Dynamic Changes of Vegetation and Its Influences in Forest-grassland Ecotone of Ili Region of Xinjiang from the Concept of Ecological Environment

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Abstract [**Objectives**] To analyze the dynamic changes of maximum vegetation coverage in Ili River Basin from 2006 to 2020, and to explore the vegetation change and its influencing factors in the forest-grassland ecotone of Ili region. [**Methods**] The pixel dichotomy model was used to process the MODIS data and analyze the change of vegetation coverage in the Ili River Basin from 2006 to 2020. [**Results**] (i) The vegetation coverage in the Ili River Basin increases gradually from west to east, and fluctuates greatly between years. (ii) By monitoring the change rate of the maximum vegetation coverage, it is found that the vegetation coverage of the basin has experienced a process of first decline and then recovery in the past 15 years. (iii) In spatial distribution, vegetation coverage has improved in some regions, while it has deteriorated in others, which may be related to regional climate change and human activities. [**Conclusions**] The vegetation coverage in the Ili River Basin showed significant spatial and temporal differences during the study period, and its changes were affected by both natural and human factors.

Key words Ecological environment, Ili region of Xinjiang, Forest-grassland ecotone, Vegetation dynamic changes

0 Introduction

The concept of ecological environment refers to the concept of strengthening the protection of the natural environment and ecosystem. It emphasizes the harmonious coexistence of man and the natural environment and ecosystem, highlights compliance with the laws of nature, considering the carrying capacity of the ecosystem, and achieving sustainable development on the basis of protecting the natural environment and ecosystem[1]. The concept of ecological environment is committed to the construction of ecological civilization, which requires people to enhance the awareness of ecological environment protection, follow the objective law, and implement protective development and utilization of nature and ecology, thereby achieving the harmonious coexistence of human and natural environment and ecosystem. This concept stresses the respect and protection of the ecological environment, and opposes over-exploitation and wanton destruction of the natural environment and ecosystem. With the intensification of human activities, vegetation ecosystems have been disturbed to varying degrees. Vegetation is sensitive to environmental changes.

The ecology in the forest-grassland ecotone of the Ili Region of Xinjiang is relatively fragile and prone to grassland degradation, soil erosion, land desertification and other issues. In order to strengthen the protection of the ecological environment of grassland ecotone of the Ili Region of Xinjiang and realize the good development of resources, it is necessary to uphold the concept of ecological environment. Therefore, studying the dynamic change of vegetation and its impacts on forest-grassland ecotone of the Ili Region of Xinjiang will provide a reference for promoting the sustainable and good development of the grassland ecotone of the Ili Region of Xinjiang.

1 Materials and methods

1.1 Overview of the study area The Ili River Basin has typical forest-grassland ecotone of Ili Region, so we selected it as the study area. The Ili River Basin is located in the western part of Xinjiang, China and the southeastern part of Kazakhstan, belonging to the continental temperate arid climate type. The basin is rich in water and soil resources, rich in wheat, cotton and other crops[2]. The latitude and longitude of Ili River Basin are 80°09′ - 84°56′ E and 42°14′ - 44° 53′ N. The overall topography of the basin is characterized by high in the east and low in the west. It is surrounded by higher mountains in the east, south and north. In this case, the westerly wind on the land can blow directly into the region and bring a large amount of moist water vapor to the area. The average annual precipitation in the basin is about 200 - 800 mm, and the average annual temperature is 8.4 ℃. Vegetation types in the basin include forest, meadow, steppe, hidden vegetation and desert.

1.2 Data sources and preprocessing

1.2.1 Data sources. We obtained data through the following ways. (i) Vegetation cover data within the Ili River Basin was extracted using MODIS data. A time-series dataset of the Normalized Difference Vegetation Index (NDVI) was acquired through the

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MOD13Q1 data product released by the National Aeronautics and Space Administration (NASA). The dataset has a temporal resolution of 16 d, a spatial resolution of 250 m, and the study cover the period from 2006 to 2020.

(ii) Meteorological data were obtained from meteorological stations in Zhaosu, Yining and other regions. The data included the precipitation and average temperature data during the vegetation growing season from 2006 to 2020. In addition, the data related to vegetation types were obtained by comparing the vegetation type maps within the territory of China.

1.2.2 Data preprocessing. Using the International Dyslexia Learning (IDL) secondary development platform, combined with the AreGIS python environment, the MOD13Q1 data was converted using the MRT tool according to the research needs. Through observing the growth cycle of vegetation in the study area, it is found that the vegetation grows best from April to September, while the vegetation growth is relatively weak in other months, and even the phenomenon of vegetation withering may occur. Based on this, the multi-source remote sensing data sets from April to September in the study area were extracted from monthly and annual time scales using the maximum synthesis method, so as to achieve more effective monitoring.

1.3 Pixel dichotomy model Vegetation coverage represents the percentage of the vertical projection area formed by vegetation in the total surface area of a specific observation area. This indicator is often used to monitor changes in the ecological environment. The pixel dichotomy model is usually used to calculate the vegetation coverage, and the calculation formula is as follows:

$$FVC = \frac{NDVI - NDVI_{soil}}{NDVI_{veg} - NDVI_{soil}} \quad (1)$$

where FVC denotes the vegetation coverage, $NDVI$ represents the normalized vegetation index value of the pixel, $NDVI_{soil}$ is the $NDVI$ value of the pixel without vegetation coverage, and $NDVI_{veg}$ is the $NDVI$ value of the pixel with pure vegetation coverage[3]. In this study, the confidence intervals of 0.5% and 99.5% were taken as the minimum and maximum values of the normalized difference vegetation index to replace the corresponding vegetation index values in the bare soil covered area and the corresponding vegetation index values in the pure vegetation covered area[4].

1.4 Analyzing the change rate of vegetation coverage on the basis of pixels and conducting grading assessment Based on the time series images, the status of the original vegetation coverage in the basin was compared and analyzed from the two dimensions of quantity and quality, and the rise and fall of the ecological environment was predicted. However, it should be noted that there is a certain lack of uniformity when observing the change of vegetation cover status from a spatial perspective. Based on the consideration of pixel location, the variation and trend of the maximum vegetation coverage in the study area from 2006 to 2020 were analyzed in depth. By simulating the change trend of each grid, the specific value of vegetation coverage during the study period was calculated, and combined with the specific year, the single linear regression method was used to analyze. According to the calculated slope, we can accurately reveal the change trend of vegetation cover in the time series. In addition, the vegetation coverage of the study area from 2006 to 2020 was assessed using the least squares method, the change slope value of each pixel was correctly fitted, and the improvement or degradation of vegetation coverage was assessed according to the criteria shown in Table 1.

Table 1 Grading assessment criteria of vegetation coverage change

Slope interval	Degree of vegetation coverage change
(0.01, 1]	Significant improvement of the vegetation coverage
(0.001, 0.01]	Moderate improvement of the vegetation coverage
(0, 0.001]	Mild improvement of the vegetation coverage
[-0.001, 0)	Slight degradation of the vegetation coverage
[-0.01, -0.001)	Moderate degradation of the vegetation coverage
[-1, -0.01)	Serious degradation of the vegetation coverage

2 Results and analysis

2.1 Temporal and spatial variation of maximum vegetation coverage in forest-grassland ecotone of Ili River Basin

2.1.1 Temporal variation of maximum vegetation coverage. The maximum vegetation coverage of forest-grassland ecotone in Ili River Basin from 2006 to 2020 was analyzed using pixel dichotomy model. The results show that the average maximum vegetation coverage in 15 years (2006-2020) was about 54.67%, and its fluctuation was large from the perspective of time series. Specifically, the average value of the maximum vegetation coverage in 2008 was the lowest, only 48.3%; it reached the highest in 2010, with an average value of 57.8%. From 2006 to 2010, the mean value of maximum vegetation coverage changed significantly. During 2010 and 2020, the fluctuation of vegetation coverage gradually decreased, and the average maximum vegetation coverage stabilized at 55.03%. It is worth noting that in 2008, the Ili River Basin was hit by floods, which caused serious damage to the local ecological environment, and the average maximum vegetation coverage in that year was correspondingly reduced to the lowest level.

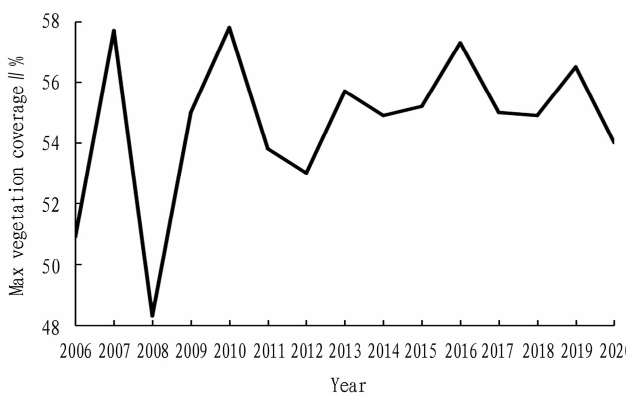

Fig. 1 Temporal variation of maximum vegetation coverage

2.1.2 Spatial variation of maximum vegetation coverage. Using the pixel dichotomy model as an analysis tool, with the time span from 2006 to 2020, we extracted the maximum vegetation coverage in the study area, and assessed its classification to reveal the specific characteristics of its spatial distribution. Through observing the whole study area, it is found that the vegetation coverage showed a trend of gradual increase from the west to the east. Specifically, the central and western regions are dominated by desert and bare land, and the vegetation coverage area is relatively small, while the eastern region is dominated by woodland, grassland and cultivated land, and has a higher vegetation coverage area. From 2006 to 2020, there were differences in the degree of change in vegetation coverage in the study area. Especially in 2007, 2009, 2010 and 2013, the vegetation coverage in the southeastern and north-central regions was higher than that in other years. By calculating the average vegetation coverage of the past 15 years in Ili River Basin, we obtained the detailed results of its spatial distribution: the vegetation coverage of the arid zone in the central and western regions of the basin was relatively low, especially in the area south of the Balkhash Lake, where the desertification was serious and the vegetation coverage was correspondingly low. In contrast, the vegetation coverage in the southern part of the Ili River Basin was higher, especially in the southeast of Yining County, Yili Region, where the maximum vegetation coverage reached 80%. In terms of the spatial distribution, the change of vegetation coverage in the Ili River Basin was as follows: the extremely low vegetation coverage area accounted for 3.74% of the total area of the basin, the low vegetation coverage area accounted for 41.13%, the medium vegetation coverage area accounted for 29.37%, and the high vegetation coverage area accounted for 13.42%.

2.1.3 Change trend of maximum vegetation coverage. From 2006 to 2020, the spatial distribution of the maximum vegetation coverage in the study area showed the following trends: the maximum vegetation coverage in the northwest and southeast fringes was gradually degraded, while the maximum vegetation coverage in the north-central region was gradually improved. The degradation of maximum vegetation coverage was particularly serious in the upper reaches of the Ili River, the Ili River Basin, the periphery of the delta and the Kapshagay Reservoir. In addition, the maximum vegetation coverage in the central and western Emin County and Tacheng City in Tacheng area showed a significant improvement. In the study area, some areas with high vegetation coverage showed a trend of degradation, while some areas with low vegetation coverage had a more obvious trend of improvement.

The statistical results of the spatial distribution of vegetation cover in the Ili River Basin reveal that the proportion of the areas with significantly improved or seriously degraded vegetation coverage was less than 4%, indicating that the overall eco-environmental quality has not shown a significant trend of improvement or degradation. Moderately and mildly improved areas account for about 53.7% of the total area, mainly distributed in the eastern part of Xinyuan County, including cultivated land, grassland and woodland. As far as the change of vegetation cover is concerned, the areas with moderate and slight degradation accounted for about 32.8% of the total area of the study area, and these areas were mainly concentrated in the delta and valley areas at the estuary of the Ili River.

2.1.4 Dynamic changes of ecological environment. The ecological environmental change of Ili River Basin from 2006 to 2020 was reflected by the change rate of maximum vegetation coverage. The results show that the ecological change of the basin has experienced a process of recession and then recovery. During this 15-year period, areas with low vegetation coverage showed signs of improvement, while those with good vegetation coverage gradually deteriorated. In the context of global warming, the temperature of Ili River Basin is gradually rising, and the precipitation is also increasing, which leads to the improvement of vegetation coverage in the original desert and bare land[5-6]. The continuous expansion of arable land around the Ili River Basin has led to an increase in the consumption of water resources, resulting in the imbalance of the regional ecological environment. During the study period, the vegetation coverage in the study area was degraded in a large area, and the original vegetation in the upstream, downstream and valley areas was also destroyed, which directly led to the deterioration of the ecological environment. The main reason for this phenomenon lies in the improper development of local water and soil resources, as well as the significant change of climate conditions in the region, and the corresponding reduction of the runoff of the Ili River[7].

2.2 Impacts of dynamic change of vegetation on forest-grassland ecotone of the Ili Region of Xinjiang in the context of concept of ecological environment Vegetation can not only conserve water and soil, but also significantly promote the effective improvement of the ecosystem. Its root system, canopy and other different layers can effectively slow down the erosion of runoff on the soil and improve the infiltration capacity of the soil, thus effectively curbing the loss and transport of sediment on the slope and further controlling soil erosion[8].

2.2.1 Impact of vegetation coverage on surface runoff. The formation of surface runoff is primarily influenced by rainfall and the characteristics of the underlying surface. The characteristics of the underlying surface are mainly reflected in soil conditions, topographic features, and vegetation coverage. Under similar topographic and soil conditions, vegetation coverage plays a decisive role in affecting surface runoff. Different vegetation coverage levels exhibit significant differences in rainwater interception and soil infiltration effects. Compared with bare ground, grassland vegetation can obstruct water flow through ground cover materials, thereby increasing the depth of slope runoff. Under these circumstances, water penetrates deeper into the soil, resulting in delayed runoff generation time on slopes. The runoff generation time for bare ground is approximately 1 min, while grassland typically maintains a runoff generation time around 2 min due to vegetation effects. Higher vegetation coverage leads to more pronounced delays in runoff generation time caused by grassland. Grassland not only significantly prolongs the concentration process after runoff generation but also increases the actual roughness coefficient of slopes through ground cover materials, resulting in more substantial reductions in both runoff volume and flow velocity on grassland slopes[9].

2.2.2 Benefits of water and sediment reduction brought by slope vegetation coverage. Rainfall condition and vegetation coverage have significant effects on the benefits of runoff and sediment reduction of grassland. Compared with the bare slope, the slope covered with grassland is more effective in reducing sand loss. Although the role of grassland in reducing runoff is relatively weak, its function in reducing sediment is very prominent. Grassland with high vegetation coverage can effectively intercept a large amount of precipitation, promote good infiltration of rainwater, enhance soil resistance to erosion, and significantly slow down the runoff rate, thus improving soil erosion resistance. In general, the effect of grassland on sediment interception is more significant than its effect on promoting precipitation infiltration and reducing runoff[10].

3 Conclusions

The Ili River Basin shows the typical ecological characteristics of forest-grassland ecotone in Ili Region of Xinjiang. By analyzing the dynamic changes of vegetation cover in this area, we reached the following conclusions. (i) The maximum vegetation coverage observed in the central and western regions was lower than that in the eastern marginal regions, which shows that the maximum vegetation coverage in the basin as a whole was gradually increasing from west to east. In time series, the mean maximum vegetation coverage of Ili River Basin experienced significant fluctuations during the 15-year period from 2006 to 2020. (ii) During the study period, the ecological environment in the study area generally showed a trend of first decline and then gradual recovery. After 2010, the ecological situation gradually tended to be stable, but the areas with low vegetation coverage began to improve, while the areas with high vegetation coverage gradually deteriorated. This change may be related to significant changes in regional climate. (iii) The utilization of cultivated land and water and soil resources in the Ili River Basin, the Delta region and the upper and middle reaches was improper, and the significant changes in regional climate have led to the gradual deterioration of vegetation coverage[11]. (iv) The vegetation coverage has a certain impact on surface runoff and the reduction of soil erosion.

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