# A spatial and temporal analysis on NDVI in Urad grassland during 2010-2019 over remote sensing

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**Abstract.** The temporal-spatial dynamic variation of vegetation coverage from 2010 to 2019 in Urad Grassland, Inner Mongolia has been investigated by analysing on MODIS NDVI remote sensing products. This paper applies pixel dichotomy approach and linear regression trend analysis method to analyze the temporal and spatial evolution trend of vegetation coverage over the past 10 years. The average annual vegetation coverage showed a downward trend in general from 2010 to 2019. The vegetation distribution and change trend analysis provide a thorough and scientific reference for policymaking in environmental protection.

## 1 Introduction

Urad Grassland as the study area in this work is located in the northern foot of Yinshan Mountain in China, with dry and windy winter and high proportion of wind erosion and desertification land. At present, over 70% grassland is seriously degraded, which is the main sand source of sandstorm and poses a threat to ecological security in North China [1][2]. Therefore, it is not only a typical ecological fragile zone which is very sensitive to global change, but also a critical ecological barrier in the mainland.

Fortunately, government has constantly funded billions of RMB in Urad Grassland since 2003 to encourage in closing grassland, restoring vegetation, returning grazing to grassland and reducing population density [1]. But very few researches have carried out on discussions with Urad Grassland that can be referred. Moreover, the only studies we can find review serious conflicts with vegetation assessment in this area. In particular, Wurina finds out the average coverage, average height and aboveground biomass of grassland vegetation have been improved from the analysis of 4 local monitoring stations since the implementation of the project of grazing to grassland [3]. However, researchers in [4] describe the opposite condition that the vegetation coverage changed from high grade to low grade obviously from 2000 to 2010.

Unlike the traditional method like field investigation in [2] or monitoring from sparsely distributed stations used in [3], remote sensing techniques are widely used as a useful tool to evaluate and analyze desertification areas for its advantages of diverse temporal and spatial data products, low cost and flexibility. In this study, remote sensing dynamic

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monitoring and analysis of vegetation coverage in the spatial and temporal perspective in Urad grassland for the past ten years are carried out.

## 2 Study area and data sources

Urad Grassland is located in the north of Inner Mongolia, belonging to the city of Bayan Nur with a total area of 6.4×104 km2 and a population of 1.76 million. Urad Grassland borders Mongolia in the north, Yinshan Mountain in the south, Alxa League in the west and Baotou City in the east. The geographical location of the selected study area is 105°11' E ~ 109°52' E, 40°27' N ~ 42°27' N, covering a total area of 5.48×104 km2. The study area composes of 3 Banners, namely Urad Front Banner, Urad Middle Banner and Urad Rear Banner, most of which are degraded grassland.

The NDVI data used in the study is the national MODIS MOD13A1 product data downloaded from NASA, with a temporal resolution of 16d and a spatial resolution of 500m, and a time span of 2010 -2019. A total of 80 remote sensing images are selected from July to August in the season of vigorous vegetation growth.

## 3 Approaches

### 3.1 Vegetation coverage via pixel dichotomy

NDVI is an excellent well-known indicator of plant growth, but it has limitation in high vegetation since the indicator saturates at some point. Pixel dichotomy model [4-6] is applied to indicate vegetation, which extends its feasibility area and improves performance by modifying NDVI. According to the principle of pixel dichotomy model, the NDVI value of a pixel can be expressed as two parts: the information contributed by green vegetation and the information contributed by bare soil. Vegetation coverage is calculated as:

$$f_{vc} = (NDVI - NDVI_{soil}) / (NDVI_{veg} - NDVI_{soil}) \tag{1}$$

in which, $f_{vc}$ is the vegetation coverage value of the study area; $NDVI_{soil}$ is NDVI value of bare soil or area without vegetation coverage, which is obtained from NDVI with cumulative percentage of 5%. $NDVI_{veg}$ is the NDVI value of pixels completely covered.

### 3.2 Spatial change trend analysis

In order to study the spatial difference of vegetation change rate in Urad grassland, the spatial change trend of annual average vegetation cover from 2010 to 2019 is simulated by using the linear regression trend analysis method [5,7] as follows:

$$\theta_{slope} = (n\sum_{i=1}^{n} iC_i - \sum_{i=1}^{n} i \sum_{i=1}^{n} C_i) / \left[ n\sum_{i=1}^{n} i^2 - \left(\sum_{i=1}^{n} i\right)^2 \right] \tag{2}$$

where $C_i$ is expressed as the grassland vegetation coverage in the first $i$ year. $\theta_{slope}$ is the change trend slope, $n$ is denoted as the monitoring time window (i.e., 10 years), and θ slope > 0 indicates that the vegetation coverage increased while θ slope < 0 indicates the opposite trend.

# 4 Results analysis

## 4.1 Temporal and spatial variation of vegetation coverage

According to vegetation coverage classification method [7], vegetation coverage is divided into five grades at equal intervals, i.e. lowest grade (0 ~ 20%), low grade (20% ~ 40%), medium grade (40% ~ 60%), high grade (60% ~ 80%) and highest grade (80% ~ 100%). The spatial distribution of average vegetation in terms of 5 grades from 2010 to 2019 of the study areas can be seen as Fig. 1. Detailed statistical results are shown in Table 1.
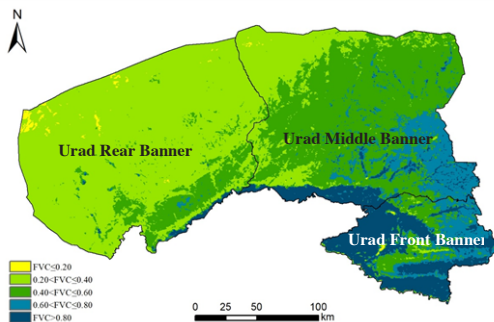


**Fig. 1.** Spatial distribution of average vegetation coverage from 2010 to 2019.

**Table 1.** Area and proportion of average vegetation coverage grades in Urad grassland.

| Grade of Vegetation Coverage | Urad Front Banner | | Urad Middle Banner | | Urad Rear Banner | | Overall | |
|---|---|---|---|---|---|---|---|---|
| | Area/km$^2$ | Ratio | Area/km$^2$ | Ratio | Area/km$^2$ | Ratio | Area/km$^2$ | Ratio |
| Lowest | 20.75 | 0.28% | 16.75 | 0.07% | 240.00 | 0.98% | 277.50 | 0.51% |
| Low | 182.25 | 2.43% | 4597.75 | 20.13% | 21019.75 | 86.05% | 25799.75 | 47.12% |
| Medium | 1466.25 | 19.59% | 13410.25 | 58.70% | 2867.50 | 11.74% | 17744.00 | 32.40% |
| High | 1893.50 | 25.29% | 3384.75 | 14.82% | 123.25 | 0.50% | 5401.50 | 9.86% |
| Highest | 3923.25 | 52.41% | 1436.00 | 6.29% | 175.75 | 0.72% | 5535.00 | 10.11% |

Fig. 1 shows vegetation coverage is generally characterized by high in the east and low in the west and decreasing from east to west. Both Fig.1 and Table 1 indicate vegetation coverage in most areas is at a low level and gradually increases from west to east in spatial distribution. Most of the areas with high vegetation coverage are distributed in Urad Front Banner in the southeast of the study area. Among the 3 Banners, the vegetation coverage in Urad Rear Banner is the lowest with 86. 05%, because most of this area is dominated by bare soil, bare rock, etc. with sparse vegetation. Urad Middle Banner has an average vegetation coverage of 20.13% and 79.8% at the low level and above respectively. Urad Front Banner has the highest vegetation coverage of 19.59% and 77.7% at the middle level and above respectively. The difference lies in the main distribution areas of agricultural activities, and vegetation coverage value is relatively high due to vigorous growth of crops.

Fig. 2 depicts annual variation trend in spatial distribution of vegetation coverage in Urad grassland from 2010 to 2019. We can see the vegetation coverage in the Urad grassland shows a slightly downward trend of wave motion on the whole. From 2010 to 2019, it showed a trend of increasing first and then decreasing.

The vegetation coverage of Urad Front Banner and Urad Middle Banner sharing the similarity in the temporal trend reaches the highest value of 0.83 and 0.57 at the same time

in 2012; Additionally, both got the lowest values in 2015 as 0.72 and 0.46, respectively. It shows quite difference with respect to vegetation coverage of Urad Rear Banner, which reaches its highest value of 0.37 in 2015 and the lowest value of 0.29 in 2019.

## 4.2 Spatial trend and evolution characteristics of vegetation coverage

Change trend of vegetation coverage is investigated by ArcGIS 10. 5 one-dimensional linear trend analysis method. The results from Fig. 3 show that the vegetation coverage in Urad grassland ecological function area generally showed a downward trend from 2010 to 2019. Table 2 illustrates statistical results of the change trend of vegetation coverage in Urad grassland over the past ten years.
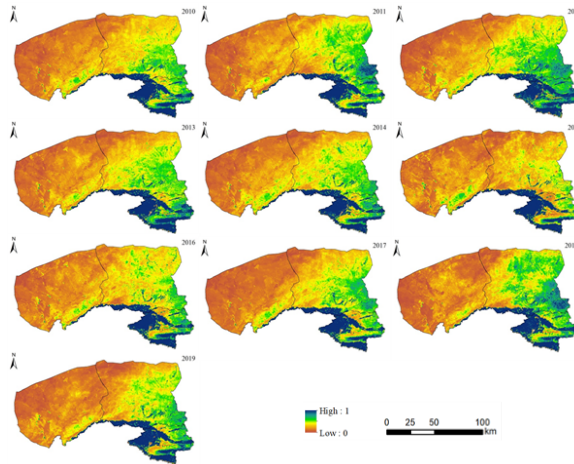


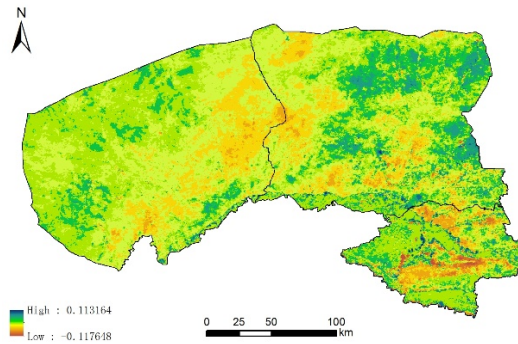**Fig. 2.** Annual spatial distribution of vegetation coverage in Urad grassland from 2010 to 2019.



**Fig. 3.** Spatial distribution map of the change trend of vegetation coverage in Urad grassland.

**Table 2.** Statistical results of the change trend of vegetation coverage in Urad grassland.

| Slope of Vegetation Change | Urad Front Banner | | Urad Middle Banner | | Urad Back Banner | | Overall | |
|---|---|---|---|---|---|---|---|---|
| | Area/km² | Ratio | Area/km² | Ratio | Area/km² | Ratio | Area/km² | Ratio |
| $\theta_{slope} \geq 0$ | 3342.00 | 44.64% | 7067.25 | 30.93% | 2476.25 | 10.14% | 12885.50 | 23.46% |
| $\theta_{slope} < 0$ | 4170.25 | 55.71% | 15752.25 | 68.95% | 21988.50 | 90.02% | 41911.00 | 76.54% |

In general, vegetation degraded areas are distributed in all counties, i.e. a percentage 76.54% of the overall Urad grassland has been suffering the vegetation degradation. Furthermore, the spatial difference of vegetation coverage and change trend is quite different. the degradation degree in the Urad Rear Banner is relatively severe. It can be seen from Table 2 that only 10. 14% of Urad Rear Banner is improved by vegetation, but over 90% is degraded. From Fig. 2 and Fig. 3, the desertification situation in Urad Rear Banner is very serious with nearly 90% of the areas belonging to desert areas, which are mainly distributed in Bayinwendur Desert and its surrounding areas. Extremely severe desertification is distributed in Haili Desert and Benbatai Desert.

Vegetation improvement area is mainly distributed in Urad Front Banner and Urad Middle Banner, with an improvement area accounting for 44.64% and 30.93%; the slightly deterioration areas account for 55.71% and 68.95% respectively. Most of these vegetation deterioration areas are urban areas with the most intensive human activities. Besides being affected by climate, human activities such as the increase of urban building area and rapid development of industry and mining have encroached on cultivated land and grassland resources, resulting in serious degradation of vegetation cover.

# 5 Conclusions

For mitigating the grassland digression and protecting from over-grazing, a serial of implementations supported by national and professional funds have been carried out in Urad grassland since 2003. However, rare research has been done focusing on this area with a thorough and accurate analysis on vegetation variation.

In this study, we employ remote sensing techniques to explore the vegetation coverage distribution in view of NDVI over the last ten years. Furthermore, spatial variation trend and temporal evolution characteristics of vegetation coverage have been thoroughly investigated with attempts to seek for helpful suggestions and useful references on ecological reconstruction of Inner Mongolia grassland. From statistical results, we find out the vegetation coverage in the study area generally shows a slightly downward trend in terms of time change from 2010 to 2019. The obvious degradation areas are mainly distributed in Urad Middle Banner and Urad Rear Banner, which are seriously disturbed by human activities. The vegetation coverage in Urad Rear Banner remains almost unchanged thanks to the protection encouragement policies from Government.

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