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SPATIO-TEMPORAL VARIATION OF VEGETATION COVERAGE AND ITS RESPONSE TO CLIMATIC FACTORS FROM 2001 TO 2015: A CASE STUDY IN ANHUI, CHINA

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Abstract

As a robust indicator of terrestrial vegetation productivity, Normalized Difference Vegetation Index (NDVI) is strongly driven by precipitation and temperature among climatic factors. Based on the Moderate Resolution Imaging Spectroradiometer (MODIS) 13A1 remote sensing data, meteorological data during 2001-2015 and land use data in 2005 from Anhui Province, temporal and spatial characteristics of vegetation cover and its response to climate factors in Anhui Province were analyzed by ArcGIS correlation technology, trend analysis method and correlation analysis method. Between 2001 and 2015, the vegetation NDVI in Anhui Province showed a downward trend and the degradation rate was faster than the growth rate with a wider range. The significant decrease areas of vegetation NDVI were mainly distributed in coastal areas, Huaibei plain areas, southern Anhui mountainous areas and Dabie mountainous areas. From 2001 to 2015, the annual change of vegetation NDVI in Anhui Province was bimodal with the highest peak in August and the second highest peak in April. In Anhui Province, NDVI was positively correlated with precipitation and temperature (R=0.065; R=0.356), the sensitivity of temperature on vegetation growth is greater than that of precipitation. The correlation degree between NDVI and climate factors in different land types was different in Anhui Province during different growing seasons, however there was no significant difference. In general, temperature was a key climatic factor influencing vegetation growth in the study area.

Keywords: climatic factors, response characteristics, spatiotemporal variation, vegetation coverage

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1. Introduction

Vegetation is an important part of the ecosystem that promotes material circulation and energy conversion, and also plays an essential role in global climate regulation, air pollution improvement, water purification, water and soil conservation, water conservation and so on (Linderholm, 2006; Yin et al., 2016; Zewdie et al., 2016). Vegetation change is one of the important topics of global change (Zhang et al., 2014). Dynamic change of vegetation coverage is related to the stability and security of ecosystem, meanwhile, the type, quantity and quality of vegetation are greatly affected by the changing climate factors. Therefore, it is necessary to detect dynamics of vegetation coverage and its response to climatic factors (Li and Shi, 2000; Liu et al., 2016). The traditional dynamic monitoring of vegetation coverage was based on field investigation, which is time consuming, manpower consuming and cost high. At the present stage, due to the development of science and technology, the dynamic monitoring of vegetation coverage is mainly based on Normalized Difference Vegetation Index (NDVI) data, which is characterized by wide coverage area, low price and good periodicity (Guo et al., 2007). It can better reflect the change of

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vegetation coverage, biomass and ecosystem parameters on a large scale (Dai et al., 2010; Zhang et al., 2015).

NDVI is the best indicator of vegetation growth state and vegetation coverage (Mahmoudi et al., 2021; Viña et al., 2011), and it is often used to indicate the quantitative characteristics of vegetation, such as vegetation coverage (Yang and Piao, 2006), vegetation type and leaf area index (Defries et al., 1995). Since the 1990s, with the comprehensive development of remote sensing technology, it has become a hot topic for many researchers to use NDVI data to explore the change trend of large-scale and multi-dimensional regional and the correlation with climatic factors (Gong et al., 2017; Li et al., 2011). Meanwhile, among many climatic factors, temperature and precipitation are the primary climatic factors affecting growth and coverage of vegetation in terrestrial ecosystems (Palmate et al., 2017).

The objectives of this study are to investigate spatiotemporal dynamics of vegetation coverage and its response to climatic factors in Anhui Province from 2001 to 2015. Our aims are to understand the principally influence factor of the vegetation coverage variations to better provide important scientific basis for reasonably planning vegetation, making full use of land and resources and protecting ecological environment.

2. Material and methods

2.1. Study area

Anhui Province is located between 114°54′-119°27′E and 29°41′- 34°38′N. The province's terrain is very different from north to south, high in the southwest and low in the northeast (Fig. 1). The region can be divided five natural regions: Huaibei plain, Jianghuai hill, the riparian plain along the Yangtze River, Dabie Mountains and Southern Mountains in Anhui Province, respectively. Anhui province is located in the transitional zone of warm temperature and subtropics with the climate characteristics of north and south. Taking the Huaihe River as the boundary, the area north of the Huaihe River lies in the warm temperate semi-humid monsoon climate zone, and the area south of the Huaihe River lies in the subtropical humid monsoon climate zone (Chen and Wu, 2018). The average annual mean temperature in Anhui Province were 14-16℃ with the extremely maximum temperature reaching more than 40℃. The average annual precipitation is around between 600 and 800 mm. Due to the influence of superior geographical location, landform and climate conditions, the region has high vegetation coverage with abundant light, temperature and water resources.

2.2. Data sources and processing

MODIS-derived composite vegetation indices (MOD13A1) NDVI data from 2001 to 2015 with spatial resolution of 500m and temporal resolution of 16 day were obtained from EOS data gateway (https://ladsweb.modaps.eosdis.nasa.gov). The 2001–2015 dataset was converted into Tiff format and re-projection by using the MODIS Reprojection Tool (MRT). Meanwhile, spatial mosaic and resample of MODIS image were completed. Then the monthly NDVI was obtained by using the algorithm of maximum value composite (MVC). Finally, the raster images of monthly NDVI data of Anhui province from 2001 to 2015 were extracted and obtained by mask with the administrative boundary map of Anhui province.

Climate data was downloaded from China meteorological data network (http://data.cma.cn), including monthly average temperature, precipitation and solar radiation during 2001-2015.

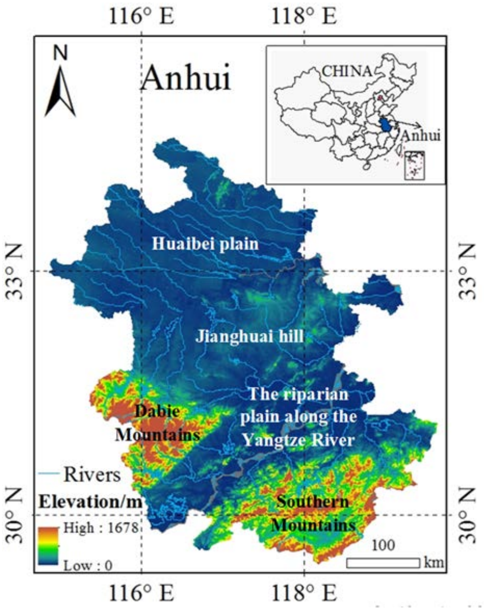

Fig. 1. Location of the study area in China and showing the distribution of water system

These meteorological data collected from 675 meteorological stations with complete records were interpolated by kriging interpolation methods with ArcGIS10.2 software (ESRI, Redlands, CA, USA) to produce raster images, and were extracted with mask by Anhui map to obtain the meteorological data from 2001 to 2015 for further analysis.

The land use data is 1:100,000 land use data set of Anhui Province in 2005 from National Earth System Science Data Sharing Infrastructure (http://www.geodata.cn). Through combination, vector data conversion to raster data and reclassification in ArcGIS software, six primary land types are obtained, which are cultivated land, woodland, grassland, water area, urban and construction land and unutilized land, respectively (Wang et al., 2018).

2.3. Methods

2.3.1. Trend analysis of vegetation coverage

In this paper, linear regression analysis model was used to simulate the spatio-temporal dynamics of vegetation coverage over time (Eq. 1):

$$\theta_{slope} = \frac{n \times \sum_{j=1}^{n} j \times NDVI_j - \sum_{j=1}^{n} j \sum_{j=1}^{n} NDVI_j}{n \times \sum_{j=1}^{n} j^2 - \left(\sum_{j=1}^{n} j\right)^2} \quad (1)$$

where: n represents the number of studied years; $NDVI_j$ means average vegetation coverage of year j; θ_{slope} is the slope of trend change; θ_{slope}>0 means increased trend of vegetation coverage from 2001 to 2015. On the contrary, it shows a decreased trend. According to the range of trend variation, it can be divided into five grades: significant decrease (<0.006), mild decrease ($-0.006< \theta_{slope}<-0.001$), basically unchanged ($-0.001< \theta_{slope}<0.001$), slight increase ($0.001< \theta_{slope}<0.006$), and significant increase (>0.006) (Zhou et al., 2013).

2.3.2. Correlation analysis between vegetation coverage and climate factors

Correlation analysis reveals the degree of correlation between two variables (Chen et al., 2001). Bivariate analysis means that one variable changes, and other variables also change accordingly. This study conducted a bivariate correlation analysis of vegetation coverage and temperature and precipitation in the growing season in Anhui Province from 2001 to 2015, and comprehensively analyzed response of vegetation coverage to climate factors based on the spatial distribution characteristics of precipitation and temperature during this period (Eq. 2):

$$R_{xy} = \frac{\sum_{i=1}^{n}\left[\left(x_i - \bar{x}\right)\left(y_i - \bar{y}\right)\right]}{\sqrt{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2 \sum_{i=1}^{n}\left(y_i - \bar{y}\right)^2}} \quad (2)$$

where: n is the number of studied month during growing season; R_{xy} is the correlation coefficient of variable x and y; x_i is vegetation coverage of ith month; $\bar{x}$ is average vegetation coverage of ith month; y_i is precipitation or temperature of the ith month; $\bar{y}$ is the average precipitation or temperature of ith month.

3. Results and discussion

3.1. Spatial distribution of average annual vegetation coverage

As shown in Fig. 2, the vegetation coverage had a definite and obvious spatial difference in Anhui Province during 2001-2015. For the whole region, the areas with the best vegetation coverage were mainly distributed in the south and west of Anhui Province. The areas where the vegetation coverage was moderate were located in the north of Anhui Province. The areas with the lower vegetation coverage were distributed in the center zones of Anhui Province. Fig. 3 showed that a significance difference of vegetation coverage occurred in six land use types. Among them, vegetation coverage of woodland and grassland was most; vegetation coverage of cultivated land and urban and construction land was more. Compared to the other land use types, the vegetation coverage of water area was the least. It was implied that, spatial distribution of vegetation coverage was close relative with land use types. The possible reason might be that south of Huaihe region was governed by the subtropical humid monsoon climate, where the Dabie Mountains and South Mountains area in Anhui Province were located. The regions were typical woodland and grassland covered areas with high vegetation coverage where had many evergreen broad-leaved forests. In comparison, south of Huaihe River was located in the warm temperate zone half moist monsoon climatic region. The areas where terrain was flat, soil was fertile and water was abundant were mostly distribution zones of temperate deciduous broad-leaved forest and the seasonal strong crop resulting in the higher vegetation coverage. The hilly area was widely distributed in the center of Anhui Province where the vegetation was mainly forest of deciduous broad-leaved, evergreen broad-leaved and some crops. Meanwhile, as the Yangtze River passed through, there were many rivers and lakes. To sum up, these reasons led to the lowest vegetation coverage in the region.

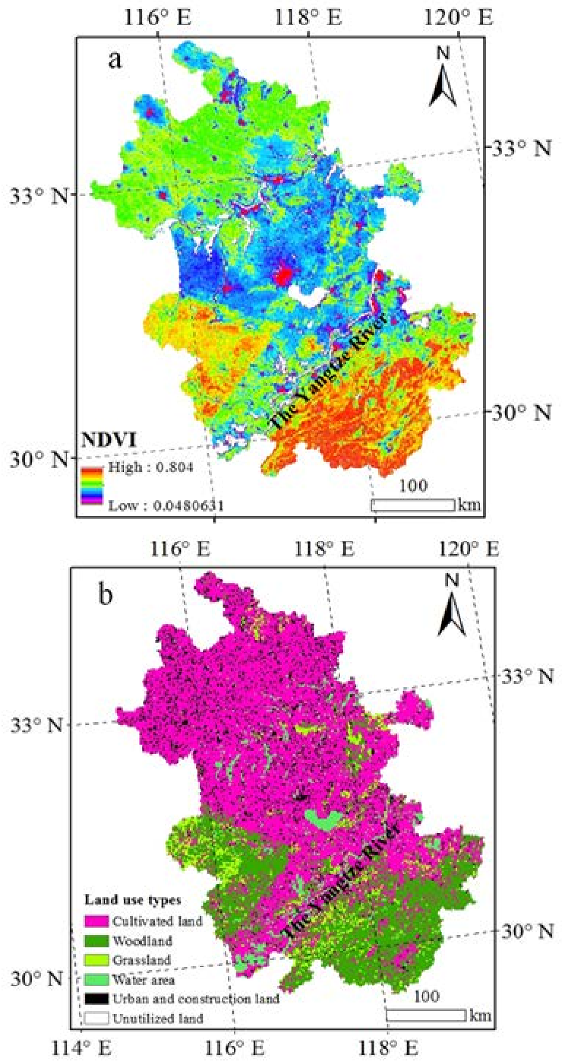

Fig. 2. Spatial distribution of average annual vegetation coverage from 2001 to 2015 (a) and land use types in Anhui Province (b)

3.2. Temporal change of vegetation coverage

3.2.1. Annual variation features of vegetation coverage

According to the statistics of annual NDVI value of vegetation in Anhui Province, annual vegetation coverage showed a fluctuant upward trend at first, and then decreased sharply (Fig. 3). The average annual vegetation coverage was 0.567 during the 15-year period with annual vegetation coverage ranging from 0.500 to 0.638. In the study period, the maximum vegetation coverage reached 0.638 which appeared in 2007; the minimum value was about 0.500 which appeared in 2012. It may be attributed to the combined effect of the precipitation and temperature variability, due to the highest average monthly temperature of 2007 and relative lower average monthly temperature of 2012 (Fig. 9).

It was shown that, in Anhui Province, the trend of average annual vegetation coverage of different land use types was nearly consistent with that of vegetation coverage in growing season during 2001-2015 (Figs. 4-5). It was fluctuating up firstly and then went down sharply and then went up slowly. Except that the maximum of NDVI of unutilized land-type vegetation appeared in 2008 and the minimum value appeared in 2011, the maximum value of average annual NDVI of other land-type vegetation and that of average annual growth season all appeared in 2007 and the minimum value appeared in 2012.

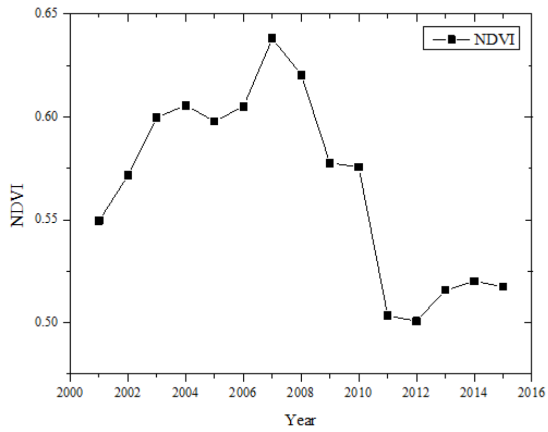

Fig. 3. Trend of average vegetation coverage in Anhui Province during 2001-2015

Before 2007, in Anhui Province, the NDVI values of different land use types had a fluctuated and increased trend, among which the NDVI values of water area land use types increased the most. From 2007 to 2012, the NDVI values of different land use types in Anhui Province showed a significant downward trend, among which NDVI values of water area dropped the most dramatically. After 2012, NDVI values of different land use types in Anhui Province exhibited a slowly rising trend that maximum and minimum value of average annual vegetation coverage could reach 0.208 and 0.053, while that of in growing season was 0.233 and 0.077, respectively. In all land use types, the NDVI values changed minimally in cultivated land, woodland, grassland, urban and construction land, while that of unutilized land-type vegetation changed more relatively more and water area land type vegetation changed most.

From the perspective of the vertical scale, the NDVI values of average annual vegetation and that of growing season vegetation had slight difference in Anhui Province from 2001 to 2015. However, the trend of average annual vegetation was similar with that of growing season. Totally, vegetation coverage was decreasing in Anhui Province. The overall level of average annual vegetation coverage was woodland > grassland > unutilized land > cultivated land > urban and construction land > water area. The overall level of vegetation coverage in the growing season was nearly consistent with that of average annual vegetation. From the overall trend, vegetation coverage was decreasing in Anhui Province.

3.2.2. Vegetation coverage variations on inter-monthly time scale

Fig. 6 presented inter-monthly change of vegetation coverage during 2001-2015. The variation curve of NDVI value in Anhui Province was bimodal, with its fluctuation ranging from 0.416 to 0.769, and the average value of which was 0.572. There were two peak which appeared in April and August, respectively. The highest peak value was in August and the second peak value was in April with their vegetation coverage being 0.769 and 0.634, respectively. According to the growth law of local vegetation, vegetation turned green from February and reached its first growth peak in April, with NDVI value being 0.634. From May to June, summer crops were ripe for harvesting resulting in vegetation coverage gradually declining.

However, due to higher temperature and more precipitation during this period, compared to other months of the year, vegetation had a good growth state and vegetation coverage had a slight decreasing. After June, autumn crops began to be planted and vegetation coverage began to increase again until reaching a one-year high of 0.769 in August. Between September and October, the vegetation coverage went down at a tremendous rate because the autumn crops were ripe and harvested, and the rainy season was over, the precipitation was a little, the light was not strong, the temperature dropped and so on. After November, due to the influence of geographical location, Anhui Province began to enter the winter time, and most of the vegetation and crops basically stopped growing resulting in vegetation coverage was relatively low. In January, it fell to a low trough, and the change range was minimally (Zhang et al., 2011).

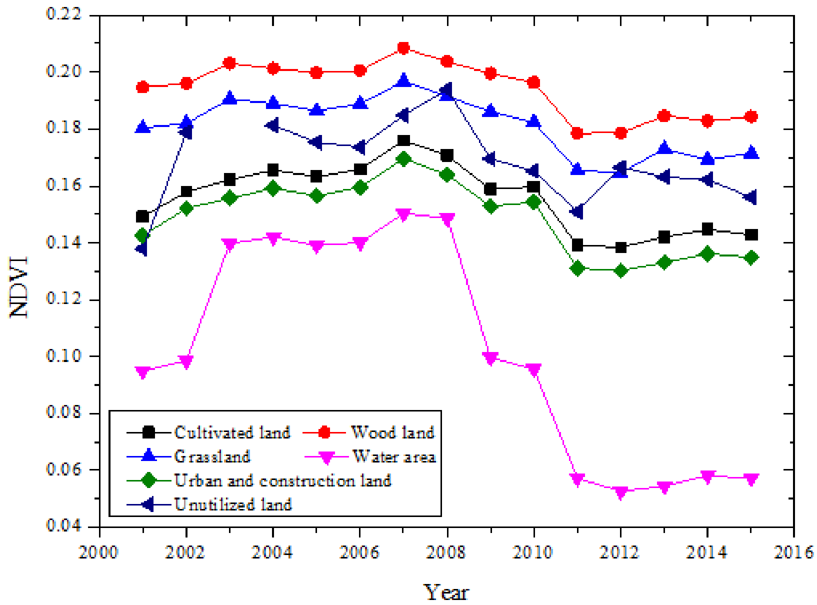

Fig. 4. Trend in annual mean NDVI of different land use types in Anhui Province during 2001-2015

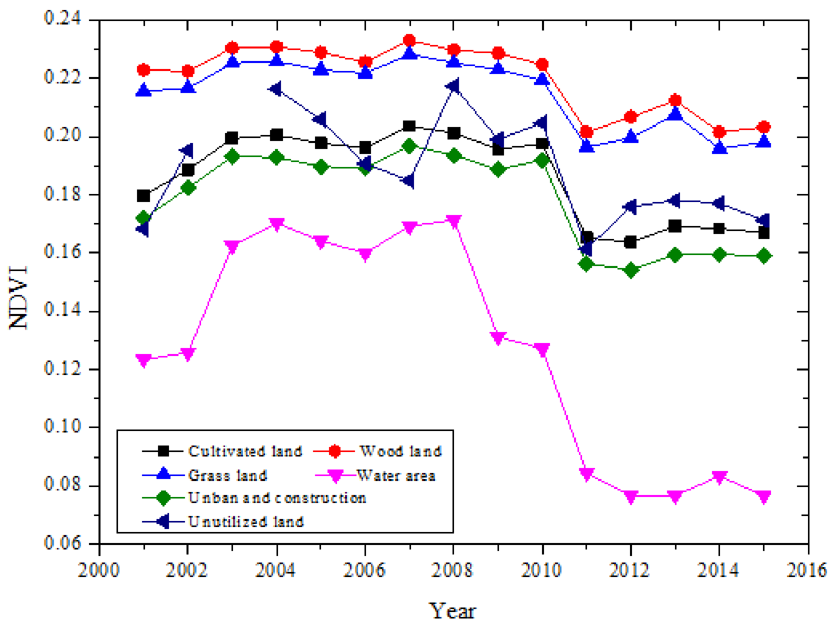

Fig. 5. Trend in annual mean NDVI of different land use types in the growing season in Anhui Province during 2001-2015

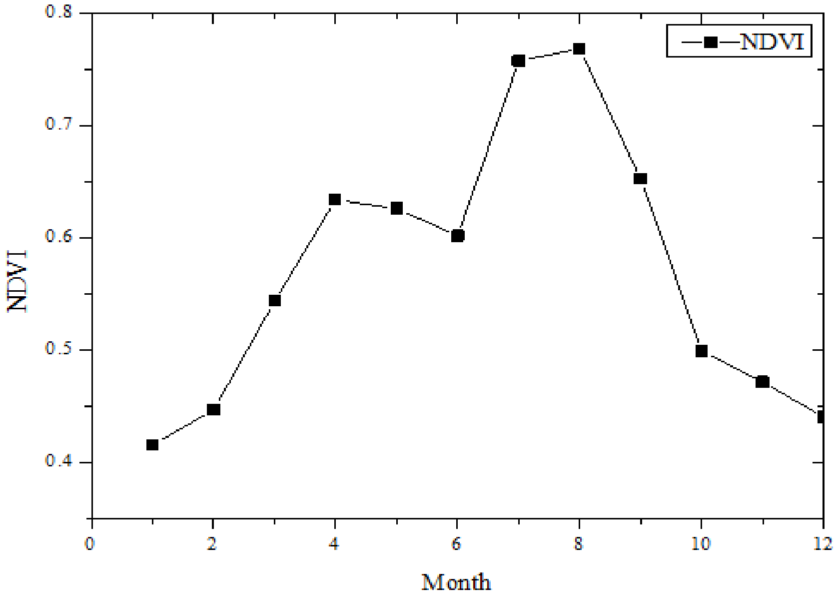

Fig. 6. The monthly changes of NDVI in Anhui Province from 2001 to 2015

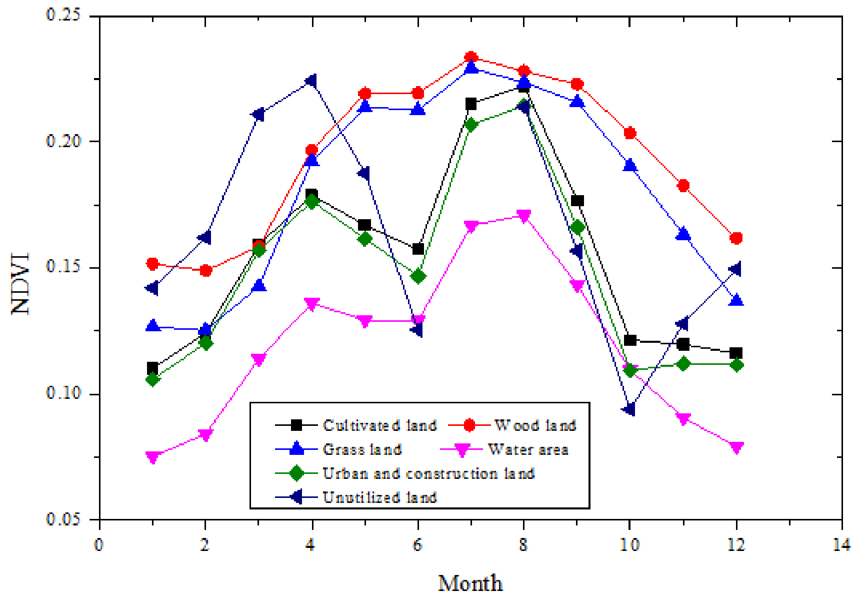

Fig. 7. The monthly changes of NDVI of different land use types in Anhui Province from 2001 to 2015

Average monthly change of vegetation coverage of different land use types were shown in Fig. 7. The monthly change trend of woodland was basically consistent with that of grassland, while they were significantly different from the other four land types in the vegetation index. The reason might be that natural vegetation was covered with woodland and grassland, and the monthly vegetation coverage was greatly affected by natural factors. Specifically, monthly change trend curve of vegetation coverage was unimodal, and the maximum value appeared in July because the combined hydrothermal conditions in Anhui Province were in a relatively good period (He et al., 2010; Wang et al., 2014). In addition, the vegetation covered on the cultivated land, urban and construction land, water area and unutilized land were mainly artificial vegetation, which was affected by human activities more than natural factors. Therefore, the NDVI value changes trend shown a bimodal pattern within the year, and the two peaks appear in April and August, respectively (Feng et al., 2012).

3.3. Analysis of change trend of vegetation coverage from 2001 to 2015

During 2001-2015, the vegetation coverage showed a decreasing trend in the whole region. Table 1 listed the surface area and percentage in each land cover type and each graduation rate. The gradation rate of significance test was shown in Fig. 8. The area where the vegetation coverage had trends of ED and MD accounted for 39.5% and 48.1% of the total area, respectively (Table 1). Meanwhile, the area where the vegetation coverage had trends of MI and EI accounted for 3.9% and 0.3% of the whole area, respectively. Spatially, the areas where the vegetation coverage had a trend of ED were mainly distributed in the central part of the Huaibei plain, the middle and lower Yangtze River plain, the mountainous areas in southern Anhui and the Dabie Mountains during 2001-2015. The areas where the vegetation coverage had a trend of MI and EI were relatively scattered distribution in the whole region accounted for 4.2%. Among them, the area where the vegetation coverage had the trend of EI was little accounted for 0.3% of the total area.

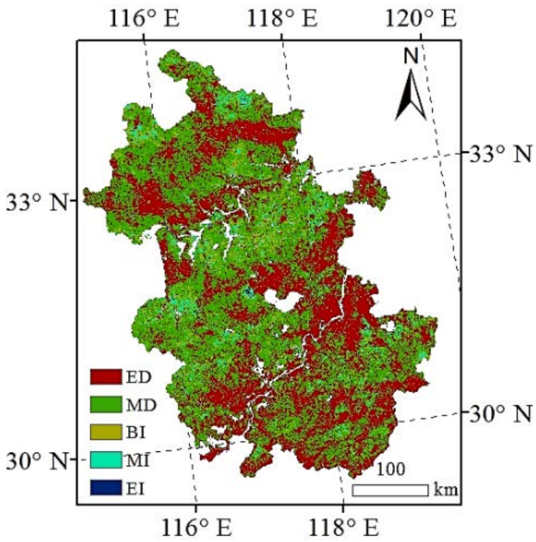

Fig. 8. Spatial distribution of trend of NDVI during 2001-2015

The reasons for the significant decrease of vegetation coverage in the Huaibei plain area and the middle and lower reaches of the Yangtze River might be as follows. Due to its superior natural conditions, these regions were the main grain growing bases in Anhui Province, which were dominated by crop vegetation coverage. However, since 2000, the urbanization of Anhui Province has entered the stage of rapid development (Ye, 2017). As the subsequent social and economic advantages, the urbanization and industrialization of these zones were significantly faster than other parts of the province (Shang et al., 2011). Consequently, the cultivated land showed a trend of continuous reduction and the crop vegetation coverage was reduced (Zhang et al., 2007).

The significant reduction of vegetation coverage in mountainous areas of southern Anhui and Dabie mountains was mainly due to the long-term deforestation, which leads to the substantial reduction of natural forests. Even though artificial forests and secondary forests have increased, the proportion of medium and young forests is larger part among them, so vegetation coverage is also significantly reduced.

The variation degree of vegetation coverage of different land use types was also significantly different. The increased area of vegetation coverage of five land use types, named cultivated land, woodland, grassland, water area and urban and construction land, was 224.25, 102.75, 35.25, 20.5 and 23 km^2, respectively, accounted for 2.32%, 1.06%, 0.37%, 0.22% and 0.24 % of the total area, respectively. Vegetation coverage of five types of land use types in cultivated land, woodland, grassland, water area and urban and construction land decreased respectively to 5016, 1992.25, 475.5, 238.5 and 712.75 km^2, accounted for 52.06%, 20.68%, 4.94%, 2.47% and 7.4% for the whole region, respectively.

During 2001-2015, the degradation degree of five land use types of vegetation was far greater than its growth degree, among which the vegetation coverage of cultivated land decreased the most. Affected by human activities, the area where vegetation coverage significantly reduced was mainly distributed in the areas along the river, the Huaibei plain, the mountainous areas in southern Anhui and the Dabie Mountains.

3.4. Correlation analysis of vegetation coverage and climatic factors

3.4.1. Inter-annual change trend of climate factors

Change of climatic factors affects phenological change of vegetation. In this paper, we primarily chose two factors that were temperature and precipitation, respectively. The change trend of average monthly temperature and average annual precipitation in Anhui Province during 2001-2015 had definite distribution as shown in Fig. 9. Overall, in Anhui Province, the annual change of average temperature showed a decreasing trend, while annual precipitation inter-annual change trend was on the rise from 2001 to 2015.

Table 1. Variations of vegetation coverage in Anhui Province during 2001-2015 (unit: km^2)

Trend index	*Cultivated Land (km^2, %)*	*Woodland (km^2, %)*	*Grassland (km^2, %)*	*Water area (km^2, %)*	*Urban and construction Land (km^2, %)*	*Total (km^2, %)*
ED	2246 23.31	837.25 8.69	185 1.92	170.75 1.77	361.25 3.75	3800.25 39.44
MD	2770 28.75	1155 11.99	290.5 3.02	67.75 0.70	351.5 3.65	4613.75 48.11
BI	467 4.85	200.75 2.08	57.25 0.59	15 0.16	53 0.55	793 8.23
MI	207.5 2.15	100.5 1.04	33.5 0.35	16 0.17	22 0.23	379.5 3.94
EI	16.75 0.17	2.25 0.02	1.75 0.02	4.5 0.05	1 0.01	26.25 0.27

Note: ED represent extremely decrease (<-0.006), MD represent mild decrease (-0.006~-0.001), BI represent basically invariability (-0.001~0.001), MI represent mild increase (0.001~0.006), EI represent extremely increase (>0.006). The area of unutilized land accounted for 0.01% of the total area.

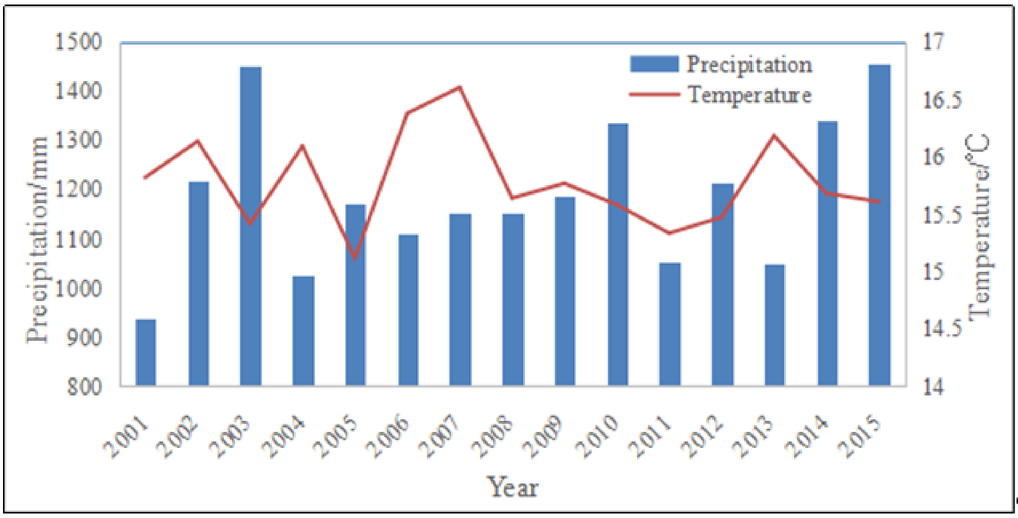

Fig. 9. Annual change trends in average temperature and precipitation in Anhui Province during 2001-2015

During the study period, the range of annual precipitation was between 937.0 mm and 1455 mm which had an increase of 11.517 mm with maximum and minimum appeared in 2015, 2001, respectively. Meanwhile, the range of average monthly temperature was between 15.1ºC and 16.6ºC which had a reduction of 0.0165ºC with maximum and minimum appeared in 2007 and 2005, respectively.

3.4.2. Correlation analysis of vegetation coverage and climatic factors

Vegetation coverage is affected by many climate factors. Due to Anhui Province is located in the transitional zone between warm temperate zone and subtropical zone, it has good hydrothermal conditions which are conducive to vegetation growth. In this paper, there were two climatic factors, precipitation and air temperature, selected to analyze the response of vegetation coverage to regional precipitation and air temperature in Anhui Province during 2001-2015. In general, the correlation of temperature on vegetation growth is greater than that of precipitation with its correlation coefficients was 0.356, 0.065, respectively.

As shown Figs. 10a and b, the response of vegetation coverage to precipitation had definite difference from temperature. In the most regions of Anhui Province, vegetation coverage was positively correlated with precipitation and temperature, while the areas where had positively correlation with precipitation were more than temperature. There was higher relation between vegetation coverage and precipitation in Jianghuai hilly region and northernmost part of Anhui with partial correlation coefficient ranging from 0.5 to 1. A slight positively correlation was observed between vegetation coverage and precipitation in the Huaibei plain area and the middle and lower reaches of the Yangtze River with partial correlation coefficient ranging from 0 to 0.3. In the southern Anhui Mountains, vegetation coverage showed a strong negative correlation with precipitation, and correlation coefficients varied from -0.7 to -0.3.

Spatially, the areas where vegetation coverage had closely relation with temperature were distributed in the hilly area of Jianghuai plain, the middle and lower reaches of the Yangtze River and the mountainous area of southern Anhui with correlation coefficient ranging from 0.1 to 1. Meanwhile, the areas where vegetation coverage had a strong negative correlation with temperature were primarily contributed in Huaibei plain area with correlation coefficient ranging from -0.3 to -1. The reason why existed spatial heterogeneity between vegetation coverage and precipitation and temperature was mainly due to the correlation with topography and vegetation types.

The agricultural areas of Huaibei plain, Jianghuai hilly and Yanjiang plain are all important agricultural production bases in China. When Anhui Province is in the growing season, there is more precipitation which is beneficial to the growth of crops. Although temperature in the whole province is relatively high, the temperature in the mountains in southern Anhui is relative lower due to the influence of the high elevation, where the growth of vegetation will be restricted. When Anhui province is in the growing season, a strong negative correlation was showed between vegetation coverage and temperature in the northern Anhui plain. A possible reason was that, the region was the dry crop area of grain and cotton, where the periods was the harvest season at the end of the growing season with falling NDVI values.

Similarly, the hilly areas in central Anhui are transitional zones for drought and flood crops, the river plain are planted with rice and rape, and the hilly areas in west Anhui and south Anhui are the main tea planting areas. In those regions, the higher temperature was conducive to the growth of vegetation. With the gradual maturity of these crops, these crops were harvested, which resulted in a decreased NDVI value. As a sequence, a negative correlation was showed between vegetation coverage and temperature in those regions.

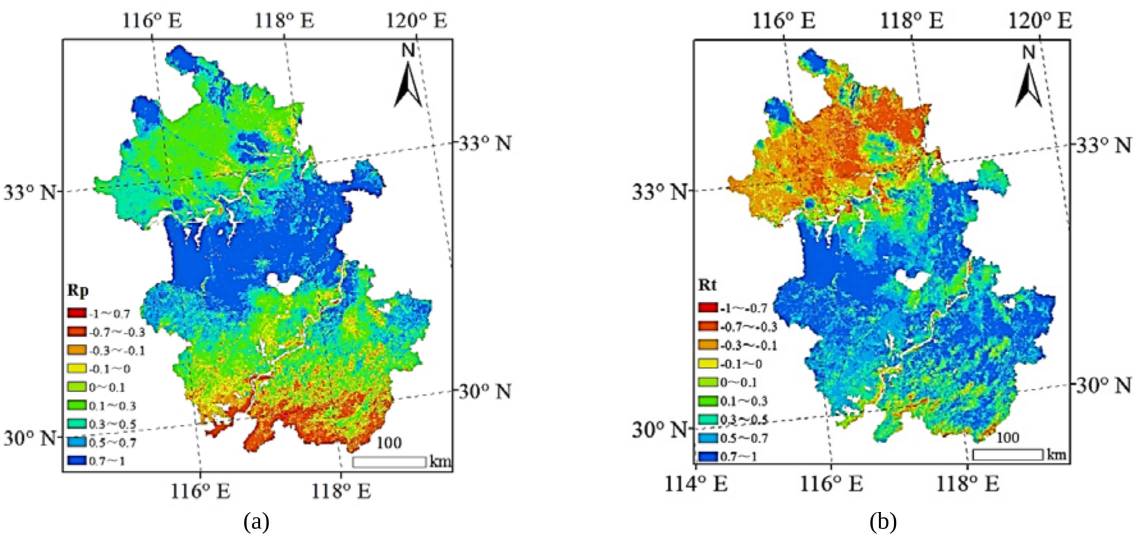

Fig. 10. Correlation relationship between vegetation coverage and climatic factors in the growing season in Anhui Province during 2001-2015: (a) with monthly mean precipitation and (b) with monthly mean temperature

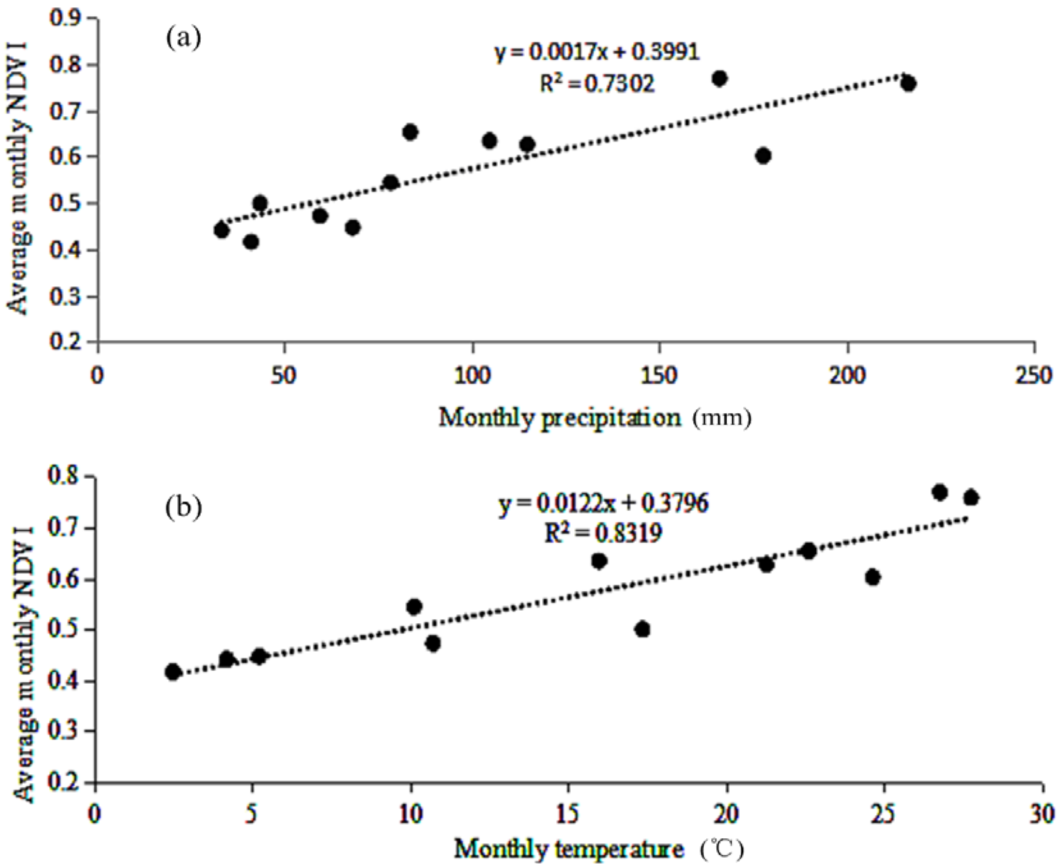

Fig. 11. Relationship between average monthly NDVI and climate factors inAnhui Province during 2001-2015: (a) with monthly precipitation and (b) with monthly temperature)

As shown in Fig. 11, average monthly vegetation coverage was strong positively correlated with monthly precipitation and temperature, under proper precipitation and temperature, vegetation growth with the increase of monthly precipitation and monthly average temperature. In general, higher temperature and more precipitation are beneficial to the growth of vegetation and increase of the vegetation coverage.

3.4.3. Correlation analysis of vegetation coverage of different land use types in the growing season and climate factors

Table 2 showed that correlation degree

between vegetation coverage and climate factors of six land use types was different for 2001-2015. Totally, a stronger correlation between vegetation coverage and average monthly temperature than monthly precipitation.

It was implying that, the effect of temperature on vegetation growth was more significant than that of precipitation in Anhui Province during the study period. In other words, temperature played a leading role in the growth of vegetation, compared to precipitation. Among the six land use types, the correlation between NDVI of grassland and temperature were the largest with correlation coefficient being 0.394. In contrast, there were negative correlation between NDVI of water area and precipitation with its correlation coefficient being -0.038.

In the cultivated land type, correlation coefficient of vegetation coverage and precipitation was 0.092, while that of vegetation coverage and average temperature was 0.386. In woodland land type, correlation coefficient of vegetation coverage with precipitation and temperature were 0.066 and 0.361, respectively. In grassland land type, correlation coefficients of vegetation coverage with precipitation and temperature were 0.0.069 and 0.394, respectively. In the land use type of water area, correlation coefficients of vegetation coverage with precipitation and temperature were -0.038 and 0.232, respectively. In the land types of urban and construction land, the correlation coefficients of vegetation coverage with precipitation and temperature are 0.095 and 0.380, respectively. In the unutilized land type, the correlation coefficients between vegetation coverage and precipitation and temperature were 0.178 and 0.348, respectively.

In addition to the negative correlation between water area type vegetation coverage and precipitation, vegetation coverage of other five land type vegetation Anhui Province was positively correlated with precipitation. Meanwhile, NDVI of these six type land use types had a positive correlation with temperature. And there was minimally difference between vegetation coverage and precipitation. It was shown that, precipitation had little influence on the land type covered by vegetation. In contrast, Temperature had more influence on vegetation coverage than that of precipitation in these land use types.

Theoretically, the warming and humidification of climate is conducive to the growth of vegetation and promotion of vegetation coverage due to global warming. However, The NDVI decreased for the study period in Anhui Province.

The most likely reason was the negative impact of too much human activity on vegetation growth and vegetation coverage.

The spatial and temporal variation of vegetation coverage and their relationship with temperature and precipitation have been studied in many regions of China. Mu et al. (2013) used NDVI data and climate data to analyze the dynamic of vegetation coverage and its correlation with climate factors in Inner Mongolia during 2001-2010. Zhang et al. (2011) used GIMMS NDVI data to analyze correlation on NDVI of different vegetation and climatic factors in Southwest China (Zhang et al., 2011). And at present, many researchers suggested significantly difference in the response of vegetation coverage with climate factors in different time and space scales (Table 3). The reason for such phenomenon might be due to the large difference in local climatic conditions, vegetation types, lagging effect of vegetation growth on climate factors, economic development level, government's policies and so on.

In other words, vegetation growth is affected not only by seasonal climatic factors, but also by pre-season climate (Hu et al., 2011; Xiao et al., 2016). In order to further understand the response mechanism of vegetation coverage to climate change, they conducted seasonal analysis in the studied region. Totally, our results also showed spatiotemporal change trend of vegetation coverage and their relationship with temperature and precipitation. However, our research lacked a discussion of lagging effect of seasonal vegetation coverage to climate change.

Table 2. Correlation between NDVI of different land use types and climate factors in Anhui Province during 2001-2015

NDVI value of different land use types	*Precipitation*	*Temperature*
Cultivated land	0.092	0.386
Woodland	0.066	0.361
Grassland	0.069	0.394
Water area	-0.038	0.232
Urban and construction land	0.095	0.38
Unutilized land	0.178	0.348

Table 3. Comparisons of the correlation between NDVI and climatic factors across China
(Dai et al., 2018; Feng et al., 2012; Gu and Gong, 2018; Zhang et al., 2018; Zhou et al., 2013)

Sources	*Study Period*	*Study area*	*Rp*	*Rt*
Zhou et al. (2013)	1999-2007	Hei River	0.922	0.942
Dai et al. (2018)	2000-2015	Qinghai Province	0.61	0.62
Gu and Gong (2018)	2001-2015	North China Plain	0.18	-0.031
Zhang et al. (2018)	2000-2015	Hulun Buir Sandy Grassland	0.714	-0.221
Feng et al. (2012)	2000-2009	Anhui Province	0.248	0.3277
This study	2001-2015	Anhui Province	0.065	0.356

Variations of vegetation coverage is affected not only by climatic factors, but also by human activities (Wang et al., 2017). Nevertheless, human activities have double effects on vegetation cover (Fang et al., 2017). On the one hand, our government initiated many programs to protect fragile environment (Li et al., 2016; Yang et al., 2014; Yin and Yin, 2010) and maintaining ecological security (Jiang et al., 2006). Over the past few decades, such as returning farmland to forest and grassland, closing hillsides to facilitate, constructing the Yangtze river shelterbelt system, protecting natural forests and so on (Li et al., 2006; Pei et al., 2008). These measures were beneficial to the increase of vegetation coverage in the region. On the other hand, with the development of economy and society in Anhui Province, area of city increased from 915 km^2 in 2000 to 1926 km^2 in 2015 and area of cultivated land increased from 4229.55 km^2 in 2000 to 58766.38 km^2 in 2015 (Anhui province Statistical Yearbook). The increasing of lands area was primary reason for degradation of vegetation coverage in the process. In addition, the decrease of natural forests, the increase of artificial forests and medium and young forests also played an important role in decreasing of vegetation coverage.

Therefore, it is necessary to further analyze the influence of climate factors on the variations of vegetation coverage combined with seasonal aspect. And quantifying assesses the impact of human activities on change of vegetation coverage should not be ignored (Fang et al., 2017).

4. Conclusions

By analyzing the NDVI value based on MOD13A1 remote sensing data and climate data from 2001 to 2015, we could explore spatiotemporal dynamics of vegetation coverage and its response to climatic factors in Anhui Province. The primary findings could be concluded as follows.

During the 15-year period, vegetation coverage decreased in Anhui Province. The area where vegetation coverage had greatly decreased were mainly distributed in the central part of the Huaibei plain, the middle and lower Yangtze river plain, the mountainous areas in southern Anhui and the Dabie mountains. At the same time, the type of land with the greatest loss of vegetation cover was cultivated land, followed by woodland. It might be due to the development of urbanization. In the variation of NDVI within the year, there were two peaks in a year, the peak value in August and the second peak value in April because of climatic conditions.

Totally, vegetation coverage was decreasing in Anhui Province. The overall level of average annual vegetation coverage was woodland > grassland > unutilized land > cultivated land > urban and construction land > water area. The overall level of vegetation coverage in the growing season was nearly consistent with that of average annual vegetation. From the overall trend, vegetation coverage was decreasing in Anhui Province. During 2001-2015, the degradation degree of five land use types of vegetation was far greater than its growth degree, among which the most obvious decline was observed in the vegetation coverage of cultivated land. A stronger correlation between vegetation coverage and average monthly temperature than monthly precipitation. It was implying that, the effect of temperature on vegetation growth was more significant than that of precipitation in Anhui Province during the study period.

In most of study region, vegetation coverage was positively correlated with precipitation and temperature, while the areas where had positively correlation with precipitation were more than temperature. On the whole, the correlation between NDVI and temperature in Anhui Province is stronger than that between vegetation coverage and precipitation (Rp, 0.065; Rt, 0.356). Although the vegetation coverage in Anhui Province shows a decreasing trend now, with the increasing awareness of environmental protection and the implementation of government's environmental protection projects, the vegetation coverage in Anhui Province is expected to increase in the near future.

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