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Development of the Spatio-temporal Variations Dataset of NDVI in Qinling-Daba Mountains of China (2000–2019)

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Abstract: The Qinling-Daba Mountains region (Qinba) is an important geographical and ecological transitional zone between the north and south of China. Based on MOD13Q1 V006 data at spatial and temporal resolutions of 250 m and 16 d, respectively, from 2000 to 2019, the seasonal and annual Normalized Difference Vegetation Index (NDVI) values were estimated using the maximum value composites and the mean value approaches. Then, the dataset of spatio-temporal variations of NDVI in the Qinba over the past two decades was developed using linear regression analysis and F test. The following parameters were included in the dataset: (1) spatial distribution of the slope of the annual and seasonal NDVI, (2) annual and seasonal variations in their significance (*P* values and the slope of NDVI through a test of 95% confidence levels), and (3) annual and seasonal average NDVI values in the Qinba during 2000–2019. The dataset was archived in .tif and .xlsx formats and consisted of 47 data files with a total data size of 994 MB (compressed into a single file of 385 MB).

Keywords: vegetation; NDVI; variation; annual; seasonal; Qinling Mountains; Daba Mountain

Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2020.06.10.V1.

1 Introduction

As a crucial component of terrestrial ecosystems[1], vegetation plays an important role in connecting the atmosphere, soil, and water, and in regulating global material and energy cycles, maintaining climate stability, and monitoring ecosystem changes[2–4]. Vegetation is also an extremely sensitive indicator of natural and anthropogenic effects on the

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environment[5–6]. Vegetation variation has become a critical issue in the field of global terrestrial ecosystem change[7–10]. Normalized Difference Vegetation Index (NDVI), a robust and simple measure in characterizing vegetation photosynthetic activity and monitoring ecological environments at different spatial scales, has been widely used to characterize the global range of vegetation states and processes[11–15].

The Qinling-Daba Mountains region (Qinba), spanning from the subtropical zone to the warm temperate zone, is adjacent to the eastern edge of the Qinghai-Tibet Plateau in the west and to the North China Plain in the east. Qinba is the only large-scale ecological corridor connecting the east and west of China, and has been recognized as an essential geographical and ecological transitional zone between the north and south of China[16]. In addition, as an area that is vulnerable to climate change and ecological variations, the spatio-temporal pattern of vegetation dynamics in the Qinba is one of the key issues in the global change research. Therefore, several relevant studies have been conducted, including Chen (2019) [15] , Chen (2019) [16], Deng (2018)[17], Liu (2015) [18], Chui (2012) [19], Ren (2012)[20], Sun (2010)[21], Luo (2009)[22] . However, previous studies that investigated vegetation dynamics in the Qinba have been focused on their annual variations, and primarily carried out in partial regions, such as the Qinling region in the Shannxi province. There is a lack of understanding of the vegetation variations and their dynamic trends across the entire Qinba as a single geographical and geomorphic unit. Moreover, characteristics of seasonal differences in vegetation changes have rarely been reported from this area. In this study, the dataset of spatio-temporal variations of NDVI in the Qinba was developed using linear regression and F test, based on MODIS (MODerate resolution Imaging Spectroradiometer) NDVI time series data (MOD13Q1-NDVI). This dataset comprehensively indicates the multi-temporal (i.e., annual and seasonal) variations and dynamic trends of vegetation over the Qinba during the past two decades, which is significant for promoting sustainable development of the regional ecological environment in this area.

2 Metadata of the Dataset

The metadata of the “Spatio-temporal variation trends dataset of NDVI in Qinling-Daba Mountains and surrounding area of China (2000–2019)”[23] is summarized in Table 1, including the dataset full name, short name, author, geographical region, year of the dataset, temporal resolution, spatial resolution, data format, data size, data files, data publisher, and data sharing policy, etc.

3 Methods

3.1 Basic Data Collection

The boundary data of the Qinba was acquired from Program funded by Ministry of Science and Technology of P. R. China[15]. The 16 d composites for 250 m MODIS NDVI product (MOD13Q1 V006) were downloaded from Earth Observing System Data and Information System[25], covering the period from February 2000 to December 2019. Two tiles (h26v05 and h27v05) were required to cover the Qinba. The original HDF format and sinusoidal projection of MOD13Q1 were transformed into a Geotiff format and Albers Equal Area Conic projection with WGS84 datum separately, and were re-sampled at a resolution of 250 m employing the nearest neighbor method, using the MODIS Reprojection Tool.

Table 1 Metadata summary of the "Spatio-temporal variation trends dataset of NDVI in Qinling-Daba Mountains and surrounding area of China (2000–2019)"

Items	Description		
Dataset full name	Spatio-temporal variation trends dataset of NDVI in Qinling-Daba Mountains and surrounding area of China (2000–2019)		
Dataset short name	QinbaNDVItrend_2000-2009		
Author	Bai, Y. AAW-8595-2020, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences; National Earth System Science Data Center, baiy@lreis.ac.cn		
Geographical region	The Qinling-Daba Mountains region: 30°43′N–35°29′N, 102°21′E–113°40′E		
Year	2000–2019		
Data format	.tif, .xlsx	Data size	382 MB (after compression)
Time resolution	Annual, seasonal	Spatial resolution	250 m
Data files	The significant characteristics and statistical data of annual and seasonal variations of NDVI in the Qinba from 2000 to 2019		
Foundations	Ministry of Science and Technology of P. R. China (2017FY100900, 2005DKA32300); Chinese Academy of Sciences (XXH-13514)		
Computing environment	Python, MATLAB, ArcGIS		
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn		
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China		
Data sharing policy	***Data*** from the Global Change Research Data Publishing &Repository includes metadata, datasets (in the *Digital Journal of Global Change Data Repository*), and publications (in the *Journal of Global Change Data & Discovery*). ***Data*** sharing policy includes: (1) ***Data*** are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use ***Data*** subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute ***Data*** subject to written permission from the GCdataPR Editorial Office and the issuance of a ***Data*** redistribution license; and (4) If ***Data*** are used to compile new datasets, the 'ten per cent principal' should be followed such that ***Data*** records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset [24]		
Communication and searchable system	DOI, DCI, CSCD, WDS/ISC, GEOSS, China GEOSS, Crossref		

3.2 Algorithm Principle

(1) Maximum Value Composite

The monthly NDVI data from 2000 to 2019 were generated using the universal maximum value composite (MVC) method (Equation 1), which could eliminate the impact of atmosphere, clouds, and solar altitude angle[26].

$$NDVI_i = Max\left(NDVI_{ij}\right) \quad (1)$$

where $NDVI_i$ is the NDVI value of the month i, $NDVI_{ij}$ is the NDVI value on the day j of the month i.

Due to the absence of the original MODIS NDVI data in January 2000, the average value of NDVI for January 2001–2019 was taken as the corresponding values of NDVI for the missing data. The annual average NDVI was defined as the average monthly NDVI from January to December. Further, average monthly composite NDVI from March to May, June to August, September to November, and December to February were defined as spring, summer, autumn, and winter NDVI, respectively.

(2) Linear Regression

The least-squares-based linear regression trend analysis was used extensively to detect the vegetation dynamics based on time series NDVI data. This method has the advantage of effectively eliminating the influence of occasional abnormal factors on vegetation growth, and truly exhibiting its variation in the long-term period[27–28]. The equation is as follows:

$$Slope = \frac{n \times \sum_{i=1}^{n}\left(i \times NDVI_i\right) - \sum_{i=1}^{n} i \sum_{i=1}^{n} NDVI_i}{n \times \sum_{i=1}^{n} i^2 - \left(\sum_{i=1}^{n} i\right)^2} \tag{2}$$

where *Slope* is the index to quantify the dynamic trend of vegetation using linear regression over the study period, n is the accumulated years of monitoring time range, i is the serial year number (valued from 1 to n), and $NDVI_i$ is the NDVI value in year i. When $Slope > 0$, there was an increasing dynamic trend in vegetation, and when $Slope < 0$, there was a decreasing dynamic trend in vegetation. The greater the *Slope* value is, the more significant the increasing trend will be.

The significance of the dynamic trend was conducted using the F test, and the results were classified into five categories: (*i*) extremely significant decrease ($Slope < 0$, $P < 0.01$), (*ii*) significant decrease ($Slope < 0$, $0.01 < P < 0.05$), (*iii*) no significant change ($P > 0.05$), (*iv*) significant increase ($Slope > 0$, $0.01 < P < 0.05$), and (*v*) extremely significant increase ($Slope > 0$, $P < 0.01$).

4 Data Results and Validation

4.1 Data Products

The spatio-temporal variation trends dataset of NDVI in Qinling-Daba Mountains and surrounding area of China (2000–2019) consists of spatial and statistics data at multi-temporal scales, i.e., annual and seasonal (Table 2). The dataset is archived in .tif and .xlsx formats.

Table 2 Composition of the “Spatio-temporal variation trends dataset of NDVI in Qinling-Daba Mountains and surrounding area of China (2000–2019)”

Main files	Description	Format	Data size
Spatial distribution data	Spatial distribution of annual *Slope* in NDVI from 2000 to 2019	.tif	76 MB
	Spatial pattern of variations with significance in annual NDVI from 2000 to 2019	.tif	153 MB
	Spatial distribution of seasonal *Slope* in NDVI from 2000 to 2019	.tif	153 MB
	Spatial pattern of variations with significance in seasonal NDVI from 2000 to 2019	.tif	612 MB
Statistical data	Statistics of annual and seasonal average NDVI from 2000 to 2019	.xlsx	12.1 KB

4.2 Data Results

4.2.1 Temporal Changes in Vegetation

(1) Annual change

From 2000 to 2019, the annual change in average NDVI shows a significant increasing trend across the Qinba, with an increasing rate of 0.048/10a ($R^2 = 0.91$, $P < 0.05$) (Figure 1(a)). The annual average NDVI value ranged between 0.53 and 0.63, reaching a peak in 2018 (0.632) and a trough in 2001 (0.533), while there were three periods with a sharp decrease during 2009–2010, 2013–2014, and 2016–2017.

(2) Seasonal changes

The linear trendline in Figure 1(b) indicates that NDVI increased significantly across all seasons in the Qinba during 2000–2019. The largest increase in the magnitude of NDVI was in spring, with a rate of 0.058/10a ($R^2 = 0.74$), followed by that in winter (0.049/10a, $R^2 =$

0.76), summer (0.042/10a, $R^2 = 0.89$), and autumn (0.042/10a, $R^2 = 0.77$).

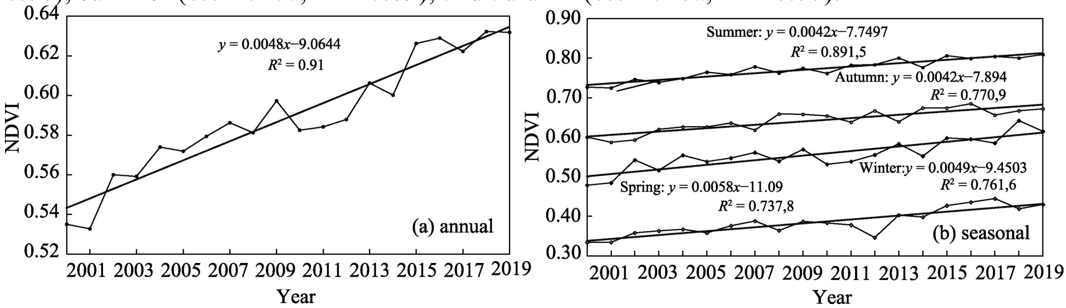

Figure 1 Temporal changes in average NDVI over the Qinba (2000–2019)

4.2.2 Spatial Variations in Vegetation

(1) Annual variations

The *Slope* of annual NDVI was between −0.032 and 0.039 from 2000 to 2019, as shown in Figure 2(a), and distinct spatial differences in the annual variations of vegetation were observed over the Qinba. In particular, the results from linear regression and F test of annual NDVI (Figure 2(b), Table 3) indicated that: (*i*) 87.81% of the entire region showed significant and extremely significant increasing trends, where the area ratio of extremely significant increase accounted for more than 81%; (*ii*) The regions with significant and extremely significant decreasing trends accounted for less than 1%, mainly concentrated in a few areas in the southwest of the Qinba (such as the junction of northern Chengdu and northern Deyang), and scattered in the Hanzhong basin, the western edge of Nanyang, and the northern part of Shangluo; and (*iii*) The regions with no significant change accounted for 11.36%, primarily distributed in the high-altitude areas of western Qinling Mountains (i.e., the northeastern part of the Tibetan and Qiang autonomous prefecture of Aba, and the north western part of the Mianyang and Deyang cities), the junction of Hanzhong and Bazhong

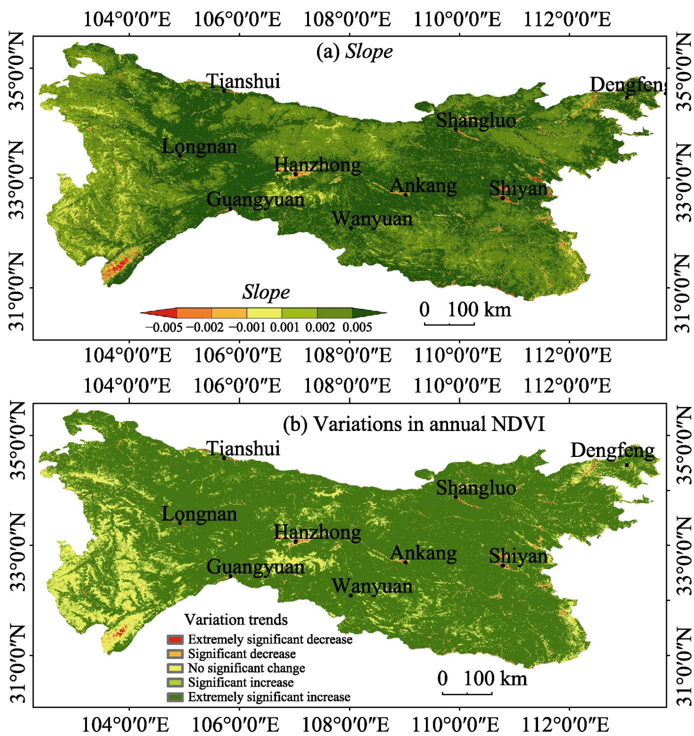

Figure 2 Spatial distribution of *Slope*, and variations in annual NDVI over the Qinba (2000–2019)

cities, as well as the low-altitude areas in the east of Qinba (i.e., the central regions of Luoyang and Xiangyang cities).

Table 3 Area proportion (%) of annual and seasonal NDVI variations in the Qinba (2000–2019)

Classification	Trend	Annual	Spring	Summer	Autumn	Winter
		Area (%)	Area (%)	Area (%)	Area (%)	Area (%)
Slope < 0, *P* < 0.01	Extremely significant decrease	0.55	0.48	0.44	0.34	0.49
Slope < 0, 0.01 < *P* < 0.05	Significant decrease	0.29	0.36	0.33	0.31	0.40
P > 0.05	No significant change	11.36	24.54	31.49	35.18	22.75
Slope > 0, 0.01 < *P* < 0.05	Significant increase	5.99	14.32	10.20	14.25	10.60
Slope > 0, *P* < 0.01	Extremely significant increase	81.82	60.30	57.54	49.92	65.76

(2) Seasonal variations

Table 3 and Figure 3 indicate that the seasonal variations in NDVI over the Qinba during the study period were dominated by extremely significant increase and no significant change. The proportion of area with no significant seasonal change was more than twice that of the annual change. In particular, the area ratios of no significant change in summer and autumn were both higher than 30%, which was clearly higher than those in spring and winter (Table 3). In spring, NDVI tended to increase in the West Qinling Mountains and the low altitude areas (i.e., central Ankang and the northern part of the Shiyan city, Figure 3(a)). Compared with spring, summer NDVI showed a stronger no significant trend in the western Qinba, southern part of Baoji, and south and north of Hanzhong (Figure 3(b)). The area characterized by no significant change in vegetation in autumn NDVI had expanded markedly in the central Qinba, whereas the areas with significant and extremely significant increase were mainly distributed in the Longnan region (i.e., Wudu, Xihe, and Lixian) in the western Qinling Mountains, Ningqiang county at the junction of the Qinling and Daba Mountains, northeast of Bazhong city, and low-altitude areas such as northern Shiyan and western Xiangyang (Figure 3(c)). The spatial variations in winter NDVI were similar to those observed in the spring (Figure 3(d)).

4.3 Data Validation

Results based on multi-temporal MODIS NDVI revealed that vegetation had an overall significant increasing trend in the Qinba over the past two decades, which is similar to the results from previous studies based on annual NDVI [17, 19, 24]. Seasonal variations of NDVI, reflecting more detailed temporal and spatial variations of vegetation over long time periods, were further described in the dataset. Seasonal variations were found to be consistent to the annual variations in the Qinba. However, the dominating category of variations in vegetation was different at seasonal and annual scales. The seasonal variations were primarily in the categories of "extremely significant increase" and "no significant change", whereas the annual variations were dominated by the categories "significant increase" and "extremely significant increase".

5 Conclusion

Annual and seasonal variations are prominent characteristics of vegetation[27]. Based on MODIS NDVI data with relatively high spatial and temporal resolution in the long time series, the dataset of spatio-temporal variations of NDVI at annual and seasonal scales in the Qinba from 2000 to 2019 were generated at a spatial resolution of 250 m based on Python and MATLAB, using MVC, linear regression, and F test methods. The results showed that in the past 20 years, variations in both annual and seasonal NDVI increased significantly and extremely significantly across the Qinba, but the dynamic trend with no significant change was much more distinct at the seasonal scale. Moreover, vegetation variations in this area demonstrated the achievements of national ecological protection and restoration programs, such as the Grain to Green Program (GTGP) implemented since 1999. This would provide scientific support for comprehensively revealing the response mechanism of vegetation to climate change, human activities or other driving factors, and for assisting local governments to develop or implement policies and projects to promote ecological security and sustainable development in the Qinba.

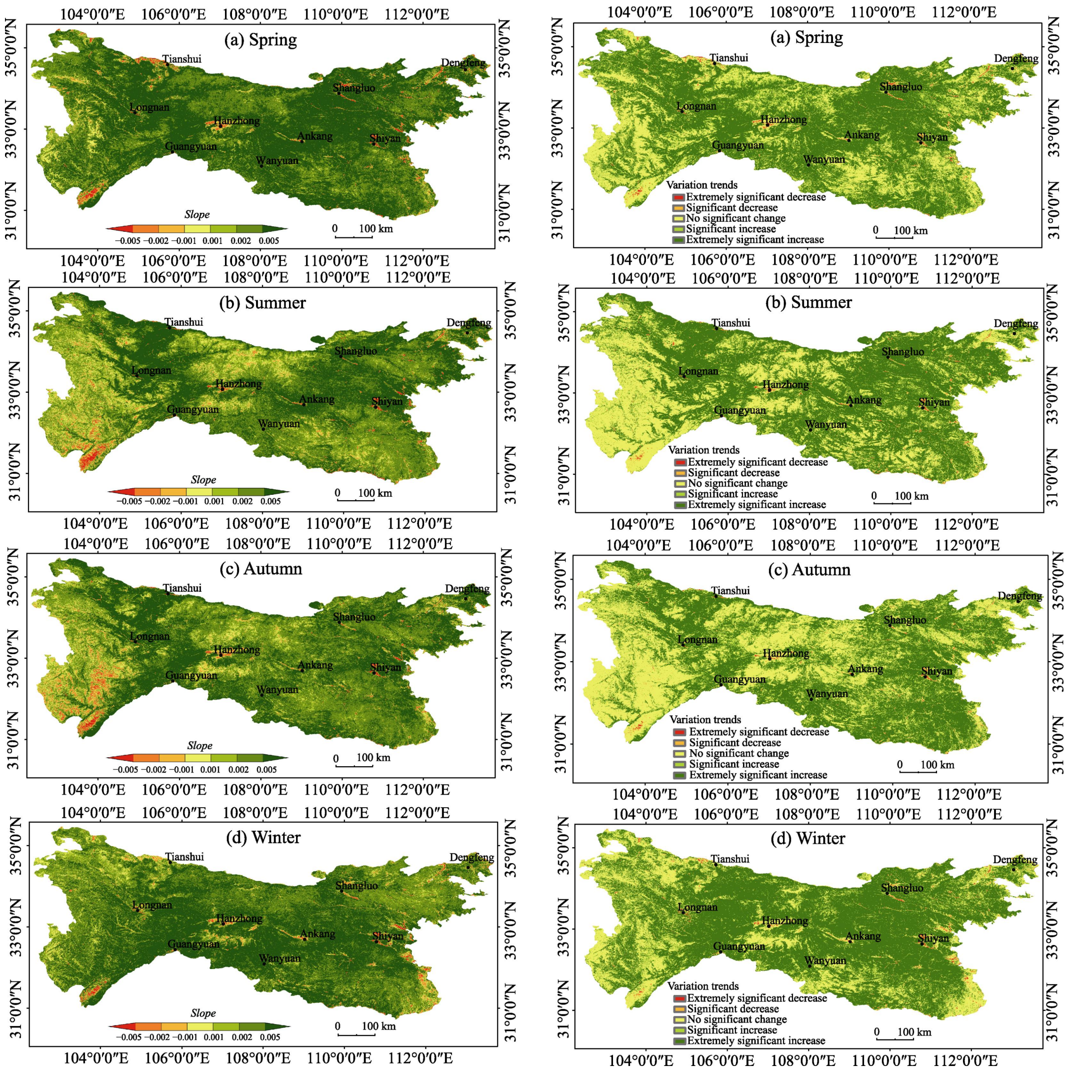

Figure 3 Map of *Slope* and variation trend in seasonal NDVI over the Qinba (2000–2019)

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