Temporal and Spatial Changes and Driving Forces of NDVI From 1982 - 2015 in Qinba Mountains, China

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Research Article

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Posted Date: May 13th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-415051/v1>

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Abstract: The spatiotemporal variation and driving force of Normalized Difference Vegetation Index (NDVI) is helpful to regional ecological environment protection and natural resource management. Using the Sen and Mann–Kendall methods, Hurt index, Space transfer matrix and Geodetector, this study investigated the temporal and spatial changes and driving forces of NDVI during 1982 - 2015. The results showed that: (1) For the period 1982 to 2015, the high vegetation coverage was mainly distributed in Qinling Mountains and Daba mountain, while the value of NDVI was low in high altitude area in the west, low altitude in the East and Hanjiang River valley. (2) The change trend of NDVI in Qinba Mountains is mainly to maintain stable and slow growth. And the slow growth changes significantly. NDVI increased slowly mainly in the East and northwest. (3) The future change trend of NDVI in Qinba Mountain is mainly slow growth and stability, which indicates that the ecological construction in Qinba Mountains is good. (4) Through the geographical detector, the main factors affecting NDVI in Qinba Mountains are natural factors mainly including rainfall, soil type and digital elevation model (DEM), while human activities mainly including population density have little influence on NDVI in Qinba Mountains. Natural environment factors and human activities make a great difference on the spatial distribution of NDVI. This study provides a help for the sustainable development of the naturel environment in Qinba Mountains.

Keywords: NDVI; Qinba Mountains; Hurt index; trend analysis; Geodetector; driving forces

Declarations

Ethics approval and consent participate: Not applicable

Consent for publication: Not applicable

Availability of data and materials: The GIMM3g datasets used to support the finding of this study were derived from the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) (<https://www.noaa.gov/research>). The climate datasets, Population density data, GDP data and land use type were acquired from the Resource and Environment Science and Data Center (<http://www.resdc.cn/>). SRTM 90m Digital Elevation Model (DEM) products come from Geospatial Data Cloud (<http://www.gscloud.cn/>).

Competing interest: The authors declare that they have no competing interests.

Funding: This research was jointly supported by the Integrated Scientific Investigation of the North-South Transitional Zone of China (Grant No. 2017FY100904), the Scientific Research Project of Education Department of Shaanxi Province (Grant No. 17JK0776).

Author Contributions: Conceptualization—H. Y.; methodology—H. Y., Z. - Y. R., L-Y.L, and J - L. P.; Writing—original draft preparation, Z. - Y. R.; Writing—review and editing, H. Y. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: We would like to thank the anonymous reviewers and editors for their valuable comments and suggestions.

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Natural environment factors and human activities make a great difference on the spatial distribution of NDVI. This study provides a help for the sustainable development of the naturel environment in Qinba Mountains.

Keywords: NDVI; Qinba Mountains; Hurt index; trend analysis; Geodetector; driving forces

1. Introduction

Vegetation is one of the most significant factors of natural ecosystem, as vegetation plays an important role in different circles (Liu et al. 2019). Climate, rainfall, soil and human activities have a great influence on the growth of vegetation. Meanwhile, vegetation is also most sensitive to environmental changes, especially climate changes (Wen et al. 2017). Thus, it is meaningful for the ecological environment to study the vegetation change and its driving forces (Tao et al. 2020).

As one of the most popular vegetation indices used for monitoring short-term and long-term variations of vegetation (Jiang et al. 2016), NDVI has been extensively used to show the level of regional vegetation coverage and vegetation growth status, which has been applied in many areas of research, such as vegetation spatial distribution, vegetation dynamic monitoring and dynamic evolution (Cao et al. 2008). Therefore, it can not only describe the temporal and spatial changes of vegetation, but also reflects the feedback of climate (Miao et al. 2012).

Based on the long-time series NDVI, domestic and foreign scholars have carried out in-depth research on the temporal and spatial variation rules and influencing factors of vegetation at different spatial and temporal scales. For example, Clement *et*

102 *al.* (2010) examines the role of vegetation dynamics in regional predictions of future
103 climate change in western Africa. Kawabata *et al.* (2001) found that NDVI increased
104 in the northern middle-high latitudes due to the rising climate. Zhao *et al.* (2017) used
105 the GIMMS3g NDVI to analyzed the spatiotemporal variability of vegetation from
106 1982 to 2013 in the Loess Plateau (LP),and showed that the average NDVI in the
107 growing season was positively (negatively) correlated with precipitation in the north
108 (south) LP during 1982–2013. Guan *et al.* (2018) analyzed spatiotemporal variations
109 in the vegetation cover of the Hexi Corridor and surrounding areas from 2000 to 2010
110 were investigated using MODIS NDVI data. Wang *et al.* (2020) investigated the
111 NDVI variation in the growing season in the region from 1998 to 2016 showed that
112 the NDVI presented an increasing trend and NDVI was positively correlated with
113 precipitation and temperature. Based on the above previous studies, the general strong
114 correlations between NDVI and environment variables indicated the possibility to
115 predict change in NDVI with respect to change in environment conditions.

116 Qinba Mountains is an important dividing line between the north and the south
117 of China, which has a sensitive climate, fragile ecology and significant height
118 difference. Therefore, Qinba Mountains used to be key areas of ecological
119 environment change. However, at present, few scholars have studied the temporal and
120 spatial changes of vegetation and the influence of climatic and environmental factors,
121 climatic environmental factors and human activities on NDVI in Qinba Mountains.
122 Based on third-generation Global Inventory Modeling and Mapping Studies
123 (GIMMS3g) dataset during 1982 - 2015, this study investigates spatiotemporal

variation and driving forces of NDVI. This study provides a scientific basis and decision reference to protect vegetation and improve the eco-environment.

2. Materials and Methods

2.1 Study area

Qinba Mountains (30°30'—34°37'N, 103°44'—113°13'E) is located on the middle of China and close to Shaanxi, Gansu, Sichuan, Hubei, Henan, and Chongqing, as show in Figure1 (Chen et al. 2019). It has a land area of about 222,300 km², which most of them are mountains and hills with basins in the middle, forming a pattern of “three mountains with two rivers” (Tang and Chen. 2018). It has a complex climate partly because it is the transitional zone between temperate and subtropical zones, and with an annual mean precipitation ranging from about 709 mm to 1500 mm and the annual average temperature ranging from 12 °C to 16 °C. The hydrological conditions of Qinba Mountains are multifarious because of it is the birthplace of Hanjiang River, Jialing River and Danjiang River (Liu et al. 2016) .The rich vegetation resources of the Qinba Mountains that the warm temperate deciduous broad-leaved forest is the main part of Qinling Mountains and Daba Mountain and its river valley are mixed forest of evergreen and deciduous broad-leaved forest because of unique natural environment has been widely concerned by Chinese and foreign scholars.

Figure1.The geographical position of Qinba Mountains

2.2 Datasets

The NDVI datasets were gained from the GIMMS group, derived from the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) (<https://www.noaa.gov/research>), at a spatial resolution of 8 km and taken at 15-day intervals for 1982 to 2015 (Piao et al. 2004). This dataset is suitable for long-term monitoring of NDVI because of it is the most extensive data in time range, and after processing and correction, the data accuracy becomes higher and the error becomes smaller (Eisfelder et al. 2012, Running et al. 2020, Ali et al. 2020). In this paper, we used GIMMS NDVI3g data from 1982 to 2015, using the Maximum Value Composite method in order to reduce the cloud and aerosol contamination (Dong et al., 2020), and then composite annual average of NDVI.

The climate elements included temperature and precipitation. We used annual

average temperature datasets and annual average precipitation datasets from 1982 to 2015, with a spatial resolution of 1km. Those datasets were acquired from the Resource and Environment Science and Data Center (<http://www.resdc.cn/>). Based on the daily observation data of more than 2400 meteorological stations in China, and it is generated through sorting, calculation and spatial interpolation.

Elevation data used SRTM 90m Digital Elevation Model (DEM) products, which come from Geospatial Data Cloud (<http://www.gscloud.cn/>), and then we extracted slope and aspect from DEM.

Population density data, GDP data and land use type are based on 2015, with a spatial resolution of 1km. The spatial distribution data of soil types in China were generated based on the 1:1 million soil map of the people's Republic of China compiled and published by the national soil survey office in 1995. These datasets were derived from the Resource and Environment Science and Data Center (<http://www.resdc.cn/>).

The above data should be processed using Extract by Mask、Projections and Transformations and Resample in ArcGIS.

2.3 Methods

2.3.1 Sen and Mann–Kendall methods

The linear regression method requires that the time series data conform to the normal distribution, and is vulnerable to noise interference (Wang et al. 2013). Sen trend degree is the median value of the calculated sequence, which can reduce the interference of noise and eliminate the interference of outliers on time series (Liu et al.

2010). The calculation formula of Sen's slope was calculated as in Equation (1)

$$q = \text{median} \frac{NDVI_j - NDVI_i}{j - i} \quad (1)$$

Where, $1 < i < j < n$, i and j are time series numbers, and $NDVI_i$ and $NDVI_j$ are NDVI values of i and j time series respectively. When the slope q is greater than 0, it means there is an upward trend, and when the slope q is less than 0, it means there is a downward trend.

Mann-Kendall (MK) test was determined the year of NDVI change (Peng et al. 2020). MK test was calculated with the following equations:

$$Z_{MK} = \begin{cases} \frac{S-1}{\sqrt{n(n-1)(2n+5)/18}} & \text{for } S > 0 \\ 0 & \text{for } S = 0 \\ \frac{S+1}{\sqrt{n(n-1)(2n+5)/18}} & \text{for } S < 0 \end{cases} \quad (2)$$

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n \text{sgn}(x_j - x_k) \quad (3)$$

$$\text{Sgn}(x_j - x_k) = \begin{cases} +1 & \text{if } (x_j - x_k) > 0 \\ 0 & \text{if } (x_j - x_k) = 0 \\ -1 & \text{if } (x_j - x_k) < 0 \end{cases} \quad (4)$$

Where n is the number of observations. x_j and x_k are the ranks of observations x_i and x_j of the time series. When the MK trend has a significance level greater than 5% ($p < 0.05$, $Z_{MK} \geq |\pm 1.96|$), the NDVI trend is considered significant (Hamed 2009).

2.3.2 Hurst index

The Hurst exponent is an effective method to describe the long term dependence of a time series and is used to estimate the persistence or anti-persistence of trends in

a time series (Bashir et al. 2020). Any methods can be used to obtain Hurst index H, and R/S analysis method is commonly used, the basic principle is as follows:

To divide the time series $\{NDVI(\tau)\}(\tau=1,2,\dots,n)$ into τ subseries $X(t)$, for each series, $t=1,2,\dots,n$

1. To define the mean sequence of the time series,

$$\bar{NDVI}(\tau) = \frac{1}{\tau} \sum_{t=1}^{\tau} NDVI_{(t)} \quad (\tau = 1, 2, \dots, n) \quad (5)$$

2. To calculate the cumulative deviation,

$$X_{(t,\tau)} = \sum_{t=1}^{\tau} NDVI_{(t)} - \bar{NDVI}(\tau) \quad (1 \leq t \leq \tau) \quad (6)$$

3. To create the range of sequence

$$R_{(\tau)} = \max X(t, \tau) - \min X(t, \tau) \quad (\tau=1,2,\dots,n) \quad (7)$$

4. To create the standard deviation sequence,

$$S_{(\tau)} = \sqrt{\frac{1}{\tau} \sum_{t=1}^{\tau} (NDVI_{(t)} - \bar{NDVI}(\tau))^2} \quad (\tau = 1, 2, \dots, n) \quad (8)$$

5. To rescale the range

$$\frac{R_{(\tau)}}{S_{(\tau)}} = (c\tau)^H \quad (9)$$

On the basis of previous studies, the value of Hurst exponent range from 0-1. when the value is equal to 0.5, it indicates that the change trend of NDVI in the time series is random, and there is no change persistence; when the value is greater than 0.5, it indicates that NDVI has a long-term positive correlation in the time series; and when the value is less than 0.5, it shows that NDVI trend has anti persistence in time series, the closer the value of Hurst is to 0, the stronger the anti-persistence.

2.3.3 Space transfer matrix

Spatial transfer matrix can quantitatively identify the spatial pattern changes of

different levels of a certain element in a certain time interval. In addition to reflecting the area changes of different levels, it can also directly reflect the transfer in and out of each level, so it is widely used in land use, vegetation cover and other aspects.

2.3.4 Geodetector

Spatial differentiation is one of the basic characteristics of geographical phenomena. Geographic detector is a tool to detect and utilize spatial differentiation. It is mainly used to analyze the driving forces, influencing factors and multi factor interaction of various phenomena. Geographic detector includes four parts: risk detection, factor detection, ecological detection and interactive detection (Wang et al. 2017).

Factor detector :

It detected the spatial differentiation of the dependent variable y (NDVI value) and the explanation degree of the independent variable x (natural factor and socio-economic factor) to the spatial differentiation of y value, the expression is as follows:

$$q=1-\frac{\sum_{h=1}^L N_h \sigma_h^2}{N \sigma^2} \quad (10)$$

Where, L is the stratification of the dependent variable NDVI or influence factor X, i.e. classification or partition; N_h and σ_h^2 are the unit number and variance of layer h respectively; N and σ^2 are the overall unit number and variance of the study area respectively. Q value measures the explanatory power of the factor to y in the range of [0, 1]. The larger the value, the stronger the explanatory power of each factor, that is, the more significant the impact on the spatial distribution of NDVI.

Ecological detector

It is used to compare the effects of two factors X_1 and X_2 on the spatial distribution of attribute y . If there is a significant difference, it is recorded as “Y”, otherwise it is recorded as “n”. According to this, we can judge which factor has more influence on NDVI.

Interaction detector

Identify the interaction between different factors x , that is, evaluate whether the two factors work together to enhance or weaken the explanatory power of Y , or the influence is independent of each other. The calculation results are obtained by comparing the q value of each single factor with the q value of interaction [$q(x_1 \cap x_2)$], such as the relationship between the two factor enhancement [$q(x_1 \cap x_2) > \text{Max}[q(x_1), q(x_2)]$] or the nonlinear enhancement [$q(x_1 \cap x_2) > [q(x_1) + q(x_2)]$].

Risk detector

Risk detection is used to determine whether there is a significant difference in the mean value of attributes between two sub regions. The greater the significance of the mean value is, the greater the value of the dependent variable is. Based on this, we can search the suitable region of factors affecting the dependent variable NDVI.

3. Result

3.1 Spatial pattern of vegetation cover

Referring to relevant studies (Hu et al. 2020) and combined with the actual situation of annual average NDVI in Qinba Mountains, the vegetation status is divided into five types as shown in Table 1 by using the Natural Breaks. Finally, the

spatial pattern of vegetation coverage in Qinba Mountains is obtained as shown in Figure 2.

Generally speaking, the vegetation coverage in Qinba Mountains is relatively high. As shown in Figure 3, the area of medium high vegetation coverage and high vegetation coverage types is relatively large, accounting for 49%, while the area of low vegetation coverage is relatively small, accounting for only 5%. In addition, there are significant differences in spatial characteristics of NDVI in Qinba Mountains, and the overall pattern shows the distribution characteristics of “high in the middle and low around”.

The high values of NDVI were mainly lies in the Qinling and Daba Mountains of Shaanxi Province, The main vegetation types are broad-leaved forest and coniferous forest, while the NDVI value is low in the high altitude areas in the west, low altitude areas in the East and Hanjiang River valley basin, which is mainly due to the low altitude, more human activities and sparse vegetation. The lowest value of NDVI is mainly distributed in the western high altitude areas, which may be due to the sparse distribution of vegetation in high altitude areas, and most of them are grassland and shrub (Chen et al. 2019).

Table 1. The types of vegetation cover

type	NDVI
Low vegetation coverage	0.39-0.62
Medium low vegetation coverage	0.62-0.79
Medium vegetation coverage	0.72-0.79
Medium high vegetation coverage	0.79-0.85
High vegetation coverage	0.85-0.94

Figure 2.Spatial pattern of vegetation cover

Figure 3.Area ratio of NDVI

3.2NDVI dynamic change

As shown in the Figure 4 and Figure 5, the change trend and significance of NDVI in Qinba Mountains during 1982 - 2015 are respectively reflected. According to the results of Sen's trend analysis, the change trend was divided into five levels, and the change significance was divided into four levels according to the results of

302 MK test at the significance level of $\alpha = 0.05$ (Hao et al. 2011).

303 From 1982 to 2015, NDVI in Qinba Mountains increased slowly and remained
304 stable. Significant slow growth was scattered in the eastern and northwest regions,
305 with a wide area distribution. The stable areas were mainly distributed in the central
306 and western parts (Cui et al. 2020). The degraded parts were scattered, mainly in the
307 southwest and northeast, and most of them were non-significant. With the
308 development of human economy and society, the urban area was expanding rapidly,
309 and the disturbance of human activities had caused severe impact on vegetation.

310
311 **Figure 4** .The variation tendency of annual NDVI in 1982 to 2015

Figure 5 .The significance of variation tendency of annual NDVI in 1982 to 2015

3.3Future trend of NDVI

According to the positive and negative persistence of H value greater than 0.5, the Hurst index and the annual NDVI mean change trend are superimposed and reclassified through grid calculation, and the NDVI future change trend distribution map as shown in Figure 6 is obtained. From the H value, we can see that the distribution of NDVI rapid growth region is less and more fragmented, mainly located in the northwest and central areas of Qinba Mountains, and the distribution of NDVI slow growth region is relatively concentrated in the east and northwest. The stable area is the largest, which also reflects that the environment in Qinba Mountains is relatively stable. There are few degraded areas, mainly distributed in the northeast and southwest, which indicates that the change of NDVI in Qinba Mountains is affected by natural and man-made factors, especially natural factors. The sustainability of

vegetation growth is not strong.

Figure 6. The variation tendency of vegetation in future

3.4 Spatiotemporal variation of NDVI

According to the vegetation cover classification of Qinba Mountains, the spatial transfer matrix of vegetation cover in 1982-1995, 1995-2005 and 2005-2015 is obtained through ArcGIS spatial overlay analysis, as shown in Table 2.

During 1982-1995, the transfer of NDVI in Qinba Mountains changed little, the proportion of low vegetation cover type and low vegetation cover type decreased slightly, and mainly converted to medium vegetation cover type and high vegetation cover type. The proportion of high vegetation cover and higher vegetation cover increased, mainly due to the transfer of middle vegetation cover and lower vegetation cover. Among them, 70% of the areas with stable vegetation cover, 19% with improved vegetation cover, and 11% with degraded vegetation cover. Generally

speaking, the transformation trend is mainly positive evolution, the effect of ecological construction is beginning to show, and the ecological environment has undergone good changes (Yue et al.2002).

During the period of 1995-2005, the proportion of high vegetation coverage increased by a small margin, which was mainly due to the transformation of medium vegetation and higher vegetation types. The largest change was the transfer of higher vegetation type to higher vegetation type. During this period, 66% of the areas with stable vegetation cover, 15% with improved vegetation cover, and 9% with degraded vegetation cover. Compared with the previous period, the area of vegetation cover improvement decreased.

In the period of 2005-2015, the type with the largest change is higher vegetation coverage, which accounts for 57%, mainly from the transformation of medium vegetation coverage and high vegetation coverage. The proportion between high vegetation coverage and higher vegetation coverage is the largest, reaching 19%, which also leads to a slight decrease in the proportion of high vegetation coverage. The former mainly transferred to the lower vegetation type and the middle vegetation type, while the latter mainly transferred to the higher vegetation type and the high vegetation type. The NDVI of this area was remarkably improved, accounting for 46% of the total area, and the vegetation coverage of this area remained stable.

Table 2.The transfer matrix of vegetation cover in Qinba mountain area

Period of time	Transform types	Initial types					
		Low	Medium low	Medium	Medium high	High	Gross
1982-1995	Low	4%	1%	0%	0%	0%	5%
	Medium low	2%	7%	1%	0%	0%	10%
	Medium	0%	5%	8%	0%	3%	17%
	Medium high	0%	0%	0%	38%	7%	45%
	High	0%	1%	5%	5%	13%	23%
	Gross	7%	13%	15%	43%	23%	100%
1995-2005	Low	3%	1%	0%	0%	0%	4%
	Medium low	2%	6%	2%	0%	0%	11%
	Medium	0%	3%	9%	1%	5%	18%
	Medium high	0%	0%	1%	35%	5%	40%
	High	0%	0%	4%	9%	13%	27%
	Gross	5%	10%	17%	45%	23%	100%
2005-2015	Low	1%	1%	0%	0%	0%	1%
	Medium low	2%	2%	1%	0%	0%	6%
	Medium	1%	4%	3%	0%	1%	9%
	Medium high	0%	1%	6%	31%	19%	57%
	High	0%	3%	7%	8%	9%	27%
	Gross	4%	11%	18%	39%	28%	100%

363 3.5Geographic detection of NDVI spatial distribution

364 Generally speaking, the main factors affecting NDVI are natural factors and
365 human factors. Therefore, this paper selected the corresponding proxy variables from
366 the above two aspects to form the influencing factors of NDVI in Qinba Mountains as
367 shown in Table 3. In ArcGIS, 8 km regular fishing net was set to divide the study area,
368 and then NDVI and its influence factors were classified and resampled, finally
369 included in the geographic detector model calculation.

370 **Table 3.**The influence factors of NDVI

Climatic factors	Human activities factors
Annual mean temperature (X1)	Population density (X6)
Precipitation (X2)	GDP (X7)
Altitude (X3)	Land-use type (X8)
Slope (X4)	
Aspect (X5)	
Agrotype (X9)	

371 3.5.1Factor detector

According to factor detector, the results of factor detection (q value) in table 4 show that it reflects the influence of each factor on NDVI in Qinba Mountains. The order of influencing factors of NDVI was Precipitation (x2) > Agrotype (x9) > Altitude (x3) > Land-use type (x8) > Annual mean temperature (x1) > Slope (x4) > Population density (x6) > GDP (X7) > Aspect (x5).

From the q value of each factor to NDVI, Precipitation, Agrotype and DEM are the main influencing factors with the explanatory power of more than 10%; land use type, temperature, slope and population density are the secondary influencing factors; while the p value of GDP and slope aspect is too large, the impact is not significant. Some natural environmental factors, mainly rainfall and soil types, are the main basic factors affecting the distribution of NDVI in Qinba Mountains, but human activities have little influence on NDVI.

Table 4.The result of factor detection

	X1	X2	X3	X4	X5	X6	X7	X8	X9
q	0.082	0.234	0.118	0.064	0.002	0.070	0.032	0.088	0.144
p	0.000	0.000	0.000	0.000	0.733	0.000	1.000	0.000	0.000

3.5.2 Ecological detector

Table 5 shows the results of ecological detector. Rainfall and temperature have significant differences on the spatial distribution of NDVI, but there is no significant difference with other factors; Agrotype has significant differences with other factors except temperature and DEM, and the number of factors with significant differences is the largest, which further proves that Agrotype is the dominant factor; DEM and air temperature have significant differences on the spatial distribution of NDVI, and there is no significant difference with other factors. There was no significant difference in

other factors, and the action mechanism of the dominant natural factors was different.

The impact of land use type, aspect and GDP on the spatial distribution of NDVI has significant difference, but has no significant difference with other factors. Population density, slope, aspect and soil type had significant differences on the spatial distribution of NDVI, but had no significant difference with other factors.

Table 5.Statistical significance of the detection factors for NDVI distribution

	X1	X2	X3	X4	X5	X6	X7	X8	X9
X1									
X2	Y								
X3	Y	N							
X4	N	N	N						
X5	N	N	N	N					
X6	N	N	N	N	Y				
X7	N	N	N	N	N	N			
X8	N	N	N	N	Y	N	Y		
X9	Y	N	N	Y	Y	Y	Y	Y	

Using F test with significance level of 0.05, y means that there is significant difference between the two factors in the spatial distribution of NDVI; n means that there is no significant difference

3.5.3Interaction detector

Table 6 shows the results of interaction detector, The detection results show that the interaction q values of different factors are greater than that of single factor, that is, they all show double factor enhancement or nonlinear enhancement, and there is no independent or weakening relationship between them. That is to say, the superposition of the two factors greatly enhances their influence on the spatial distribution of NDVI.

Among the natural factors, precipitation $\cap$ temperature and precipitation $\cap$ DEM [q (x1 $\cap$ x2) = 0.467] have the strongest explanatory power for NDVI spatial distribution, and precipitation, Agrotype, DEM and other natural factors still occupy the dominant position.

The explanatory power of the interaction between all socio-economic factors and

other factors increased significantly, especially the interaction with natural factors, in which the explanatory power of land use type and temperature was the strongest. For the population density and GDP with weak explanatory power of single factor, the explanatory power of their interaction with natural factors is mostly nonlinear. This shows that the natural environment and human activities have a greater impact on the spatial distribution of NDVI.

Table 6. The analyze of interaction between the dominant factors

	X1	X2	X3	X4	X5	X6	X7	X8	X9
X1	0.082								
X2	0.467	0.234							
X3	0.154	0.467	0.118						
X4	0.153	0.299	0.175	0.064					
X5	0.104	0.252	0.138	0.079	0.002				
X6	0.209	0.294	0.231	0.130	0.084	0.070			
X7	0.151	0.288	0.162	0.103	0.053	0.109	0.032		
X8	0.191	0.320	0.227	0.153	0.103	0.154	0.127	0.088	
X9	0.249	0.328	0.265	0.204	0.161	0.221	0.185	0.224	0.144

3.5.4Risk detector

According to the risk detection as show in table 7, we calculated and analyzed the suitable range or type of each factor to the change of NDVI distribution. In Qinba Mountains, when the altitude is 1098-1424 m and the slope is 33-44 °, the NDVI value is higher. These areas are not suitable for production and living, so the

vegetation coverage is higher. At the same time, when the annual average temperature is 10.6-12.2 °C and the precipitation is 1096-1186 mm, it has better hydrothermal conditions and higher vegetation coverage. In addition, as widely distributed in grassland and forest area, leached soil also plays a positive role in vegetation growth in this area.

Table 7. The suitable range or type of different factors

Factors	Comfort type or range	NDVI
temperature	10.6-12.2°C	0.841
Precipitation	1096-1186mm	0.834
Altitude	1098-1424m	0.847
Slope	33-44°	0.833
Aspect	southeast	0.817
Population density	3.36-77.5 Person/ km ²	0.831
GDP	274-666×10 ⁴ yuan· k m ²	0.82
Land-use type	woodland	0.833
Agrotype	Alfisols	0.835

4. Discussion

Qinba Mountains is the cross of natural environment in China. The special location of Qinba Mountains makes it have a complex ecological environment. Therefore, it is significant to learn the temporal and spatial changes and driving factors of NDVI in Qinba Mountains. This paper analyzes the temporal and spatial changes of NDVI from 1982 to 2015 at different scales, and explores the response mechanism among vegetation growth, natural environment and human activities at medium and small scales (Qin et al. 2020).

We found that the vegetation coverage in Qinba Mountains was good from 1982

to 2015. Through the analysis of the temporal and spatial changes in Qinba Mountains, it is found that the vegetation coverage in Qinba Mountains has increased steadily, which indicates that the ecological environment has been optimized and the effect of ecological construction is obvious (Yue et al. 2020). The future development trend of NDVI in Qinba Mountains is relatively stable, but we still need to improve the awareness of environmental protection. In the future, ecological construction needs to implement precise policies and strengthen ecological protection in fluctuating and degraded areas.

Geographic detector can accurately identify the relationship and interaction between multiple factors. Geographic detector can accurately identify the relationship and interaction between multiple factors. In this paper, the relationship between NDVI spatial differentiation and influencing factors is studied by using geographic detector. The dominant factors are consistent with the natural law of vegetation growth in Qinba Mountains, and are also relatively consistent with the same type of research conclusions (Zhang et al. 2020). We found that natural factors had a great influence on the spatial distribution of vegetation NDVI, and dominated the overall pattern of vegetation spatial distribution. Among them, rainfall is the primary factor affecting NDVI. The main factor of intranasal variation is positively correlated with NDVI. Qinba Mountains is widely distributed in mountainous areas, and its geographical division span is large, which leads to less influence of human activities on its NDVI. However, there is no clear basis for the spatial division of the impact factors in the application process of the geographical detector, and the factor selection may not be

complete, and the explanatory power of the factors is weak subjectivity (Wu et al. 2019).

5. Conclusion

Using Sen and Mann–Kendall models, Hurt index and Geodetector, this study investigated the spatiotemporal variation and driving forces of NDVI, based on the GIMMS3g during 1982 -2015. Our findings are summarized as follows:

(1) From 1982 to 2015, the vegetation in Qinba Mountains grew well, and the overall vegetation coverage was high, but the spatial characteristics were significantly different. The overall pattern showed the distribution characteristics of “high in the middle and low around”.

(2) The NDVI in Qinba Mountains mainly increases slowly and keeps stable and the slow growth changes significantly, while the degradation is only distributed in some areas of northeast and southwest, which indicates that the effect of ecological construction is significant.

(3) From the point of view of sustainable change of NDVI, the sustainability is good, with few regional fluctuations, mainly due to the obvious anti sustainability characteristics in the northwest, southwest and other mountainous areas, as well as the northwest and central areas of Qinba Mountains where NDVI is growing rapidly. The stable area is the largest, which also reflects that the environment in Qinba Mountains is relatively stable.

(4) From the change of NDVI transfer, the vegetation growth in Qinba Mountains was mainly in positive evolution from 1982 to 2015. The areas of low vegetation

coverage and low vegetation coverage reduced continuously, while the areas of high vegetation coverage and high vegetation coverage increased, indicating that the ecological environment in Qinba Mountains was continuously optimized.

(5) The result of Geodetector show that the influencing factors of NDVI in Qinba Mountains are rainfall, soil type, DEM and land use type, in turn, and the natural environmental factors are the main basic elements influencing the spatial and temporal distribution of NDVI in Qinba Mountains. However, human activities have little influence on NDVI. Natural environment factors and human activities together have an important impact on the spatial and temporal distribution of NDVI.

Declarations

Ethics approval and consent participate: Not applicable

Consent for publication: Not applicable

Availability of data and materials: The GIMM3g datasets used to support the finding of this study were derived from the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) (<https://www.noaa.gov/research>). The climate datasets, Population density data, GDP data and land use type were acquired from the Resource and Environment Science and Data Center (<http://www.resdc.cn/>). SRTM 90m Digital Elevation Model (DEM) products come from Geospatial Data Cloud (<http://www.gscloud.cn/>).

Competing interest: The authors declare that they have no competing interests.

Funding: This research was jointly supported by the Integrated Scientific

Investigation of the North-South Transitional Zone of China (Grant No. 2017FY100904), the Scientific Research Project of Education Department of Shaanxi Province (Grant No. 17JK0776).

Author Contributions: Conceptualization—H. Y.; methodology—H. Y., Z. - Y. R., L-Y.L, and J - L. P.; Writing—original draft preparation, Z. - Y. R.; Writing—review and editing, H. Y. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: We would like to thank the anonymous reviewers and editors for their valuable comments and suggestions.

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Figures

Figure 1

The geographical position of Qinba Mountains Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 2

Spatial pattern of vegetation cover Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 3

Area ratio of NDVI

Figure 4

The variation tendency of annual NDVI in 1982 to 2015 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 5

The significance of variation tendency of annual NDVI in 1982 to 2015 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 6

The variation tendency of vegetation in future Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.