Spatio-Temporal Variation Characteristics of Vegetation Coverage and Its Correlation with Climate Factors in Henan Province from 2006 to 2015

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Abstract. Vegetation coverage is an important parameter for comprehensively quantifying vegetation status. Using the remote sensing data of MODIS MODND1M and the meteorological data such as temperature and precipitation, on the base of ArcGIS, taking maximum value composite(MVC), vegetation index, kriging interpolation, linear regression analysis, correlation analysis and significance test methods, this study analyzed the spatio-temporal variation characteristics and the trend of changes of vegetation coverage, and its relationships with temperature and precipitation from 2006 to 2015. The results showed that: 1) From the aspect of Space, the vegetation coverage is generally higher in the eastern and western parts and lower in the middle part in Henan Province. 2) From the aspect of time, the vegetation coverage with a variation range of 85.62% - 87.78% firstly increased and then decreased and then increased from 2006 to 2015. 3) The change trend of vegetation coverage is obvious regional spatial difference characteristics. 4) The responses of different vegetation types to climate factors were different.

1. Introduction
Vegetation, as an important part of the earth's ecosystem, plays an irreplaceable role in the climate, hydrology and energy balance[1]. Its Spatio-temporal variation reflect the environmental impact of natural and social activities. Vegetation coverage is an important index to reflect the vegetation cover of the surface and to monitor the ecological environment[2]. With the continuous development of remote sensing technology, monitoring the vegetation cover using remote sensing images has become a hot spot of common concern in the scientific community. NDVI can accurately reflect the degree of vegetation change and growth status, and has become one of the most commonly used vegetation activity monitoring indicators. Many scholars[3-5] use NDVI to dynamically monitor the changes of vegetation on the surface and achieved good results. Henan Province is a major agricultural province in China. The dynamic changes of its ecosystem directly affect food security and affect Henan's social and economic development. Therefore, the real-time and effective monitoring of vegetation cover in Henan Province is an important guarantee for coordinating resources and environment in an all-round way, making full use of the advantages of Henan's natural and economic conditions and improving the sustainable development of economy.

2. Study Area
Henan Province (110 ° 21'-116 ° 39'E and 31 ° 23'-36 ° 22'N) is located in the central-eastern part of China. The terrain is generally high in the west and low in the east, with elevations between -60 and 2400 m. The annual average temperature is 13-16°C. The average annual precipitation is 500 ~
1100mm. Henan Province is the Central Plains Economic Zone’s main business, but also China’s important agricultural food base. The dynamic changes of its ecosystem can not be underestimated for the socio-economic development.

3. Material and Method

3.1. Data Source and Processing
The MODND1M data used in this study comes from the geospatial data cloud platform. With the support of MRT software, the format conversion and reprojection of MODND1M were performed and then cropped. The maximum annual NDVI value was obtained using maximum value composite (MVC). The meteorological data are from the monthly average temperature and precipitation of 20 benchmark meteorological stations provided by China Meteorological Science Data Sharing Service. The Kriging interpolation, resampling and cropping are used to obtain the raster image with the same cell size as the vegetation coverage data.

3.2. Vegetation Index Method
In this study, vegetation index method was used to extract vegetation coverage. The formula[6] is as follows. Among them, NDVI is the normalized difference vegetation index, taking NDVIV = 0.70 and NDVIS = 0.00. And, Fv takes a value of 1 when a pixel's NDVI value is greater than 0.70, and Fv takes a value of 0 when NDVI is less than 0.00.

\[ F_v = \frac{(NDVI - NDVIS)}{(NDVIV - NDVIS)} \]  \hspace{1cm} (1)

3.3. Linear Regression
The univariate linear regression analysis can eliminate the influence of extreme climate in a particular year, so this method is used to analyze the trend of vegetation coverage in Henan Province. The rate of change is calculated as follows[7]:

\[ \theta_{dope} = \frac{n \times \sum_{k=1}^{n} (k \times X_k) - (\sum_{k=1}^{n} k) (\sum_{k=1}^{n} X_k)}{n \times \sum_{k=1}^{n} k^2 - (\sum_{k=1}^{n} k)^2} \]  \hspace{1cm} (2)

3.4. Correlation and Significance
Correlation analysis is often used to study the degree of correlation and related directions between elements. In this study, pixel-based Pearson correlation coefficient method was used to study the relationship between vegetation coverage and temperature, as well as precipitation with P <0.10 and P <0.05 confidence levels. Correlation and significance analysis is as follows[8]:

\[ r_{x,y} = \frac{\sum_{k=1}^{n} (x_k - \bar{x})(y_k - \bar{y})}{\sqrt{\sum_{k=1}^{n} (x_k - \bar{x})^2 \sum_{k=1}^{n} (y_k - \bar{y})^2}} \]  \hspace{1cm} (3)

\[ R_{x_{y_1}y_2} = \frac{r_{x_{y_1}y_2} - r_{x_{y_2}y_1} r_{x_{y_2}y_2}}{\sqrt{1-r_{x_{y_2}y_2}^2} \sqrt{1-r_{y_1y_2}^2}} \]  \hspace{1cm} (4)

\[ R_{x_{y_2}y_{y_2}} = \sqrt{1-(1-r_{x_{y_1}y_1})(1-r_{x_{y_2}y_2})} \]  \hspace{1cm} (5)

\[ T = \frac{r_{x_{y_1}y_2}}{\sqrt{1-r_{x_{y_1}y_1}}} \sqrt{n-m-1} \]  \hspace{1cm} (6)

\[ F = \frac{R_{x_{y_2}y_{y_2}}^2}{1-R_{x_{y_2}y_{y_2}}} \times \frac{n-k-1}{k} \]  \hspace{1cm} (7)

4. Results Analysis

4.1. Spatial Distribution
The average NDVI and vegetation coverage in Henan Province during 2006-2015 are shown in Figure 1. The annual average vegetation coverage was mostly between 0.95 and 1, which was consistent with the spatial distribution of NDVI. Overall, the vegetation coverage was higher in the east and west and lower in the middle. The coverage of low vegetation is mainly distributed in the city and the surrounding areas, indicating that the rapid development of urbanization and industrialization bring economic benefits while reducing the quality of ecological environment. Vegetation coverage is also low due to sparse vegetation near large reservoirs and rivers. The vegetation in the southeastern part of Henan Province is dominated by broad-leaved forests and has a strong photosynthesis. Therefore, the vegetation coverage in this area is extremely high.

![Figure 1. Distribution of mean NDVI(A) and Vegetation coverage (B) in Henan Province.](image)

### 4.2. Temporal Variation

Using land cover type data in Henan Province, based on ArcGIS, the average vegetation coverage in different statistical regions such as urban and built-up areas, farmland areas and natural vegetation areas in Henan Province during 2006-2015 was statistically analyzed (Table 1). The vegetation coverage increased firstly and then decreased and then rose again in Henan Province from 2006 to 2015, with a range of 85.62% ~ 87.78%. The lowest vegetation coverage in Henan Province in 2006 was 85.62%. The highest vegetation coverage in 2015 was 87.78%.

| Area            | Year 2006 | Year 2007 | Year 2008 | Year 2009 | Year 2010 | Year 2011 | Year 2012 | Year 2013 | Year 2014 | Year 2015 |
|-----------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Urban and Built-up | 62.76     | 61.51     | 60.64     | 59.75     | 59.63     | 58.34     | 57.88     | 57.96     | 56.43     | 56.68     |
| Farmland        | 77.35     | 77.04     | 76.57     | 76.38     | 75.72     | 76.25     | 76.37     | 77.16     | 76.28     | 75.41     |
| Forest          | 87.57     | 89.51     | 89.68     | 89.89     | 91.24     | 91.64     | 91.88     | 90.85     | 87.63     | 92.69     |
| Shrublands      | 81.34     | 85.44     | 86.24     | 86.38     | 87.66     | 87.56     | 87.87     | 88.97     | 83.41     | 89.34     |
| Grasslands      | 76.49     | 76.21     | 75.68     | 76.10     | 75.01     | 75.02     | 76.42     | 76.29     | 75.98     | 76.39     |
| Henan Province  | 85.62     | 86.01     | 86.23     | 86.41     | 87.26     | 87.45     | 87.61     | 86.54     | 86.21     | 87.78     |

### 4.3. Trend Change

Based on pixel size, a linear regression analysis was conducted on the interannual variability of vegetation coverage in Henan Province from 2006 to 2015. The trend of vegetation coverage of each grid in the study area is obtained, and the results are classified by standard deviation (Figure 2). The change trend of vegetation coverage is obvious regional spatial difference characteristics. The areas with the increasing vegetation coverage are mainly located in southern Xinyang, northeastern Nanyang, southwest of Kaifeng and other regions. The areas with the declining vegetation coverage are mainly located in the vicinity of Taihang Mountain, along the Yellow River ecological...
conservation zone, Funiu Mountain, Xiong’ershan area, parts of the Danjiang River basin and surrounding areas of cities and counties. The interannual variation of vegetation coverage in Henan Province from 2006 to 2015 was between -0.08 and 0.09. The rate of change in most areas was between 0.0009 and 0.0071 (Table 2). The area which is basically unchanged trend accounts for 48% of the total area in Henan Province. The area which is upward trend accounts for 28.09%. The area which is downturn accounts for 28.09%.

![Figure 2. The spatial distribution of Vegetation Coverage slope in Henan Province from 2006 to 2015.](image)

### Table 2. Statistical result of the change trend of Vegetation Coverage from 2006 to 2015

| Change Trend of Vegetation Coverage | Degree of change          | Area/10^4Km^2 | Area% |
|------------------------------------|---------------------------|----------------|-------|
| Slope≤-0.0116                      | Serious degradation       | 0.28           | 1.73  |
| -0.0116≤Slope≤-0.0054              | Moderate degradation      | 0.68           | 4.21  |
| -0.0054≤Slope≤0.0009               | Slight degradation        | 3.02           | 18.69 |
| 0.0009≤Slope≤0.0071                | Basically unchanged       | 7.64           | 47.28 |
| 0.0071≤Slope≤0.0133                | Slight improvement        | 3.91           | 24.20 |
| 0.0133≤Slope≤0.0196                | Moderate improvement      | 0.53           | 3.28  |
| Slope≥0.0196                      | Significant improvement   | 0.10           | 0.61  |

4.4. Correlation Analysis
The correlation coefficient between vegetation coverage and average temperature is -0.90 ~ 0.93(Figure 3). The positive and negative correlations accounted for 59.82% and 40.18% of the study area respectively. 63.1%, 41.4% of the pixels passed the 0.10 level, 0.05 level of T-significance test, respectively. The correlation coefficient between vegetation coverage and rainfall ranged from -0.91 to 0.98(Figure 3). The positive and negative correlations accounted for 74.22% and 25.78% of the study area respectively. 76.3%, 53.6% of the pixels passed the 0.10 level, 0.05 level of T-significance test, respectively. Vegetation coverage changes of different types vegetation have different responses to climatic factors (Table 3). The correlation coefficients between vegetation coverage of forest, shrublands, grassland, other vegetation and climatic factors showed positive and negative coexistence.
Figure 3. Spatial distribution of correlations between Vegetation Coverage and temperature, as well as precipitation in Henan Province during 2006–2015.

Table 3. Coefficients of Vegetation Coverage in different vegetation types with temperature and precipitation

| Correlation coefficients | Forest   | Shrublands | Grassland | Farmland | Others |
|--------------------------|----------|------------|-----------|----------|--------|
| R_{NT}                   | -0.23    | 0.41       | -0.22     | 0.28     | 0.15   |
| R_{NP}                   | 0.52     | -0.23      | 0.49      | 0.24     | -0.24  |
| R_{NT,P}                 | -0.31    | 0.57       | -0.32     | 0.58     | 0.14   |
| R_{NP,T}                 | 0.73     | -0.34      | 0.52      | 0.54     | -0.23  |
| R_{NP,TP}                | 0.63     | 0.48       | 0.61      | 0.43     | 0.35   |

5. Conclusion

(1) From the aspect of Space, 70% of the plain is farmland in Henan Province. The annual average vegetation coverage was mostly between 0.95 and 1. Overall, the vegetation coverage was higher in the east and west and lower in the middle.

(2) From the aspect of time, the vegetation coverage with a variation range of 85.62%–87.78% firstly increased and then decreased and then increased in Henan Province from 2006 to 2015. In different types of land cover area, the highest vegetation coverage is the forest area and the lowest value is the urban and built-up area in each period.

(3) The change trend of vegetation coverage is obvious regional spatial difference characteristics. The interannual variation of vegetation coverage in Henan Province from 2006 to 2015 was between -0.08 and 0.09. The rate of change in most areas was between 0.0009 and 0.0071.

(4) The correlation between vegetation coverage and temperature as well as precipitation showed obvious regional differences. Vegetation coverage changes of different types vegetation have different responses to climatic factors.

6. References

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