Analysis on the Change Trend of Vegetation Index in the Wei River Basin of the Loess Plateau from 2000 to 2016

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Abstract. We used the normalized difference vegetation index (NDVI) data of the MODIS images in the Wei River Basin of the Loess Plateau from 2000 to 2016 based on the support of RS/GIS technology. The results indicate that: (1) The vegetation cover in the Wei River Basin has accelerated and improved since 2000. Afterwards, the vegetation decreased slightly; (2) More than 90% of the area in the past 17 years showed vegetation restoration. The significant recovery area mainly accounted for 6.80% of the vegetation reduction area in the Ziwuling and Liupanshan areas, and was mainly attributed to the urbanization process. The acceleration of the results further confirms the remarkable achievements of the ecological restoration project on the Loess Plateau and provides theoretical support for regional sustainable development.

1. Introduction
Vegetation is a natural link between soil, water and environment, and plays an important role in terrestrial carbon balance and climate system regulation. Monitoring the dynamic changes of vegetation and assessing the impact of human activities and climate change on vegetation changes have important practical value for determining reasonable ecological engineering layout and adaptive management strategies[1-3]. It has become a frontier and hotspot in the research field of sustainable management of vegetation ecosystems in a changing environment. By analyzing the characteristics and trends of the temporal and spatial variation of the normalized difference vegetation index (NDVI) in the Wei River Basin, it can provide an important reference for local ecological environment planning[4-7].

2. Materials and methods

2.1 Study areas
The Wei River has a total length of more than 800 km and is the largest primary tributary of the Yellow River. The Wei River Basin is located between 102.5°E–112.5°E and 32.5°N–37.5°N, including 13 areas in the three provinces of Shaanxi, Gansu and Ningxia. The environment within the basin is complex, with the Loess Plateau in the north and the Qinling Mountains in the south, with a total area of about 135,000 km². The Wei River Basin is located in the central area of China's geographical
position. It has been an important traffic artery since ancient times and a necessary area to the southwestern southwest[8].

2.2 Data source
We obtained the MOD13A1 of the MODIS standard data covering the Wei River Basin from 2000 to 2016. The product is a 16-day synthetic 500-meter resolution vegetation index derived from the National Aeronautics and Space Administration (NASA) Earth Data Center (http://ladsweb.nasom.nasa.gov/data/search.html).

2.3 Research methods
• One-way linear regression analysis
  One-way linear regression is a method of regression analysis of a set of time-varying variables that can predict future trends [9]. Using the 17-year NDVI maximum for each pixel, we can simulate the change trend formula of the pixel during 2000-2016:

\[
\theta_{\text{slope}} = \frac{17 \sum_{i=1}^{17} (i \times NDVI_i) - \sum_{i=1}^{17} \sum_{i=1}^{17} NDVI_i}{17 \sum_{i=1}^{17} i^2 - (\sum_{i=1}^{17} i)^2}.
\]  

(1)

Where: variable \(i\) is the year number, \(NDVI_i\) is the value of NDVI in 17 years from 2000 to 2016. \(\theta_{\text{slope}}\) is the linear regression slope of the unit, indicating the growth of the annual average NDVI. When \(\theta_{\text{slope}} > 0\), it means that the vegetation is growing; when \(\theta_{\text{slope}} = 0\), the vegetation has no change; when \(\theta_{\text{slope}} < 0\), the vegetation is reduced. This time, there will be seven levels to distinguish the degree of spatial change in vegetation.

• Maximum value synthesis method (pixel statistical method)
  The maximum NDVI was obtained after the maximum synthesis to study the overall variation characteristics of spatial for vegetation [10]. formula:

\[
M_{NDVI_i} = \text{Max}(NDVI_{i1}, NDVI_{i2}).
\]  

(2)

In the formula, \(i\) is the month serial number, and the value is 1-12; \(M_{NDVI_i}\) is the NDVI value of the i-th month; and \(NDVI_{i1}\) and \(NDVI_{i2}\) are the NDVI values of the early and late months, respectively.

3. NDVI-based spatiotemporal variation characteristics

3.1 NDVI changes in Time
• NDVI changes from 2000 to 2016
  Using the average of the pixel values of vegetation NDVI from 2000 to 2016, the distribution of NDVI inter annual variation in the Wei River Basin was obtained. Overall, the NDVI has been fluctuating since 2000 in the Wei River Basin. Among them, the NDVI value was the smallest (0.55) in 2000, and then increased significantly every two years. The NDVI was as high as 0.70 in 2013, but there was a significant volatility decline thereafter. This change was related to the local implementation of returning farmland to forests (grass) and other factors. With the implementation of the policy of “returning farmland to returning farmland, afforestation and grassland, and forestry and enriching the people”, the vegetation in the Wei River Basin has been significantly improved under the long-term protection(Fig. 1).
Monthly changes of NDVI in Wei River Basin

The middle and lower reaches of the Wei River Basin are rich in water, and the rainfall will be collected from July to September. Therefore, the changes in vegetation during the year are also obvious. From the trend of monthly average NDVI since 2000, the vegetation is in a state of stagnation in January and February, and the NDVI is at the lowest value in the year, 0.23, 0.24 respectively. The vegetation was at the end of the stagnation in March, that was beginning to wake up, and enter the greening period. And then, the NDVI increased slightly. The vegetation enters the growing season from April to May, and the growth rate of NDVI is fast, with an average daily increase of 0.003. The precipitation was sufficient and the climate was comfortable in July and August. It was conducive to promoting plant growth and entering the lush vegetation. At this time, the chlorophyll content in the body increased and the growth peaked. It was 0.58 of the highest NDVI in August. The temperature showed a downward trend and the climate gradually became dry from the end of August to the autumn, the vegetation gradually turned yellow, and the vegetation NDVI decreased significantly. At the end of October to December, with the fall of frost and snow, it entered the winter completely, and the vegetation NDVI decreased further(Fig.2).

3.2 Analysis of spatial variation trend of vegetation NDVI

- Annual average NDVI spatial distribution characteristics

The spatial distribution of NDVI in the Wei River Basin is extremely uneven, and the whole is gradually decreasing from southeast to northwest. Among them, the NDVI in the hilly area of the middle and lower reaches of the Wei River is high, mainly includes the Ziwuling Mountain area in north, the Liupan Mountain in west and the Qinling Mountain in south. However, the NDVI in the Plain of Guanzhong was low due to the rapid development of urbanization. The area around the Huan River in the upper reaches of the Wei River was seriously degraded due to the climate, and the NDVI value was the lowest. The average annual of NDVI was as low as 0.26(Fig.3).

- Analysis of spatial variation trend based on NDVI

| $\theta_{\text{slope}}$ | Degree of change           | Area ($\text{km}^2$) | Proportion (%) |
|------------------------|----------------------------|----------------------|----------------|
| -0.387~0.0037          | significant reduction      | 3819                 | 3.03           |
| -0.0037~0.0020         | moderate reduction         | 1819                 | 1.44           |
| -0.0020~0.0003         | mild reduction             | 2939                 | 2.33           |
| -0.0003~0.0003         | substantially constant     | 1593                 | 1.26           |
| 0.0003~0.0013          | mild increase              | 6119                 | 4.85           |
| 0.0013~0.0151          | moderate increase          | 99550                | 78.95          |
| 0.0151~0.0353          | significant increase       | 10251                | 8.13           |
By calculating the change trend ($\theta_{slope}$) of the NDVI by-pixel in the Wei River Basin from 2000 to 2016, the magnitude of the spatial variation of vegetation was indicated. Positive and negative NDVI indicate increase and decrease, respectively. The trend slopes were graded into 7 categories: significant reduction, moderate reduction, mild reduction, substantially constant, mild increase, moderate increase and significant increase, and area statistics were calculated to calculate different changes. Since 2000, the NDVI spatial changes in the Wei River Basin have been restored as a whole, with a recovery area of 115,900 km², accounting for 92% of the total area. However, the degree of restoration is not high, with moderate recovery. Among them, vegetation restoration was most significant in the areas of Liupan Mountain and Ziwuling Mountain. It shows that the implementation of the project of returning farmland to forests and afforestation since 2000 has achieved good results and made important contributions to the ecological environment construction of the Wei River Basin. Although the area of vegetation reduction area was less than 10%, the distribution was very concentrated, mainly in the Guanzhong Plain area, which was closely related to the negative impacts of the rapid urbanization and human activities in the region over the years (Fig.4, Tab.1).

4. Conclusion
- The vegetation growth in the Wei River Basin was the best in July and August, and the monthly average NDVI reached 0.58. the NDVI of the basin has continued fluctuations in volatility since 2000, and the average vegetation index reached 0.7 in 2013.
- The spatial distribution of vegetation NDVI is uneven, and it is low in the southeast and northwest. The spatial variation of vegetation is obvious, and more than 90% of the areas are characterized by vegetation restoration. The vegetation degradation area was small, but its distribution was very concentrated especially in the Guanzhong Plain.

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