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DYNAMIC MONITORING OF VEGETATION COVERAGE IN WEIBEI DRY PLATEAU BASED ON REMOTE SENSING

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Abstract

Taking Fu County, a typical area of Weibei dry plateau, as the research object, the normalized difference vegetation index (NDVI) was calculated by using Landsat 8 OLI remote sensing image. On this basis, the vegetation coverage in the study area was estimated and graded according to the binary pixel model, and the dynamic changes of vegetation coverage in the study area from 2013 to 2017 were quantitatively analyzed. Results showed that the overall NDVI value in the study area increased from 2013 to 2017. The vegetation cover in the study area is dominated by extremely high vegetation cover. The coverage area of low, medium and high vegetation cover decreases, and the coverage area of extremely high and extremely low vegetation cover increases. The coverage area of high vegetation and extremely high vegetation cover accounts for more than 75% of the study area. The study area showed a transfer trend of extremely low vegetation→low vegetation→medium vegetation→high vegetation coverage. The vegetation coverage generally developed to a good trend, but there was also a transfer of high vegetation coverage to medium vegetation coverage. The areas with the greatest changes in the study area are mainly concentrated in the northwest and near the southern Damagou, and the high NDVI area of Ziwuling National Nature Reserve has moved eastward and narrowed. Accuracy assessment indicates that the dynamic monitoring using the fused image time series produces results with relatively high accuracy.

Introduction

The Weibei dry plateau is located in the south of the hilly and gully region of northern Shaanxi, and the north of the Guanzhong Plain is part of the Loess Plateau, including 25 counties (districts) of five cities in Shaanxi Province. Fuxian County of Yan'an City in Shaanxi Province is located in the transition zone from the hilly and gully region to the plain area, and is also one of the key counties of soil and water conservation in the national key control area of soil and water loss in the Ziwuling Mountains. A full understanding of the current situation and changes of vegetation cover in this region can not only test the effectiveness of returning farmland to forest and grassland and gully construction projects, but also provide theoretical methods and scientific basis for ecological environment construction in Weibei dry plateau.

As one of the most essential components of ecosystems, vegetation plays a vital role in alleviating soil erosion, maintaining ecological balance, improving windbreak and sand fixation capacity and maintaining regional sustainable development (wang and wang 2013). Surface measurement and remote sensing monitoring are currently the main methods for estimating vegetation coverage, and with the development of satellite remote sensing technology, which provides a low-cost and high-efficiency optimization approach in estimating vegetation coverage by virtue of its advantages of large-scale, multi-scale and multi-temporal. In addition, among the dozens of remote sensing vegetation index algorithms (Liu *et al.* 2008) that have been studied and

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developed, the normal difference vegetation index (NDVI) is the most representative. Its calculation is simple, and it is very sensitive to the growth of vegetation, which can well reflect the prosperity of surface vegetation, therefore, it is widely used to monitor vegetation dynamics. At the same time, NDVI is also widely used in land cover type classification, vegetation productivity estimation (Yu *et al.* 2018, Zhang *et al.* 2019), drought monitoring (Pastick *et al.* 2018, Urban *et al.* 2018), desertification monitoring (Li *et al.* 2009, Guo *et al.* 2019), and regional ecological environment quality assessment (Xu 2013, Li *et al.* 2015).

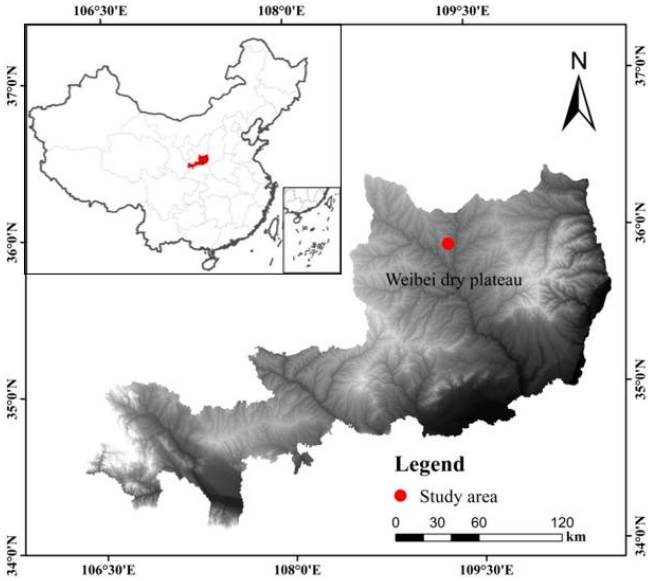

Fig.1. Schematic diagram of the geographical location of the study area.

Landsat 8 image satellite was successfully launched in California, the United States on February 11, 2013. Compared with the previous series of satellites, the radiation resolution increased from 8 bits to 12 bits, expanding the contrast between vegetation and non-vegetation information in panchromatic images and better displaying details (Xu and Tang 2013). In the present study, Landsat 8 OLI remote sensing images were used to estimate the vegetation coverage of Fuxian County in Weibei dryland area in 2013 and 2017 based on the normalized vegetation index, and the temporal and spatial distribution of vegetation index and vegetation coverage in the study area from 2013 to 2017 were studied and analyzed.

Materials and Methods

Fu County is located in northern Shaanxi Province and southern Yan 'an City, at the junction of Shaanxi, Gansu and Ningxia, located in the transition zone from the hilly and gully region to the plain area. The county has a vast territory, rich resources, clear four seasons, mild climate, sufficient sunshine and moderate precipitation. It belongs to the continental warm temperate monsoon climate. The annual average temperature is about 7-9℃, and the annual average precipitation is 500-600 mm. The topography of the area includes river terraces dominated by Luohe River and Huluhe River, gully areas in the central plateau, hilly and gully areas in the north of the plateau, and low earth-rock mountainous areas in the east and west.

Two Landsat 8 OLI remote sensing images selected by the USGS website (https://earthexplorer.usgs.gov) are used as the main data sources. In order to minimize the error caused by seasonal differences, the image imaging time is as same as possible. The acquisition dates are June 25,2013 and June 20,2017, respectively. The image cloud amount is less than 0.5, and the quality is good. In order to ensure the accuracy of the calculation of normalized vegetation index and vegetation coverage, the radiometric calibration, atmospheric correction and geometric correction of the two images were carried out before calculation. On this basis, the vector number of Fuxian administrative division was used.

Normalized Difference Vegetation Index (NDVI) is defined as the ratio of the difference between the values of near infrared and visible red bands and the sum of these two bands. The vegetation of NDVI is limited to the range [-1,1]. It is generally believed that vegetation is scarce when it is less than 0.1, and the NDVI value of desert, water and other terrain is very low or negative. For Landsat 8 OLI data, the calculation formula is :

$$NDVI = (\rho_5 - \rho_4)/(\rho_5 + \rho_4) \qquad \text{(Eq.1)}$$

where, and are the spectral reflectance values of band 4 and band 5 of OLI, respectively.

Although NDVI can directly reflect the vegetation change in the region, it still belongs to an indirect variable in the ecological environment evaluation. It is necessary to convert NDVI into vegetation coverage through certain methods. Vegetation coverage is recognized as a factor that can directly study and analyze the regional vegetation coverage. The present study, the calculation of vegetation coverage Fr (Equation 2) is based on NDVI, according to the formula proposed by Carlson and Ripley (1997) :

$$F_r = \left(\frac{NDVI - NDVI_{\min}}{NDVI_{\max} - NDVI_{\min}} \right)^2 \qquad \text{(Eq.2)}$$

where NDVI is the actual NDVI value of a pixel on the NDVI map ; NDVImin and NDVImax represent the minimum and maximum NDVI values corresponding to bare soil and total vegetation cover, respectively. In this study, Carlson and Ripley's approach, namely NDVImin = 0.20, NDVImax = 0.86.

For the calculated regional vegetation coverage, the present study was divided into five levels [16] : extremely low ($Fr < 0.2$), low ($0.2 \le Fr < 0.4$), medium ($0.4 \le Fr < 0.6$), high ($0.6 \le Fr < 0.8$) and extremely high ($Fr \ge 0.8$).

The change of NDVI in Fuxian County from 2013 to 2017 adopts the difference index of NDVI in two periods [15]. NDVI2017 and NDVI2013 are the actual values of NDVI of a pixel on the NDVI map of Fuxian County in 2017 and 2013, respectively, and the range of values is [-2,2]. Some studies have pointed out that when the NDVI value is greater than 0.1, the pixels represents are vegetation pixels, so the NDVI difference index is calculated by using the regions where the NDVI value is greater than 0.1 in the year. The classification of NDVI difference index is shown in tables (Table 1).

Table 1. The hierarchical graph of NDVI difference value classes.

Level	Change value
Severe degradation	$\Delta NDVI \le -0.15$
Moderate degradation	$-0.15 < \Delta NDVI \le -0.05$
slight degradation	$-0.05 < \Delta NDVI \le 0$
Minor improvement	$0 < \Delta NDVI \le 0.05$
Moderate improvement	$0.05 < \Delta NDVI \le 0.15$
Extreme improvement	$\Delta NDVI > 0.15$

Results and Discussion

The NDVI spatial distribution map of the study area was obtained by band combination calculation of Landsat 8 OLI images. It can be seen from Fig. 1 that the vegetation index of Fuxian County has the following characteristics: 1) The areas with high vegetation index are mainly distributed in the Ziwuling Nature Reserve in the southwest direction, while the areas with low vegetation index are mainly distributed around the main urban area of the county in the form of radiation and along the low mountainous areas of soil and rock in the northeast. 2) Compared with 2013, the average NDVI of the whole county increased from 0.3883 to 0.3951 in 2017. Therefore, the vegetation status of the whole county was improved, but the vegetation index was not obvious.

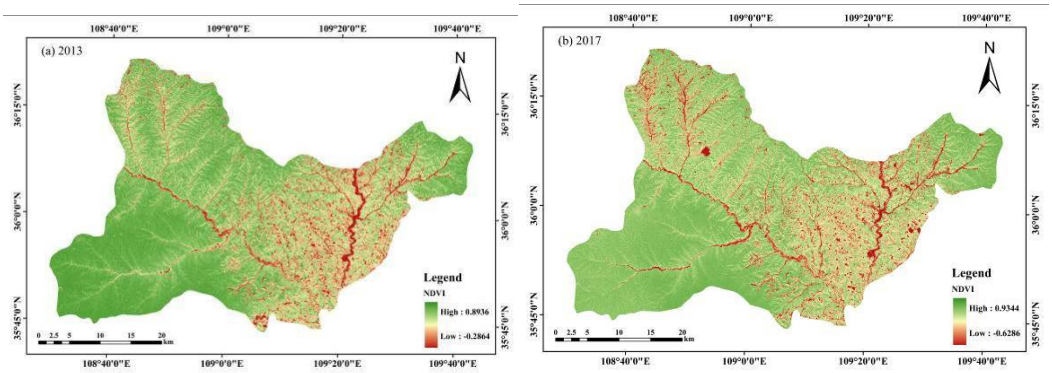

Fig. 2. The NDVI spatial distribution of Fu county in 2013 and 2017.

According to the vegetation coverage distribution map estimated by NDVI in the study area, the classified area and proportion in different periods are shown in Table 2. From 2013 to 2017, the area of extremely high vegetation coverage in the study area increased by 8.65%, and the areas of low coverage and high coverage decreased. The area of medium vegetation coverage decreased by 2.97%, and the area of low vegetation coverage decreased by 0.74%, showing the characteristics of increased area of high vegetation coverage, decreased area of low vegetation coverage, and increased overall vegetation coverage. After further analysis, the coverage of low-coverage vegetation areas in the study area increased significantly, while the phenomenon that high-coverage vegetation areas changed into extremely high-coverage vegetation areas was obvious, indicating that the vegetation coverage in the study area showed an overall upward trend, and the quality of vegetation coverage was significantly improved.

Table 2. Area ratio statics of vegetation fraction in different region from 2013 to 2017.

Vegetation coverage grade	2013		2017	
	Area/km^2	proportion/%	Area/km^2	proportion/%
Very low（$F_r < 0.2$）	217.42	5.31%	280.67	6.85%
Low（$0.2 \leq F_r < 0.4$）	305.64	7.46%	275.51	6.72%
Mid（$0.4 \leq F_r < 0.6$）	554.65	13.54%	432.99	10.57%
High（$0.6 \leq F_r < 0.8$）	924.86	22.57%	659.19	16.09%
Polar altitude（$F_r \geq 0.8$）	2094.29	51.12%	2448.49	59.77%

It is apparent from Fig.3 that the areas with low vegetation coverage in the study area are evenly distributed in the densely populated areas of Zhangjiawan Town in the northwest and the eastern towns. The areas with high vegetation coverage are distributed in the Ziwuling National Nature Reserve in the southwest, and the areas with the most intense changes in vegetation coverage are also distributed in this range. The spatial distribution patterns of vegetation coverage in different periods in Fuxian County are roughly similar. The vegetation coverage in Ziwuling National Nature Reserve in the southwest is the highest, followed by the north, the east is low, and the main urban area is the lowest.

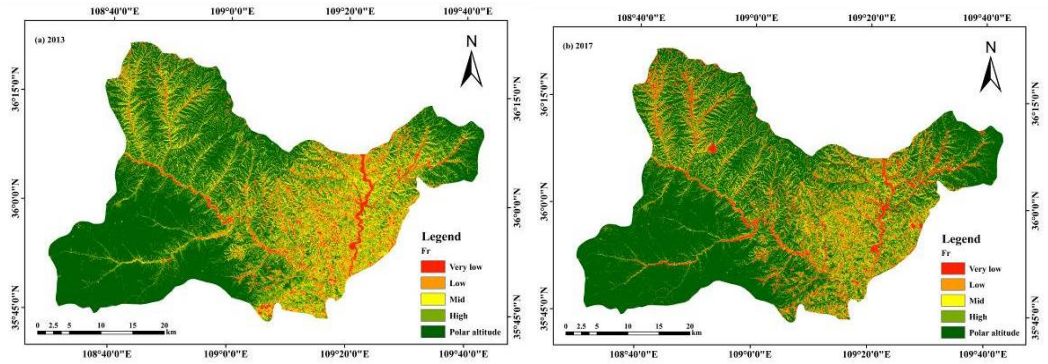

Fig. 3. The hierarchical graph of vegetation fraction distribution of Fu county in 2013 and 2017.

The characteristics of different levels of vegetation cover transfer in the study area from 2013 to 2017 were analyzed (Table 3). From 2013 to 2017, the vegetation coverage in the study area mainly showed a trend of extremely low vegetation→low vegetation→ medium vegetation ⇌ high vegetation ⇌extremely high vegetation transfer. During this period, the extremely low vegetation cover in the study area was mainly transferred to low vegetation cover, with a transfer rate of 27.81%. The low vegetation cover was mainly transferred to medium vegetation cover, with a transfer rate of 33.50%. The medium vegetation cover was mainly transferred to high vegetation cover, with a transfer rate of 25.63%. The high vegetation was mainly transferred to medium vegetation, with a transfer rate of 28.57%. The supplement of high vegetation mainly comes from high vegetation, with a supplement of 10.21%.

Table 3. Characteristics of different levels of vegetation cover transfer in 2013~2017.

2013	2017				
	Very low vegetation/%	low vegetation/%	Mid vegetation/%	High vegetation/%	Extremely high vegetation/%
Very low vegetation	54.77	27.81	10.96	4.15	2.31
low vegetation	16.27	42.11	33.50	6.94	1.18
Mid vegetation	2.99	19.89	49.41	25.63	2.08
High vegetation	0.61	3.08	28.57	57.54	10.21
Extremely high vegetation	0.08	0.15	1.40	16.56	81.80

The change of vegetation cover in Fuxian County from 2013 to 2017 was represented by the difference index of NDVI in two periods. The results of NDVI difference index analysis in Fu County showed that the areas of ecological degradation are mainly distributed in the northwest, and the areas of ecological extreme improvement are mainly distributed near the Damagou in the south. From Table 4, it can be seen that from 2013 to 2017, the area of slight improvement in the study area is the most, followed by moderate improvement, and the total area of the two accounts for 71.49 % of the land covered by vegetation in the study area. The area of vegetation degradation accounted for 27.2 % of the land covered by vegetation in the study area, and the proportion of severe and moderate degradation in the area of vegetation degradation was far less than that of slight degradation.

Table 4. Statistics of NDVI difference value classes from 2013 to 2017 in Fu county.

Level	Area/km^2	Proportion/%
Severe degradation	106.4979	2.60%
Moderate degradation	285.5223	6.98%
slight degradation	714.3885	17.47%
Minor improvement	2198.2302	53.75%
Moderate improvement	727.6680	17.79%
Extreme improvement	57.2571	1.40%

Figure 4 reflects the spatial distribution characteristics of NDVI difference in Fuxian County during the study period, and the severely degraded areas are mainly distributed in the northwest direction, and the extremely improved areas are mainly distributed near the Damagou in the south. The high value area of NDVI in Ziwuling National Nature Reserve moved eastward and the area decreased.

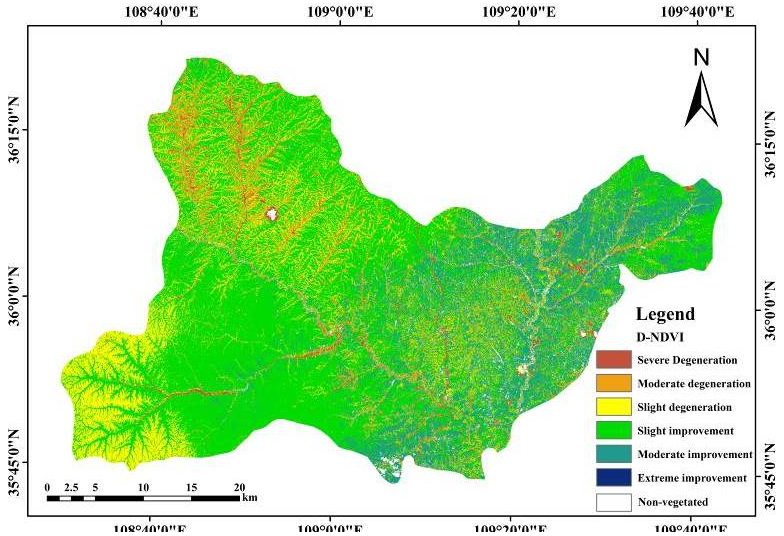

Fig. 4. The hierarchical graph of of NDVI difference value classes from 2013 to 2017 in Fu county.

The dynamic change of vegetation cover in Fuxian County of Yan ' an City from 2013 to 2017 was quantitatively analyzed and the change trend was studied in details. It may be concluded that from the perspective of vegetation index characteristics, the average NDVI in the study area increased from 0.3883 to 0.3951 in 2017 compared with 2013, and the overall NDVI average increased, but the change was not obvious from the spatial distribution of NDVI. From the perspective of vegetation coverage characteristics, the study area was dominated by extremely high vegetation coverage from 2013 to 2017. The areas of low, medium and high vegetation coverage decreased, and the areas of extremely high and extremely low vegetation coverage increased. However, high vegetation and extremely high vegetation still accounted for more than 75 % of the study area. From the perspective of vegetation coverage type transfer, the study area showed a trend of extremely low vegetation → low vegetation→medium vegetation→high vegetation coverage transfer, and vegetation coverage generally developed to a good trend. However, the transfer of high vegetation coverage to medium vegetation coverage also occurs, which needs attention. From the results of vegetation difference with NDVI greater than 0.1 in the study area, the areas with the largest change were mainly concentrated in the northwest and near the southern Damagou. The high-value area of NDVI in Ziwuling National Nature Reserve moved eastward and the area decreased.

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