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Impacts of climate change and human activities on vegetation cover changes in the Fen River headwaters based on long time series data

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ABSTRACT

As an indicator of climate change, the change of vegetation cover directly reflects the ecosystem dynamics of the region. In this paper, the spatial and temporal characteristics of vegetation cover in the headwaters of the Fen River and the effects of temperature, precipitation, GDP and population on the changes of vegetation cover were statistically analyzed by using the Theil-Sen median slope and the Mann-Kendall test and Pearson's correlation coefficient from 2000 to 2020. The results showed that: (1) from 2000 to 2020, the vegetation cover of the Fen River headwaters showed an overall upward trend, and the mean value of NDVI was 0.55. The fluctuation increased from 2000 to 2011; the significant increase was observed from 2011 to 2013; and the fluctuation of the value of NDVI from 2013 to 2020 was relatively small $(p<0.01)$. (2) Climate change affects changes in vegetation cover. On the time scale, the 2000-2020 mean NDVI values are positively correlated with temperature and precipitation, but the correlation is not significant $(p=0.053>0.05, p=0.185>0.05)$. On the spatial scale, vegetation cover was weakly negatively correlated with air temperature as a whole, while positively correlated with precipitation as a whole. (3) The influence of human activities on vegetation cover was dominant, NDVI and GDP were positively correlated, with only 5.13% negatively correlated in the central and northeastern part of the region, and NDVI and population were strongly positively and negatively correlated, with alternating distribution in the study area. (4) The vegetation cover of the Fen River headwaters area shows an increasing trend, but there are still ecological and environmental problems, and it is necessary to continue to improve the implementation of the relevant ecological protection policies in order to achieve the goal of sustainable development. The results of the study can provide scientific references for the restoration of vegetation cover and protection of fragile ecosystems in the transition zone of semi-arid and semi-humid climate.

Keywords: Fen River headwaters are, vegetation cover change, climatic factors, human activities

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1. Introduction

Vegetation plays a major role in terrestrial ecosystems and is very sensitive to environmental changes and is an indicator of ecological changes [1]. Vegetation can prevent rainwater from striking the soil surface directly, reduce the impact force of raindrops, and decrease the rate of soil erosion. Therefore, vegetation cover has the effect of erosion prevention, water and sand reduction, and the restoration of vegetation cover can prolong the time of slope flow production, increase infiltration, and reduce the production of flow and sand production [2-3]. In addition, vegetation cover can protect biodiversity, mitigate climate change and provide ecological services. Therefore, monitoring and evaluating the change of vegetation cover has certain theoretical and practical guiding significance for soil erosion management, ecological environmental protection, resource utilization, and future environmental decision-making [4-7].

Due to the spatial and temporal heterogeneity of vegetation changes, it is difficult for traditional measurement methods to monitor vegetation dynamics on a large scale and in real time. Remote sensing technology has gradually been applied in the monitoring of ecological changes at large scales [8]. In 1973, the normalized vegetation index (NDVI) was proposed and widely used in the monitoring of large-scale vegetation dynamics changes, which is the most classical and effective index reflecting the vegetation cover and growth status [9]. The index is influenced by climate, topography, human activities and other factors. Among them, temperature, precipitation, humidity and seasonal variations are considered as important climatic factors affecting the spatial distribution of vegetation NDV1 [10]. Among them, the changes in environmental factors such as temperature and precipitation due to climate change have led to changes in physiological activities such as flowering, budding, and growth of plants, or changes in the areas where plants are adapted to grow, which exacerbate the aging process of plants and lead to vegetation degradation [11-13]. With the warming of the climate, the growing season of vegetation has changed. For example, the flowering period of some plants is advanced and the growth cycle of leaves is prolonged, leading to changes in vegetation cover, while warmer temperatures lead to glacier melting and sea level rise, which in turn affects the distribution of vegetation in coastal areas [14-15]. More seriously, extreme weather events such as extreme droughts [16], heavy rains [17], storms [18], and dust storms [19] can cause damage to the vegetation cover, resulting in poor vegetation growth or outright death, or even desertification, while excessive precipitation may lead to overproduction of vegetation and affect the stability of the ecosystem. And the ecological changes caused by climate warming may lead to the extinction or migration of certain plant species, affecting the diversity of vegetation cover [20].

In addition, human activities such as large-scale deforestation, urbanization, agricultural cultivation and expansion, and engineering construction can cause significant changes in vegetation distribution and type. Traditional farming practices, such as shifting cultivation and deep plowing, have increased land productivity to a certain extent, but they have also led to soil erosion and vegetation destruction, and over-cultivation and over-grazing are important causes of vegetation degradation [21]. With the growth of population, people's demand for land and resources is increasing, resulting in a large amount of land being reclaimed and overgrazed, which leads to a decrease in vegetation cover and an increase in soil erosion. In addition, with economic development and population migration, the urbanization process in some areas has accelerated, and urban expansion has led to large-scale deforestation and destruction of natural vegetation, and the construction of a large number of buildings, roads, and other infrastructure in the process of urbanization has also caused damage to land and vegetation [22-23]. Furthermore, industrialization and resource exploitation have also affected the vegetation cover [24-25]. Industrial production requires a large amount of energy and a large amount of resources are exploited, which not only destroys the vegetation cover on the ground surface, but also leads to problems such as land subsidence and water pollution.

Fen River is located in Shanxi Province, China, and is an important water source protection area in Shanxi Province, which is famous for its unique natural landscape and rich water resources. The headwaters area of Fen River has a high terrain, complex and diverse geomorphology, and its ecological environment is relatively pristine, with high vegetation cover and rich plant resources [26]. Assessing the impacts of climate change and human activities on the change of vegetation cover in the Fen River headwaters area is of great significance for the management of the Fen River.

The headwaters area of the Fen River belongs to the semi-arid and semi-humid region, which is an important part of the Loess Plateau ecosystem in China, and plays a crucial role in the prevention and control of desertification, environmental protection, and maintenance of regional sustainable development. According to the Ecological Functional Area Planning of Shanxi Province, the Fen River headwaters area is positioned as an ecological functional area for water conservation and biodiversity protection. There have been a series of ecological and environmental problems in the Fen River headwaters area, such as vegetation degradation, land sanding, soil erosion and so on. At present, driven by the policy of "ecological civilization and beautiful China", the ecological environment of the Fen River headwaters area has been improved and the vegetation has been restored, so it is imperative to analyze the changes in the spatial and temporal patterns of vegetation cover in the Fen River headwaters area, and to explore the driving force of the formation of the spatial and temporal patterns of vegetation. However, there are fewer studies on the driving mechanism of vegetation cover changes in the Fen River headwaters. In view of this, this paper selects Ningwu County, Wuzhai County and Bali County as the study area to carry out the following studies:

1) Analyze the spatial and temporal change characteristics based on the vegetation cover data from 2000 to 2020.

2) On this basis, the impacts of climate change and human activities on the vegetation changes at the headwaters of the Fen River were investigated, and the influence coefficients of the factors of vegetation cover were derived.

3) Understand the response process of vegetation to climate change and human activities, and make scientific and effective ecological protection and management suggestions for the driving factors.

2. Overview

In the species of climate change and human activities on vegetation cover, most scholars have carried out relevant studies, and based on NDVI data, the vegetation cover of different regions has been studied. Literature [27] used GA-SVM model combined with NDVI to analyze the change of vegetation cover in Weihe River affected by climate change and human activities, and the realistic impact of human activities was smaller than climate change, and the model reproduced the evolution between NDVI and rainfall and temperature.

In terms of time span, literature [28] analyzed the vegetation NDVI data of the Haihe River Basin for 13 years by Sen and Mann-Kendall model, Hurst index, and partial correlation analysis, and the vegetation cover in the region changed in a growth mode, with the growth rate decreasing in the later period. Literature [29] analyzed the relationship between human activities and climatic factors and vegetation cover changes with a span of 15 years by three methods: segmented linear regression, bivariate partial correlation analysis, and factor analysis using a medium image meta-model, and the study was analyzed both temporally and spatially. Literature [30] explored the vegetation cover change in Ethiopia on the basis of 15 years time series, temperature and rainfall affected the vegetation cover differently in time and space while human activities were the major influencing factors. Literature [31] analyzed the vegetation cover changes in the Yellow River Basin over 18 years using a geoprobe supported by time series NDVI and weather data, weather and vegetation cover changes showed spatial heterogeneity, and rainfall was the main factor. Literature [32] analyzed the vegetation cover changes in the Yangtze River Basin over a period of 19 years using NDVI and climate data, and the coverage increased dynamically, showing spatial high in the middle and low on both sides. Literature [33] analyzed the change of vegetation cover in sandy land spanning 19 years under climate change and human activities based on NDVI data, and segmented the impacts of climate change and human activities using residual analysis, and rainfall and temperature showed significant impacts, while land cover type had no impact. Literature [34] analyzed the response of vegetation cover change to climate change and human activities in the Hulun Lake Basin using the residual trend method and under the 38-year spatial and temporal dimensions, during which forests, wetlands, and croplands had the highest vegetation cover, and grassland vegetation degradation was severe, with rainfall having the greatest impact. The above studies comprehensively analyzed the changes of vegetation cover in different regions considering NDVI data, weather data, human activities, topography, etc. Weather data were mostly rainfall and temperature, while human activities were dominated by grazing and so on.

In the study of Fen River basin, literature [35], based on NDVI, analyzed the vegetation cover in the upper and lower Fen River basin for 21 years with linear trend analysis and topographic correction, and found that the vegetation cover in the mountainous area was higher than that in the plateau. Literature [36] analyzed the 40-year vegetation change of the Fen River by kernel-NDVI, three kinds of climate change (rainfall, temperature, and solar radiation), and the GGP, and rainfall was the main climate change factor, followed by temperature and solar radiation, and the GGP enlarged the greening area but exacerbated climate change in the perception of the vegetation. The current study is only based on single-factor human activities and common rainfall and temperature changes, and other types of climate change and human activities have not been addressed, while the Fen River is rich in water resources and has a complex topography, these studies alone are not sufficiently informative for management decisions.

3. Materials and methods

3.1. Overview of the study area

In this study, the headwaters area of the Fen River (longitude 111°13'-120°40'E, latitude 38°29'-39°17'N) was used as the research object, which includes Ningwu County, Bali County, and Wuchai County, with a total area of 6812.35 km² (Figure 1) The area is located in the transition zone between semi-arid and semi-wet climate, and belongs to the temperate continental climate. It is cold in winter and hot in summer, with a large annual temperature difference, and precipitation is concentrated in summer, with an average annual precipitation of 462mm, four distinct seasons, and an average annual temperature of 5.6°C. The main soil types are brown, brown, brown, brown, brown, brown, brown, brown, brown, brown, brown, brown and brown. The main soil types are brown soil, meadow soil, mountain meadow soil and mountain brown soil, and the main natural vegetation is dominated by coniferous forests and mixed coniferous and broad-leaved forests. The six ecosystems of "mountains, water, forests, fields, lakes and grasses" are complete. The vegetation cover of the Fen River headwaters is high, but human activities, such as urban and rural construction and irrational exploitation of mineral resources, have led to vegetation degradation in some areas of the region. It is important to study the drivers of vegetation cover in the Fen River headwaters to maintain the surrounding ecological environment.

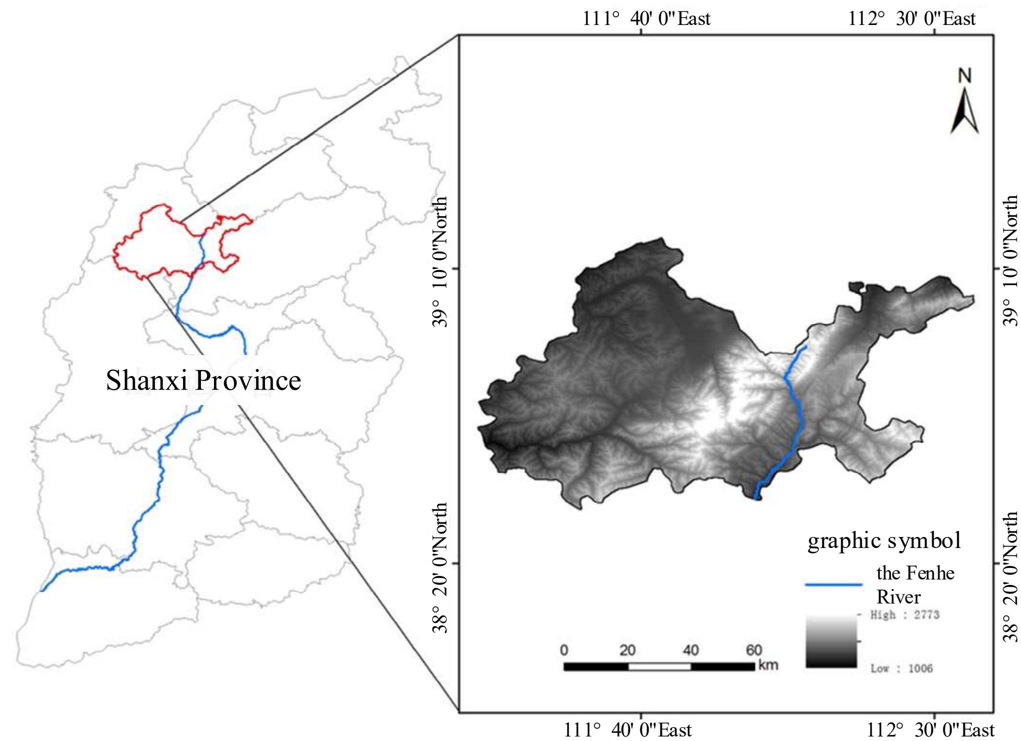


Fig. 1. Map of Fen River Headwaters area

3.2. Data sources

The national vegetation index (NDVI) data for the period 2000-2020 were obtained from the Earth Resources Data Cloud Platform (www.gis5g.com). This dataset is based on Google Earth Engine cloud computing platform, with data from Landsat5/7/8/9 remote sensing satellites, and the maximum value of NDVI in a year for each pixel in the period of 2000-2020 is obtained by using maximum synthesis through data preprocessing and data smoothing methods. The spatial resolution is 30 m and the temporal resolution is year. Meteorological data such as precipitation and temperature during 2000-2020 were obtained from the National Meteorological Center of China Meteorological Administration (http://data.cma.cn). The total population and GDP data of the study area from 2000 to 2020 were obtained from the Statistical Yearbook; the total population includes rural and urban population, and the GDP includes data of primary, secondary and tertiary industries.

The unified geographic coordinate system for the above data is GCS_WGS_1984, and the projected coordinate system is WGS_1984_UTM_Zone_48N, with a spatial resolution of 30m.

3.3. NDVI Data calculation methods

NDVI can assess the vegetation growth condition, which is the ratio between infrared and visible bands of surface reflectance measured by remote sensing technology, and the NDVI data were processed by using ArcGIS 10.8 software.The true value of NDVI is converted by multiplying the initial value of the image element of the NDVI data (Digital Number,DN) by 0.0001, and its value range is -0.2~+1.

$$NDVI = \frac{\rho NIRI - \rho RED}{\rho NIRI + \rho RED} \tag{1}$$

ρRED and $\rho NIRI$ are the reflectance of red (620-670 nm) and near-infrared (841-875 nm) light, respectively.

3.4. Trend analysis - Theil-Sen median slope and Mann-Kendall test

1) Theil-Sen median slope is a robust non-parametric statistical approach to trend. It is calculated by the formula:

$$\beta = Median\left(\frac{x_j - x_i}{j - i}\right), \forall j > i \tag{2}$$

β is the slope, β greater than 0 indicates an upward trend in the time series; β less than 0 indicates a downward trend in the time series; x_j and x_i are time series data, n is the number of data.

2) Mann-Kendall test can reasonably and scientifically measure the fluctuation characteristics of vegetation long time series. Its statistical test method is as follows. For the time series x_i, $i = 1, 2, \ldots i, \ldots j, \ldots, n$ 。x_j and x_i are time series data, n is the number of study data. Definition of statistical variable S:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign\left(x_j - x_i\right) \tag{3}$$

$sign\left(x_j - x_i\right)$ is the indicator function, according to $x_j - x_i$ the plus and minus signs take the values 1,0 or -1.

$$sign\left(x_j - x_i\right) = \begin{cases} 1, x_j - x_i > 0 \\ 0, x_j - x_i = 0 \\ -1, x_j - x_i < 0 \end{cases} \tag{4}$$

S the variance of the statistic is:

$$Var\left(S\right) = \frac{n\left(n-1\right)\left(2n+5\right)}{18} \tag{5}$$

When $n > 10$, define the standardized test statistic Z:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{Var\left(S\right)}}, S > 0 \\ 0, S = 0 \\ \dfrac{S+1}{\sqrt{Var\left(S\right)}}, S < 0 \end{cases} \tag{6}$$

During the MK test, the parameter $UF > 0$ indicates that the vegetation cover shows a continuous growth trend, and the value of UF is at the significance level, which indicates that it passes the 95% significance test. the intersection of UF and UB is within the confidence interval, which indicates that the NDVI is growing rapidly at this point.

At a given significance level $\alpha = 0.05$, when $|Z| = 1.96$, it means that the confidence level of the trend is 95%, and when $|Z| > 1.96$, it means that the trend passes the 95% significance test. The NDVI changes were graded based on the natural breakpoints and the actual annual mean NDVI, and combined with the results of the MK test (Table 1).

Table 1. Mann-Kendall test tread categories

Variation trend	MK test for significant levels Z
Significant reduction	$Z \leq -2$
No significant reduction	$-2 < z \leq 0$
No significant increase was observed	$0 < z \leq 2$
Significant increase	$Z \geq 2$

3.5. Pearson correlation coefficient

The Pearson correlation coefficient, often denoted by the letter r, measures the linear relationship between two random variables. The overall Pearson correlation coefficient between two variables is defined as the quotient between the covariance and the standard deviation between the two variables with the following formula:

$$\rho = \frac{cov(X,Y)}{\sigma_X \sigma_Y} = \frac{E\left[(x-\mu_X)(y-\mu_Y)\right]}{\sqrt{\sigma_x^2 \sigma_Y^2}} \tag{7}$$

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{X})(y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{X})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{Y})^2}} \tag{8}$$

r denotes Pearson correlation, P denotes significance (two-tailed); $\bar{X}$ and $\bar{Y}$ denote the sample means of the two, respectively; $r=1$ denotes a perfect positive correlation, i.e., a relationship that satisfies $Y=aX+b(a>0)$; $r=-1$ denotes a perfect negative correlation, i.e., a relationship that satisfies $Y=aX+b(a<0)$; $r=0$ denotes that the two are not linearly correlated.

4. Results and Analysis

4.1. Characteristics of the temporal distribution of vegetation cover

The vegetation cover and its trend from 2000 to 2020 in the headwaters area of the Fen River are shown in Figure 2. From the figure, it can be seen that the inter-annual variation of NDVI ranges from 0.43 to 0.65, and the average annual NDVI value is 0.54, with an overall upward trend, and the trend was fitted with an average growth rate of 1% and r^2 of 0.79.In the MK trend test, it was shown that the mutation point appeared in 2012. The changes of NDVI in the past 20 years were divided into three stages as follows: (1) the vegetation cover of 0.45 increased steadily to 0.49 between 2000 and 2011; (2) the vegetation cover increased rapidly to 0.64 between 2011 and 2013; and (3) the vegetation cover was relatively stable between 2013 and 2020, and the vegetation improved gradually.

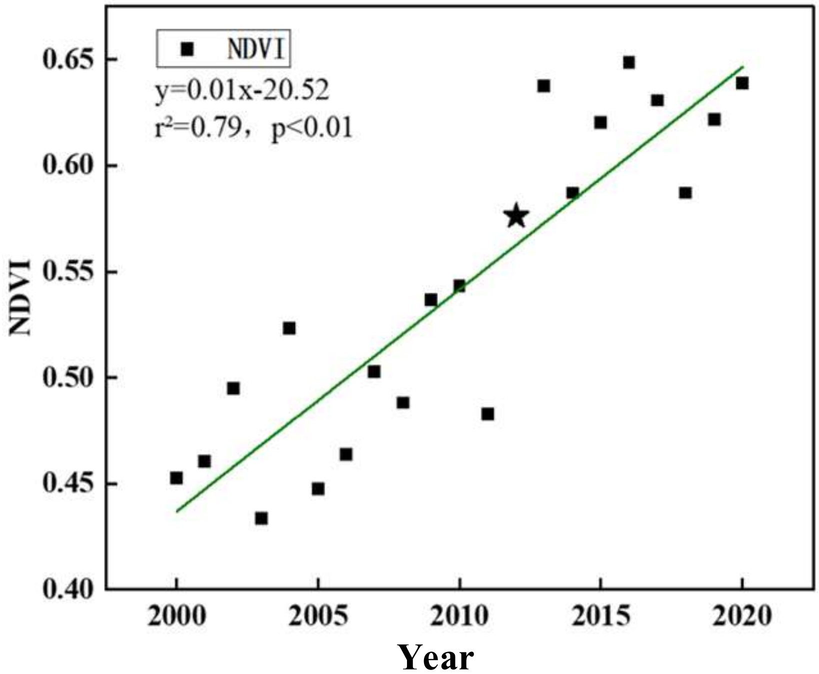


Fig. 2. Changes in mean annual NDVI at the headwaters of the Fen River, 2000-2020. (★indicates 2012 as the mutation point for the MK test)

Combined with the vegetation characteristics of the study area, the NDVI is divided into four classes: very low vegetation cover [-0.2~0.2], low vegetation cover [0.2~0.4], medium vegetation cover [0.4~0.6], and high vegetation cover [0.6~1] (see Figure 3). 2000-2020, the Fen River headwaters had the lowest proportion of very low vegetation cover, and the vegetation cover of the area was dominated by medium and low cover and accounted for more than 80% of the area. In 2000 and 2005, the overall vegetation cover in the region was dominated by medium and low cover, with an area of 4000 km² and a proportion of more than 80%. 2010 saw a significant increase in the area of high cover, which accounted for more than 50% in 2020, and a significant decrease in the area of low cover, which accounted for less than 5% in 2020. In terms of inter-annual changes, the proportion of low-cover and medium-cover areas showed a decreasing trend, while the proportion of high-cover areas showed an increasing trend, indicating that the vegetation cover in the study area has been effectively improved.

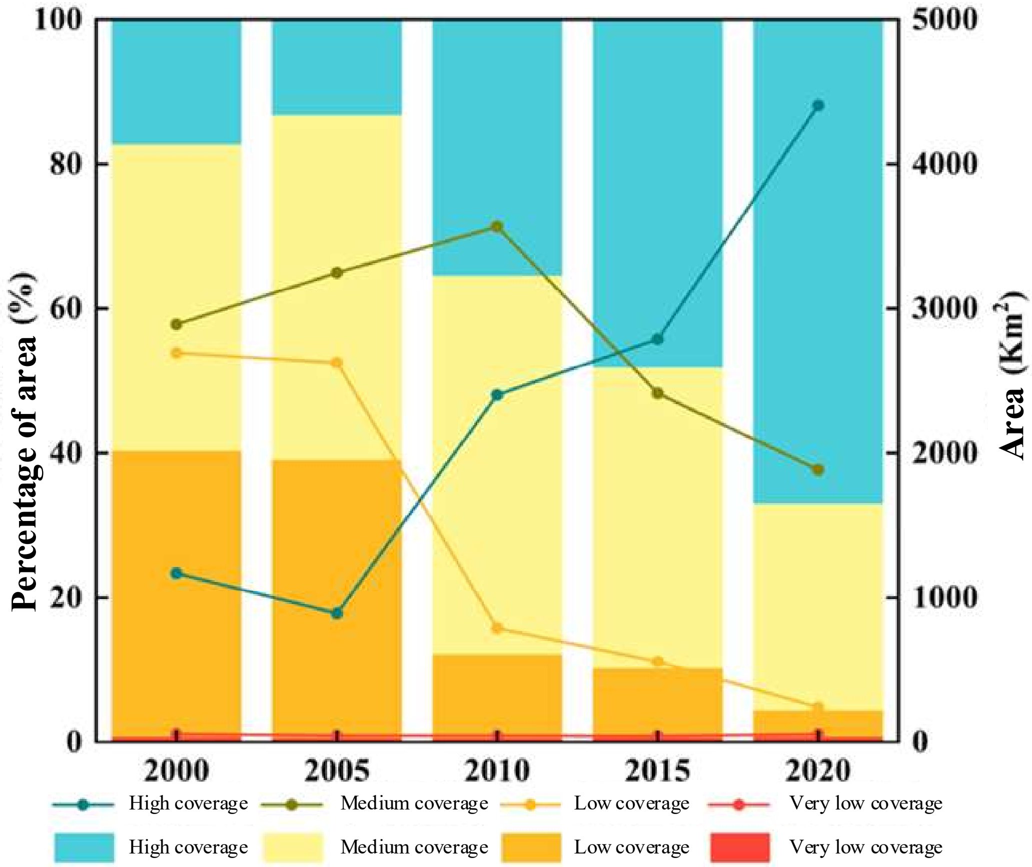
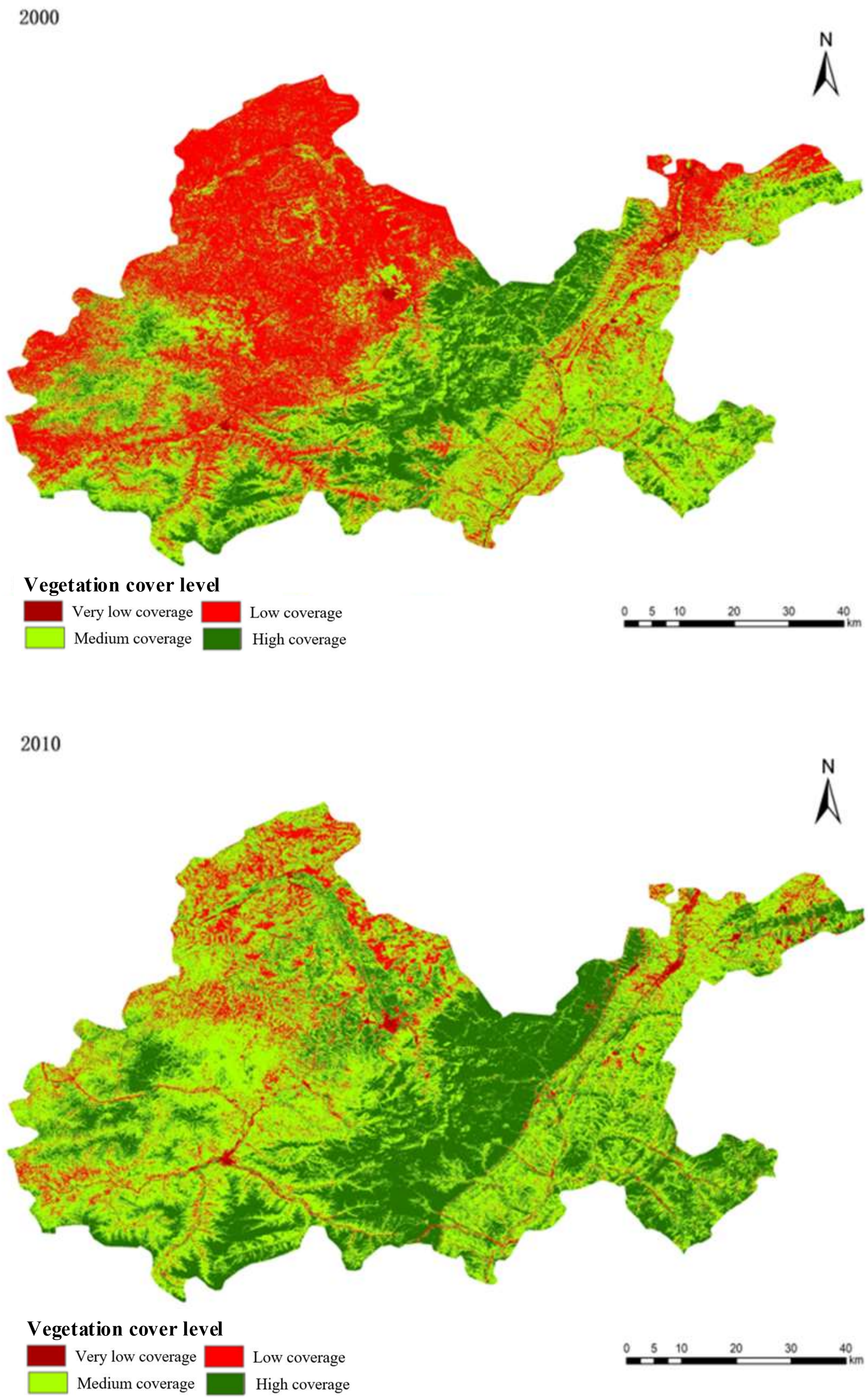


Fig. 3. Changes in the area of different classes of vegetation cover and their share in the 5-year period

4.2. Characteristics of spatial distribution and changes in vegetation cover

In this study, the Sen trend degree of vegetation NDVI was calculated for the period of 2000-2020 and M-K test was performed, and the results are shown in Figure 4. The changes of NDVI were categorized into four increasing trends: significantly decreasing, non-significantly decreasing, non-significantly increasing, and significantly increasing, with the areas of 104.02km², 262.30km², 2111.48km², and 4334.54 km². The overall change of vegetation cover in the Fen River headwaters area showed an increasing trend, and the area of increasing trend accounted for 94.62%. Significantly increasing areas are mainly distributed in the central and southern parts of Bali and Ningwu counties, non-significantly increasing areas are mainly in the central part, and significantly decreasing areas are mainly distributed in the northeastern part of Ningwu County.During the past 20 years, the decrease of low vegetation cover in Wuchai County is the most obvious, and the increase of high vegetation cover in Bali County is the most obvious, and the vegetation cover along Luga and Guanxian Mountains has been relatively good.


2000
N
Vegetation cover level
Very low coverage
Low coverage
Medium coverage
High coverage
0 5 10 20 30 40
km
2010
N
Vegetation cover level
Very low coverage
Low coverage
Medium coverage
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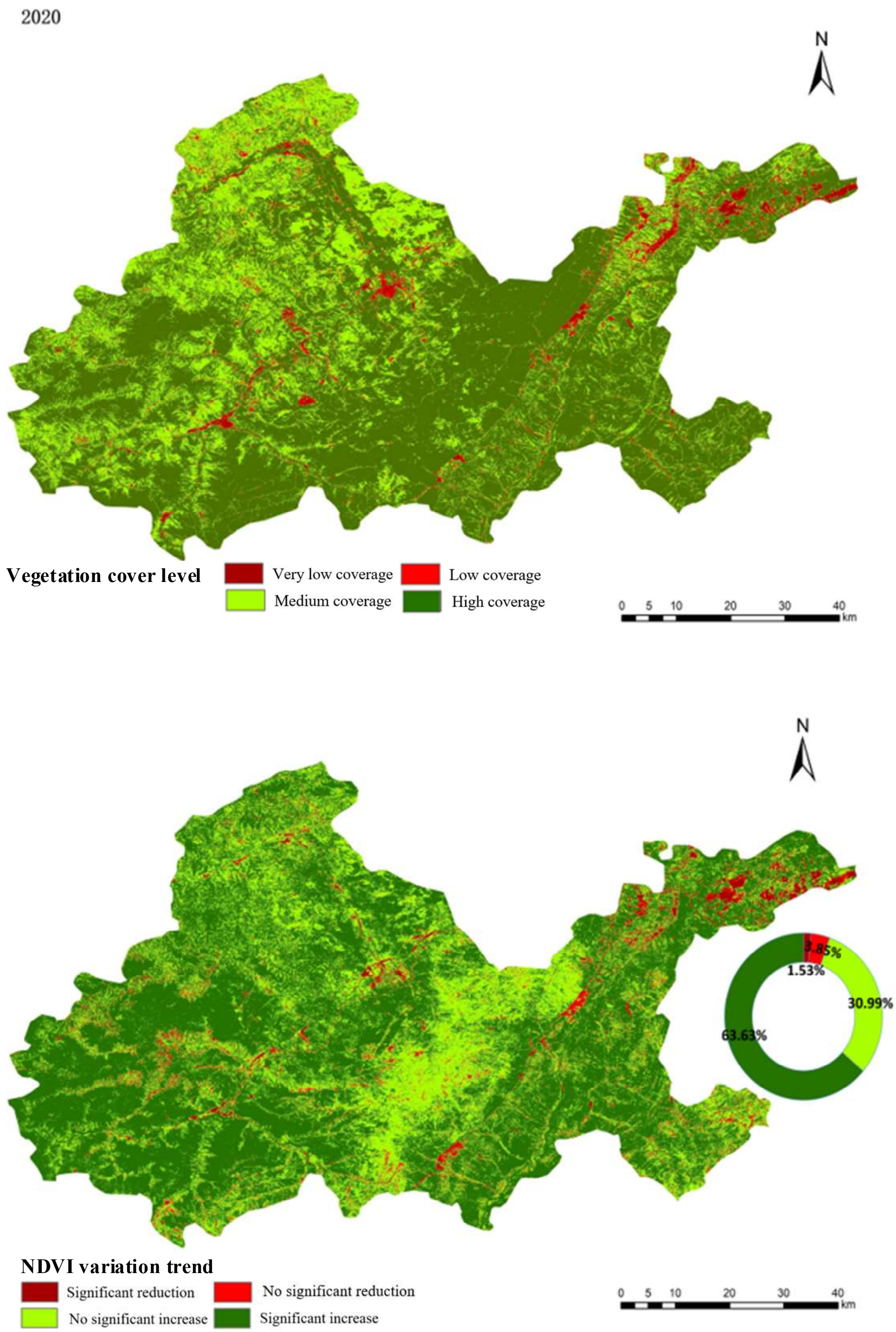


Fig. 4. Spatial distribution of vegetation cover and its changes in the headwaters of the Fen River

4.3. Driver correlation analysis

4.3.1. Correlation analysis between NDVI and temperature. As shown in Figure 5a, there is a significant positive correlation between NDVI and air temperature on the time scale $\left(r = 0.470, P < 0.05\right)$ .Overall, the peaks and troughs of the NDVI trend appeared almost simultaneously with air temperature, indicating that the changes in NDVI had a positive feedback on the changes in air temperature. As shown in Figure 5B, on the spatial scale, the correlation coefficient between vegetation cover and air temperature was around the value of 0. The area of the region with negative correlation was 3608.5 km² accounting for 52.97%, which was mainly distributed in the west and east of the region, and the negative correlation was stronger in the edge areas. The positive correlation between vegetation NDVI and air temperature is 47.03%, mainly with 0-0.2 coefficients, distributed in the junction of three counties in the central part of the region, Luya Mountain and Guanxian Mountain area.

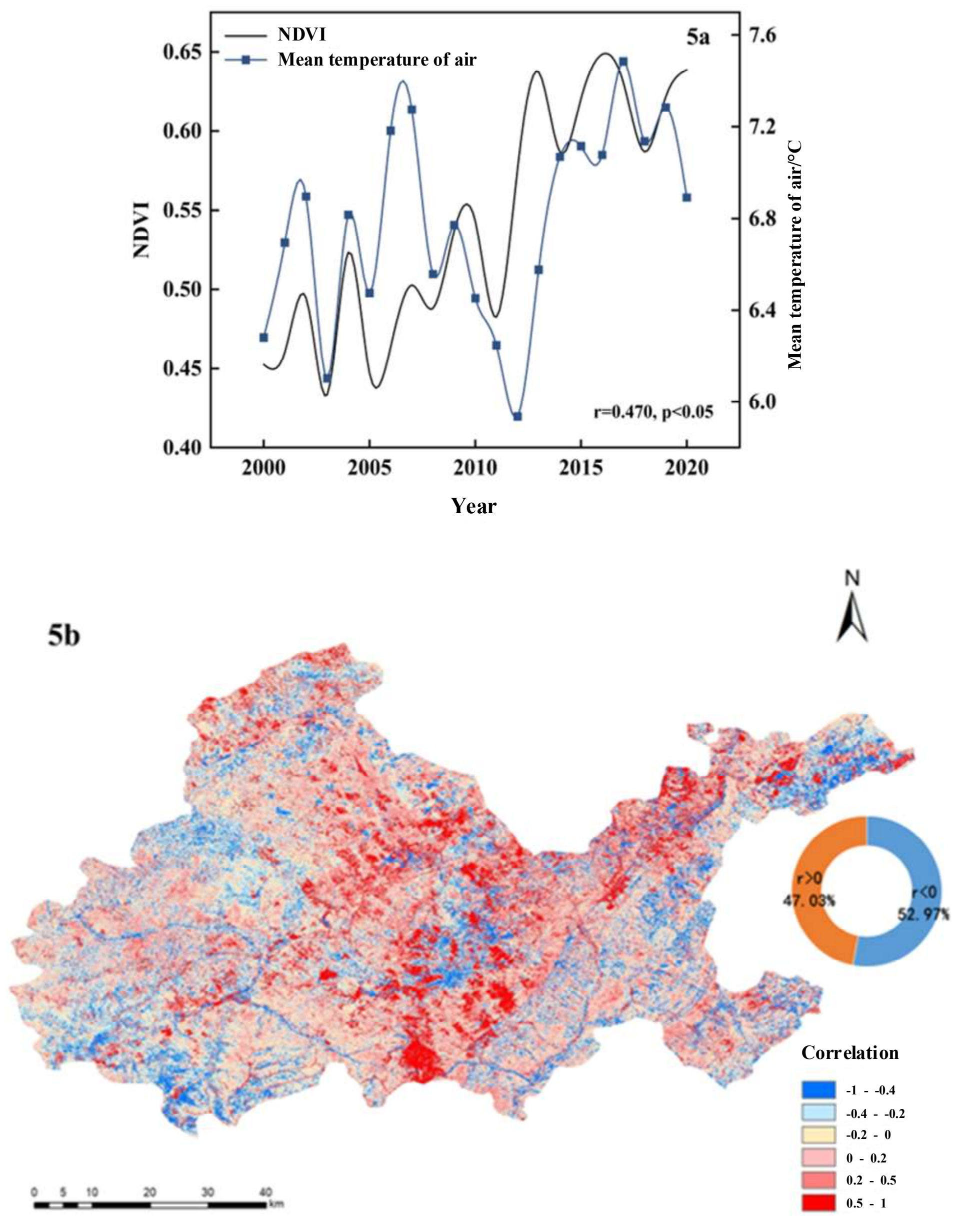
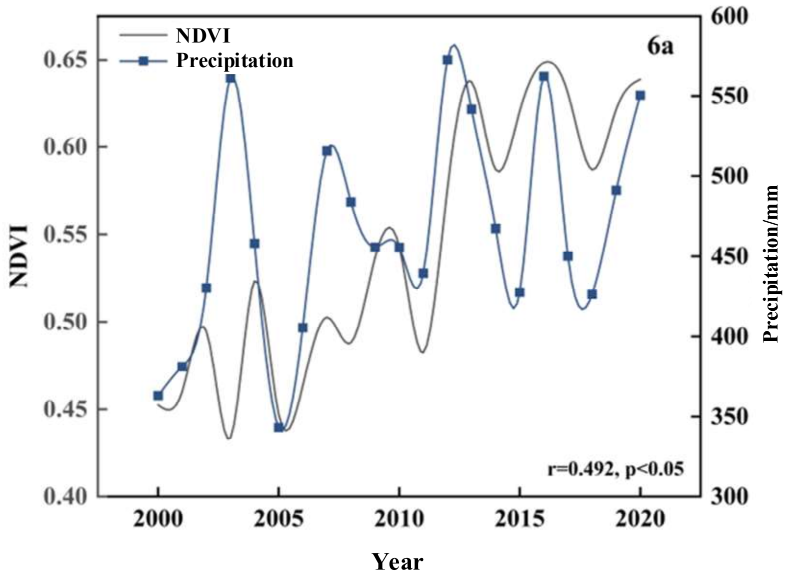


Fig. 5. Correlation between vegetation cover and temperature factors at the headwaters of the Fen River, 2000-2020

4.3.2. Correlation analysis between NDVI and precipitation. As shown in Figure 6a, there was a significant positive correlation between NDVI and precipitation on the time scale $(r = 0.492, P < 0.05)$.With the change of precipitation, the NDVI values also showed peaks and troughs, indicating that the change of precipitation positively affected the change of NDVI. As shown in Figure 6b, on the spatial scale, vegetation cover and precipitation as a whole showed a positive correlation in 83.29% of the area, with the correlation coefficients mainly in the range of 0.5-1 in the northwest and 0.2-0.5 in the east. NDVI was negatively correlated with precipitation over 16.71% of the area in the region, with correlation coefficients of -0.2-0, concentrated in the central part of the study area. Strongly negative correlation areas with correlation coefficients of -1-0.4 are mainly scattered in the central and northeastern parts of the study area.



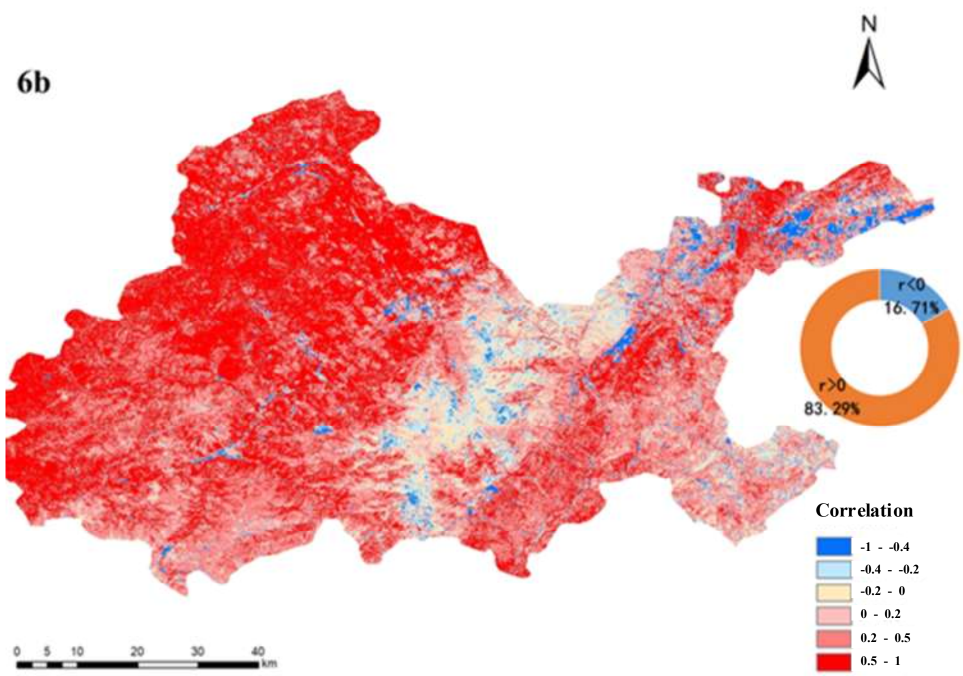
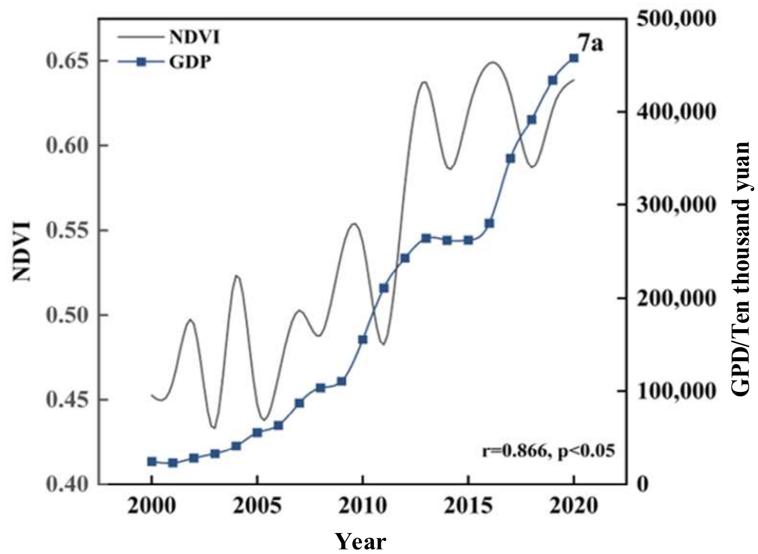


Fig. 6. Correlation between vegetation cover and precipitation factors at the headwaters of the Fen River, 2000-2020.

4.3.3. Correlation analysis between NDVI and GDP. As shown in Figure 7a, on the time scale, GDP shows an increasing trend from year to year, and NDVI values also show a fluctuating increase, and the overall trend of the two is consistent with a significant positive correlation $(r = 0.866, P < 0.05)$,It showed that the increase of GDP promoted the increase of vegetation cover. As shown in Figure 7b, at the spatial scale, the overall positive correlation between NDVI and GDP was observed in the headwaters of the Fen River, with an area of 6,462.54 km², accounting for 94.87% of the area. Among them, 5.13% of the area had a correlation coefficient of 0.5-1, demonstrating a strong positive correlation. The areas with negative correlation between NDVI and GDP were mainly dispersed in the central and northeastern parts. Overall, NDVI and GDP show extremely strong positive and negative correlations, with only a few regions in the center showing weak correlations.



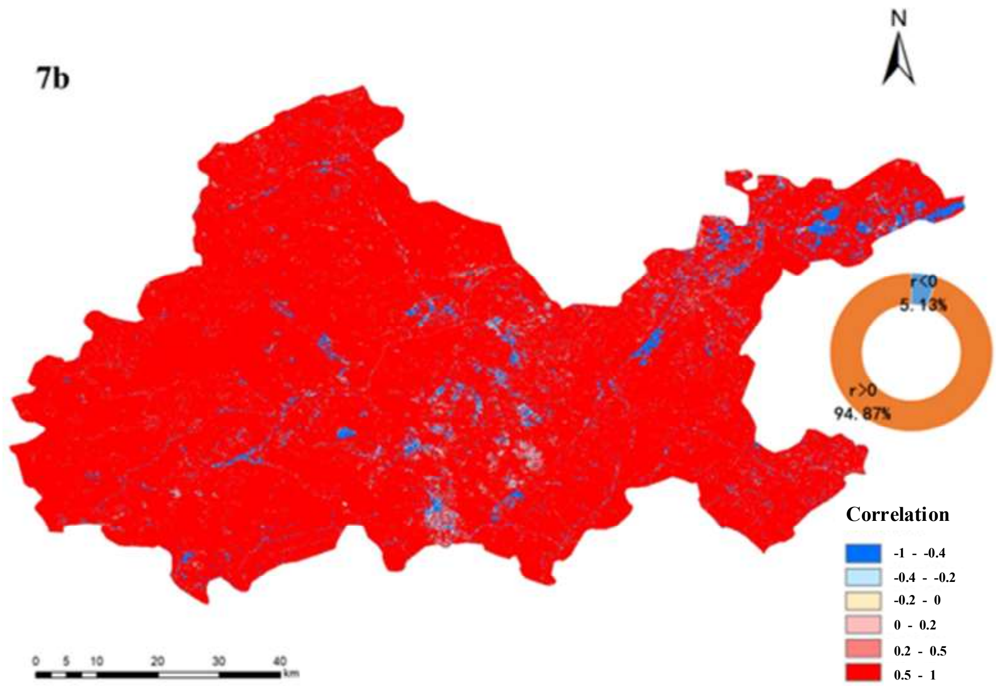
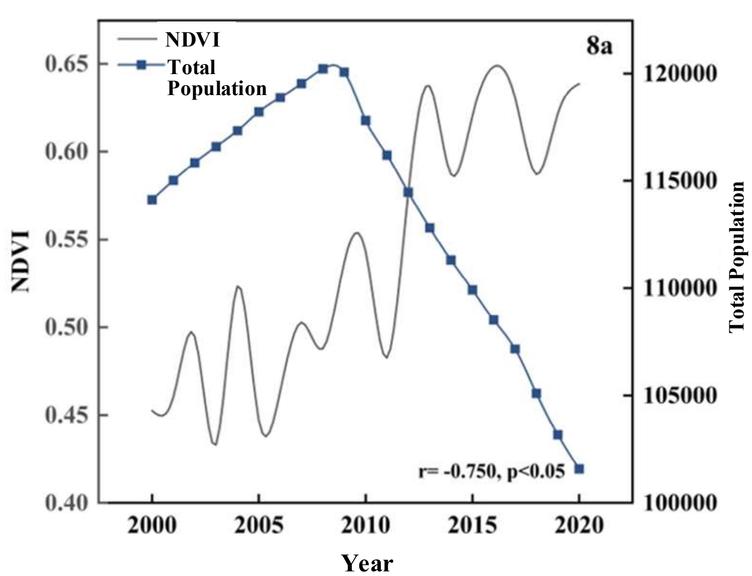


Fig. 7. Correlation between vegetation cover and GDP factors at the headwaters of the Fen River, 2000-2020

4.3.4. Correlation analysis between NDVI and population size. As shown in Figure 8a, NDVI is significantly negatively correlated with precipitation on the time scale $(r = -0.750, P < 0.05)$. As shown in Figure 8b, at the spatial scale, 34% of the area was negatively correlated and was mainly distributed in the northwestern part of the study area, dominated by agricultural land. 66% of the area was positively correlated and was widely distributed within the study area, mainly dominated by forests. Overall, NDVI showed very strong positive and negative correlation with the total population, and was alternately distributed within the study area.



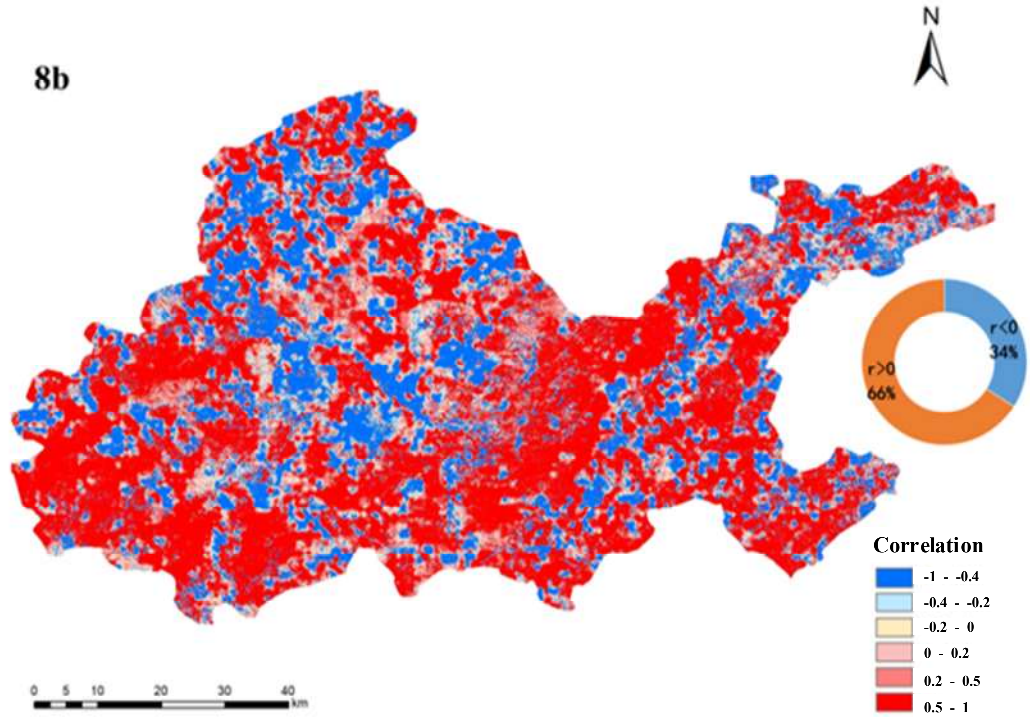


Fig. 8. Correlation between vegetation cover and total population factors at the headwaters of the Fen River, 2000-2020

5. Discussion and conclusions

This paper explored the change characteristics of vegetation cover and its driving factors in the Fen River headwaters area during 2000-2020, and found that the overall NDVI in the Fen River headwaters area showed a fluctuating upward trend between 2000 and 2020, a result that is consistent with the conclusions of Ma Xiaohong and Zhang Huixia et al. on the change of vegetation cover in the Fen River Basin. Among them, the annual average NDVI in the region was above 0.5 after 2008, which increased significantly in Ningwu County, mainly due to the fact that the relevant departments of Shanxi Province introduced a number of policies to support ecological protection, management and restoration in this year, such as one of the five major ecological protection policies in Shanxi Province - "Revision of the Master Plan of Ningwu County", which promoted the Fen River source management and adapted to the needs of tourism development.

The change of vegetation cover in the Fen River basin is caused by a combination of climate change and human activities, in which temperature, precipitation and GDP are positively correlated with NDVI, and the number of population is negatively correlated with NDVI. An appropriate increase in temperature will promote the release of water from plant leaves, accelerate transpiration, and maintain water balance, as well as increase photosynthetic utilization, thus favoring vegetation growth. Precipitation is a key source of moisture for plant growth, and when there is sufficient precipitation, the soil is moist and favorable for plant growth.

The relevance of human activities is stronger than climatic factors. The result that human activities have a contributing effect on the change of vegetation cover in the Fen River headwaters area is consistent with the findings of Zhang Hongwei et al. The main reason is that in 2008, the government arranged corresponding supporting financial funds of more than 160 million yuan to implement the Shanxi government's Fen River Basin Protection, Restoration and Governance

Master Plan, which promoted the improvement of the ecological level.The GDP continued to grow exponentially and significantly after 2010, which is mainly due to the fact that the Fen River source area was mainly dominated by agriculture and coal mining industry from 2000 to 2010, while in the 2011-2020 stage is dominated by eco-agriculture and eco-tourism, which also shows that human beings have been paying attention to the coordinated development of economy and environment. The areas with negative correlation between the number of population and vegetation cover are distributed in the northwestern part of the country, where most of the land use is farmland, which is also a human settlement, and where there are many people and little land, which damages the soil. While the area with positive correlation is widely distributed and dominated by forests, more than 130,000 mu of afforestation patches have been constructed in the upper reaches of the Fen River in 2007, and the increase in the number of population, i.e., the labor force, promotes the construction and development of planted forests, which in turn improves vegetation cover and promotes the sustainable development of the region.

This study also has the following shortcomings: the influence factors of vegetation cover changes were explored through two aspects of climate and human activities, and more influence factors will be selected for comprehensive analysis in the following. Predicting the future vegetation changes while the subsequent study will use the time series prediction model and so on to predict the vegetation cover and keep focusing on the dynamic changes in the region, to provide decision-making suggestions for the ecological protection of the Fen River headwaters area.

To summarize, the vegetation cover of the Fen River headwaters area showed an overall increasing trend from 2000 to 2020, and through the Sen trend analysis and M-K test, the highest percentage of the area with significant increase (94.62%) was obtained, and the vegetation cover condition was restored and improved. The change of vegetation cover in the Fen River headwaters area is the result of the combined effect of human activities and climate change, but the main driving factor is human activities. Among them, NDVI was positively correlated with precipitation as a whole, and negatively correlated in local areas; NDVI was insignificantly negatively correlated with air temperature as a whole; with the increase of GDP, the NDVI value gradually increased, and both of them were significantly positively correlated. These results help to reveal the response of vegetation changes to climate and human activities in the headwaters of the Fen River, and provide assistance for vegetation restoration and improvement.

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