation Area

From 2002 to 2015, the total area of vegetation in the Qaidam Basin showed a significant increase and fluctuation trend, with a growth rate of 644.11 km²/a (R² = 0.0157). Among them, the vegetation area was the largest in 2012, and the minimum value appeared in 2006 and 2008, which is much lower than the multi-year average. From the 3-year sliding average of vegetation area, the change in vegetation area in the Qaidam Basin showed an increase→decrease→increase Large→decrease, especially the area of vegetation continued to increase during 2009-2012 (Figure 1).

![Figure 1. Changes in the total area of vegetation in the Qaidam Basin from 2002 to 2015](image)

3.2 Vegetation Coverage

Vegetation coverage refers to the percentage of the vertical projected area of all plant individuals (including leaves, stems, branches, etc.) in the plot to the total area of the plot. It is an intuitive criterion for evaluating the growth of vegetation and can characterize the vegetation of the ecosystem. The growth status of the community and the quality of the eco-environment are crucial for its accurate quantification in many studies such as soil erosion, soil and water conservation, land-air interaction, and desertification control [22]. Therefore, the establishment of a high-precision vegetation cover estimation model is of great significance to the research in related fields.

The remote sensing monitoring results of the vegetation coverage in the Qaidam Basin from 2002 to 2015 show that the medium and high coverage vegetation in the Qaidam Basin is mainly distributed in Dulan, Ulan, Delingha and Golmud, and the low coverage vegetation is mainly distributed in Central, western and northern Qaidam Basin. It can be seen from the change trend of vegetation...
coverage of different levels of coverage that the overall change in vegetation coverage in the Qaidam Basin is obvious. The total vegetation area, low, medium, and high coverage vegetation areas increased from 2002 to 2015, respectively. It is 300km²/a, 242.8km²/a, 101.2km²/a, and 644.1km²/a. The specific changes are as follows: taking 2005 as the boundary, the vegetation changes in 2002, 2003, and 2004 were not obvious. In 2005, the area of low-cover vegetation decreased, the medium and high-cover vegetation increased, and the vegetation coverage in the basin increased significantly. After that, except for the obvious reduction in the overall vegetation coverage area in 2006 and 2008, the area of low, medium and high coverage vegetation in other years increased year by year. The vegetation coverage in the basin increased year by year, indicating that the vegetation ecology in the Qaidam Basin has a trend of benign development (Figure 2).

**Figure 2.** Temporal and spatial pattern of vegetation coverage in the Qaidam Basin from 2002 to 2015

### 3.3 Aboveground Biomass of Vegetation

Monitoring results using EOS / MODIS satellite data from 2002 to 2015 showed that the above-ground biomass of vegetation was mainly low-yield vegetation of less than 1500 kg/hm², followed by vegetation of 1500-3000 kg/hm², and the area accounted for less than 10% of the total vegetation area. The vegetation area of the other grades is very small, only scattered sporadically, while the high-yield vegetation of more than 6000kg/hm² is distributed in the southeast of the basin and in the high-altitude local areas around the basin; in the past 14 years, the Qaidam Basin the area of low-yield vegetation showed an increasing trend, with a growth rate of 418.37km²/a, followed by a vegetation growth rate of 1500-3000kg/hm² above-ground vegetation, with an area growth rate of 111.32km²/a. In addition, in 2006 and 2008, the above-ground vegetation in the river basin was the lowest, and the highest in 2012. In 2010, the above-ground vegetation was second only to 2012, which is a high-yielding year.

### 4. Response of Vegetation to Climate Change

In recent years, Chinese scholars have also made a lot of research on the relationship between vegetation and climate factors by using vegetation index. Song Chunqiao et al.[23] extracted the important phenological information of the whole northern Tibet Plateau from 2001 to 2010 by using dynamic threshold method, including the vegetation rejuvenation period, withering yellow period and growth season length. Combined with the ground observation data, the impact of temperature and precipitation on vegetation phenological change was analyzed. Liu Shaohua et al.[24] analyzed the interannual variation and correlation of NDVI, accumulated temperature≥10°C and precipitation of
vegetation with pixel as calculation unit, and took meteorological stations and national vegetation division as research objects respectively, combined with surface and point scale analysis; Wang Erli et al.\textsuperscript{[25]} Based on the vegetation index data set of SPOT satellite data in Ebinur basin from 1998 to 2012, and used the multiple correlation analysis The partial correlation analysis method discussed the climate driving factors of vegetation cover change in the study area; Jin Xiaomei et al.\textsuperscript{[19]} calculated the vegetation cover rate of Qaidam basin with MODIS NDVI data from 2000 to 2013, and analyzed its dynamic change law. Meteorological factors, elevation, buried depth of groundwater level and mineralization degree of groundwater are the main influencing factors of vegetation change. This study shows that there is a certain coupling relationship between climate and vegetation change in Qaidam Basin, which is reflected in the positive correlation between total vegetation area and annual precipitation, precipitation from May to September and summer precipitation, and the correlation significance is that summer precipitation $>$ May to September precipitation $>$ annual precipitation. However, it is negatively correlated with winter precipitation, but not with autumn precipitation and annual average temperature ($P > 0.5$) (Figure 3).

5. Conclusion and Discussion
Vegetation, as a sensitive indicator of climate change, has an impact on hydrological, climatic and biogeochemical cycle processes. The main conclusions are as follows:

(1) From 2002 to 2015, the vegetation index (NDVI) of Qaidam Basin shows that the total area of vegetation in the study area is increasing, with a growth rate of 644.11km$^2$/a ($R^2 = 0.4919$). Among them, the vegetation area was the largest in 2012, and the minimum in 2006 and 2008. In recent 14 years, the change of vegetation area shows the trend of increasing $\rightarrow$ decreasing $\rightarrow$ increasing $\rightarrow$ decreasing, especially during 2009-2012 in Qaidam Basin.

(2) During the period of 2002-2015, the vegetation area of each level of vegetation coverage showed an increasing trend, and the increasing rates were 300.2km$^2$/a, 242.8km$^2$/a and 101.2km$^2$/a.
respectively. In 2002, 2003 and 2004, the vegetation change was not obvious. In 2005, the low coverage vegetation area decreased, the medium and high coverage vegetation increased, and the basin vegetation coverage increased significantly. In 2006 and 2008, the vegetation coverage decreased significantly, and in other years, the medium and high coverage vegetation area increased year by year. The vegetation coverage in the basin increased year by year, indicating the vegetation growth in Qaidam Basin The trend of development from state to benign state.

(3) The above ground biomass of vegetation mainly consists of low-yield vegetation less than 1500kg/hm², followed by vegetation of 1500-3000kg/hm², with the area accounting for less than 10% of the total vegetation area. The rest of the vegetation areas are very small and only scattered, while the high-yield vegetation greater than 6000kg/hm² is distributed in the southeast of the basin and alpine mountains around the basin.

There are few measured data of grassland vegetation in Qaidam Basin, which affects the accuracy verification of vegetation remote sensing monitoring model, and then affects the fine monitoring of important ecological factors vegetation in the basin. Terra/Aqua satellite, which is used to retrieve vegetation coverage, is close to being abandoned. What satellite data will be used to replace MODIS satellite in the future to construct the long-range data set of aboveground biomass and vegetation coverage and the data assimilation between different satellite data in different periods? In the follow-up study, it is considered that the newly launched fy3d and FY4 satellites in China with similar channel values and high calibration and positioning accuracy can be used to build vegetation coverage and aboveground biomass monitoring model by combining the visible light data with the ground measured data to solve the problem of MODIS satellite abandonment at any time. In view of the inconsistency between the monitoring time of the vegetation sample on the ground and the transit time of the satellite, and the problem affecting the accuracy of the vegetation monitoring model, in the future research, in addition to the timely measurement of the vegetation sample on the ground when the monitoring satellite passes through the local area as far as possible, at the same time, the satellite data of 50m spatial resolution of the high-resolution four satellite with shorter transit period can be used in combination with the UAV real-time aerial photographing of the vegetation sample To improve the inversion accuracy of the above ground biomass and coverage model of grassland vegetation.

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