Study on spatial-temporal dynamic change of vegetation coverage and its influencing factors in blue economic zone of Shandong Peninsula: taking Qingdao as a case

Fangyu Liu, Xingyuan Xiao*, Luxiang Shang and Xiao Huang
Geomatics College, Shandong University of Science and Technology, Qingdao China

*Corresponding author: xingyuanxiao@sdust.edu.cn

Abstract. The vegetation cover of Qingdao city has changed significantly under the dual influence of climate change and the implementation of blue ocean strategy. The spatial-temporal dynamic change characteristics of vegetation coverage in Qingdao were quantitatively studied on the county-level scale and the man-made and natural driving factors were analysed spatial-statistically by using the dichotomy pixel model based on Landsat remote sensing data of Qingdao in 2000, 2008 and 2016. The results suggest that: (1) the overall evolution of vegetation coverage declines from 65% to 63% from 2000 to 2016. (2) Significant spatial difference of vegetation coverage is found at the county scale. The vegetation coverage of Jiao Nan increased, while that of Jimo decreased from 2000 to 2008. Jiao Nan had the highest vegetation coverage between 2008 and 2016, while Jiao Nan, western Jimo and Pignut all increased significantly. The vegetation coverage of eastern coastal urban area dropped dramatically to reach the lowest record in each phase of the three-year data. (3) The influence of climate factors on vegetation coverage is not significant, while the human activity is the leading factor causing the evolution of vegetation coverage in Qingdao where urbanization is negatively correlated with the change in vegetation coverage. Furthermore, population migration also has an impact on the vegetation coverage.

Keywords: Qingdao City, fractional vegetation cover, urbanization.

1. Introduction
Vegetation is a natural link among soil, atmosphere and water, and plays an important role in land surface energy exchange, hydrological cycle and climate regulation [1]. Fractional Vegetation Cover (FVC) refers to the percentage of the total area of the statistical area of vegetation (including leaves, stems and branches) projected vertically on the ground [2,3], is an index derived from the normalized Difference vegetation index (NDVI) to reflect the vegetation coverage information. It solves the deficiency that NDVI is easy to saturate vegetation with high coverage but difficult to distinguish vegetation with low coverage to some extent [4, 5]. As the most important index to measure the surface vegetation coverage, vegetation coverage directly reflects the regional ecological environment [6–10], and vegetation coverage affected by climate change and human activities [11–16].

At present, most relevant studies in China focus on the spatial-temporal dynamic change characteristics of vegetation coverage in inland areas and the analysis of its relationship with climate...
factors, and significant results have been achieved: Mu Shaojie et al. analyzed the response of fractional vegetation cover to climate change based on the rainfall and temperature data of Inner Mongolia from 2001 to 2010 [12]; Liu Lvliu et al. studied the sensitivity of NDVI to climatic factors in the Yellow River basin [17]; Fang Li et al. studied the impact of climate change on vegetation growth in the Heilongjiang river basin from 2000 to 2014 [18]. In recent years, the impact of human activities on the ecological environment has been gradually expanding, and the relationship between human activities such as urbanization and vegetation cover has also become the focus of scholars. Xiao Xiao et al. qualitatively analyzed the relationship between vegetation cover change and urbanization level in Liaoning Province [19]; Deng Chenhui et al. explored the dual response mechanism of vegetation coverage to climate change and human activities in Qinling Region from 2000 to 2015 [20]; Li Shiji et al. quantitatively evaluated the impact of rural labor migration on regional vegetation cover in Inner Mongolia from 2000 to 2010 on the county-level scale [21]. Although the above researches have achieved certain results, the relationship between urbanization factors and vegetation cover change in coastal areas remain to be clarified.

Qingdao is the leading city of the Shandong Peninsula blue economic zone with high rate of net migration, especially since the implementation of Blue Ocean Strategy in Shandong Province in 2012, the population of Qingdao has been increasing constantly, and the intensification of human activities has changed the land use mode, which has caused a certain impact on the vegetation coverage in the region. All these have aroused people's attention to the regional ecological environment. On the basis of previous studies, this paper discusses the influence of climate factors and urbanization factors caused by human activities on the vegetation cover changes in Qingdao. Combining spatial and statistical data, the various influencing factors are analyzed separately and then comprehensively analyzed, in order to clarify the degree of influence of various factors, so as to provide reference for the development of Qingdao’s blue ocean economy and how to scientifically guide urban construction and land use, and provide a basis for regional ecological protection.

2. Overview of the Research Area
Qingdao is located in the southeast of Shandong Peninsula (119°30'-121°00' E, 35°35'-37°09' N), bordering the Yellow Sea in the southeast, bordering Yantai city in the northeast, Weifang City in the west, and Rizhao City in the southwest, with a total area of 11,282 square kilometers.

![Figure 1. The DEM map of Qingdao](image-url)
Qingdao is a typical peninsula city, with the terrain high in the east and low in the west, low in the middle and slightly raised in the north and south (Fig. 1). The climate of Qingdao is temperate monsoon climate, but also there is maritime climate characteristics with abundant rainfall and appropriate temperature. In 2008, the Sailing competition of Beijing Olympic Games was held in Qingdao. In 2011, Qingdao Jiaozhou Bay Bridge and Jiaozhou Bay Tunnel were opened to traffic; in 2016, Qingdao was named "the most livable city in China" and "the happiest City in China". In 2012, Qingdao city carried out administrative division adjustment. For the convenience of statistical analysis, the old administrative divisions are still used in this paper. The following analysis will be carried out from urban areas and 5 county-level cities.

3. Data and Method

3.1. Data sources and processing

3.1.1. Data sources. The data used in this paper mainly include remote sensing data and statistical data. Remote sensing data are derived from the website of geospatial data cloud. Landsat TM remote sensing image data and Landsat OLI remote sensing image data from June to July in the summer of 2000, 2008 and 2016 were selected with a spatial resolution of 30m.

The statistical data are obtained from Qingdao Statistical Yearbook of Qingdao Municipal Bureau of Statistics, mainly including population indicators, economic indicators and meteorological indicators in 2000, 2008 and 2016. Among them, population index includes total population, rural population, population density, rural labor force, and population mechanical change. Economic indicators include total GDP, per capita GDP, gross product of the primary industry, gross product of the secondary industry and gross product of the tertiary industry. Meteorological indicators include annual average temperature and annual precipitation.

3.1.2. Data processing. Data processing mainly includes remote sensing image preprocessing and raster calculation, and spatial interpolation of meteorological data. Firstly, NDVI in the study area was calculated. Secondly vegetation coverage was estimated and graded based on the dimidiate pixel model, and the area of each grade was counted to obtain the distribution diagram of vegetation coverage in the third phase. Then the spatial distribution diagram of vegetation coverage change was obtained by grid subtraction in Arcgis. Finally spatial interpolation of temperature and precipitation data from 7 stations in Qingdao city was carried out to obtain spatial interpolation images of temperature and precipitation in the third period.

3.2. Research methods

3.2.1. Calculation of FVC. Dimidiate pixel model is a common method to calculate FVC. It is assumed that the NDVI value of each pixel is composed of vegetation and soil, that is, the pixel information is the synthesis of the information contributed by green vegetation and the information contributed by soil, and the formula is obtained as follows [22–23]:

$$FVC = \frac{(NDVI - NDVI_s)}{(NDVI_v - NDVI_s)}$$  \hspace{1cm} (1)

Where NDVI is the normalized difference vegetation index value of pixel; NDVI_s is the normalized difference vegetation index value of pure soil pixel, which is close to 0 in theory. NDVI_v is the normalized difference vegetation index value of pure vegetation pixel, which is theoretically close to 1. In this study, 0.5% confidence was used to intercept the upper and lower thresholds of NDVI, and the upper and lower limits represented NDVI_s and NDVI_v, respectively. Finally, the vegetation coverage of each year in the study area was obtained through formula (1).
3.2.2. Classification of vegetation cover. Referring to the Soil Erosion Classification and Classification Standards issued by the Ministry of Water Resources, PRC in 2008, in combination with the Ecological Environment and Protection Regulations of Qingdao, based on the vegetation cover and land use of Qingdao, and combined with remote sensing estimation results, this paper divides the vegetation cover of Qingdao into five grades: 0-10% (low-VC), 10%-30% (slightly low-VC), 30%-60% (medium-VC), 60%-80% (slightly high-VC), 80%-100% (high-VC). Then the hierarchical mapping is carried out.

3.2.3. Principal component analysis. Principal component analysis (PCA) is a mathematical transformation method of dimensionality reduction processing technology, which can convert multiple original variables into a few new variables, and these new variables can retain as much information as possible reflected by many original variables [24]. In this paper, 12 indicators are selected for principal component analysis, and impact factors are classified and explained.

4. Results Analysis

4.1. Analysis of spatial-temporal change of vegetation coverage

According to the classification standard of Vegetation coverage in Qingdao, the temporal and spatial distribution of vegetation coverage (Figure 2), the spatial distribution of vegetation coverage change (Figure 3-4) and the statistical table of vegetation coverage classification (Table 1) of Qingdao in the three periods were obtained. As can be seen from the chart, the characteristics of vegetation cover change in Qingdao are as follows:

(1) In different periods, there was little difference in the dominant vegetation coverage levels in Qingdao, which were mainly at medium, slightly high and high levels, and the overall vegetation coverage was good. In 2000 and 2008, the slightly high-VC was 37.76% and 38.81%, respectively. The slightly low-VC increased slightly, increasing the area by about 174.67 square kilometers. By 2016, it will be dominated by high-VC, accounting for more than 35%, with an area of about 3,864.02 square kilometers. From 2000 to 2016, the overall average vegetation coverage in Qingdao has been in a continuous downward trend, from 65% to 63%. Among them, the proportion of slightly high-VC decreased most significantly, about 12%, and the decreased area was 1310.76 square kilometers.
Table 1. Classification and statistics of vegetation coverage in Qingdao.

| Vegetation coverage levels | Vegetation coverage interval (%) | 2000       | 2008       | 2016       |
|----------------------------|---------------------------------|------------|------------|------------|
|                            | Area (km²)                      | Proportion (%) | Area (km²) | Proportion (%) | Area (km²) | Proportion (%) |
| Low-VC                    | 0—10                            | 353.46      | 3.22       | 339.12      | 3.10       | 540.45       | 4.93       |
| Slightly low-VC           | 10—30                           | 641.80      | 5.86       | 816.47      | 7.45       | 1128.02      | 10.30      |
| Medium-VC                 | 30—60                           | 2691.26     | 24.56      | 2684.53     | 24.50      | 2598.12      | 23.71      |
| Slightly high-VC          | 60—80                           | 4136.82     | 37.76      | 4143.27     | 37.81      | 2826.06      | 25.79      |
| High-VC                   | 80—100                          | 3133.33     | 28.60      | 2973.28     | 27.14      | 3864.02      | 35.27      |

(2) From 2000 to 2008, the vegetation coverage in the southwest of Qingdao increased significantly, and the overall area increased significantly to about 1,465.65 square kilometers. The regions with significantly and extremely significantly decrease were mainly distributed in the central part of Qingdao city. From 2008 to 2016, the vegetation coverage of the eastern coastal zone decreased significantly, and the overall area decreased significantly was about 215.63 square kilometers. The significantly increase area was mainly in the Midwest and northwest of Qingdao. In the two periods, the basic stable FVC area accounted for the largest proportion, and the area that decreased extremely significantly was larger than that increased extremely significantly.

Figure 3. Spatial distribution map of vegetation coverage change in Qingdao.
4.2. Spatial-temporal analysis of vegetation coverage based on county-level scale

On the whole, from 2000 to 2016, the average vegetation coverage in Qingdao showed a downward trend, but the changes on the county-level scale showed great differences. It can be seen from the analysis in Figure 2 that the vegetation coverage on the county unit has the following characteristics:

The average coverage of Jiaonan was higher and had an upward trend, and the vegetation coverage changed from middle and high level to high level. The vegetation coverage in Laixi and Jimo is relatively good, but the vegetation coverage level presents an obvious downward trend. The proportion of high vegetation coverage in the region is reduced, and the average vegetation coverage is reduced by more than 10%. The vegetation coverage in Pingdu and Jiaozhou decreased first and then increased, and the high level coverage area in the region also experienced a process of decreasing first and then increasing. Urban areas had the lowest VC levels and continued to decline, especially from 2008 to 2016. On the one hand, the expansion of urban construction land takes up the green space; on the other hand, the urban area has the least amount of cultivated land, which makes the urban area has poor vegetation coverage.

4.3. Analysis of factors affecting vegetation coverage in Qingdao

In the process of growth, surface vegetation is affected by various climatic factors and human activities, among which temperature and precipitation are the most direct and important ones [17]. In this paper, the influence factors of vegetation cover will be analyzed from the factors of air temperature and precipitation, and finally the comprehensive analysis of climatic factors and human factors will be carried out.

4.3.1. The influence of climatic factors. Based on the data from 7 meteorological stations in Qingdao city, spatial interpolation of temperature and precipitation data in the third phase was carried out, and the interpolation images of temperature and precipitation in the third phase were obtained.

As shown in Fig.5, the distribution locations of the high and low temperature zones in the third phase are almost unchanged. Among them, the low value area is located in the northeast of Qingdao (Laixi), while the coastal urban areas are affected by the warm and humid airflow from the ocean, and the high temperature values are divided here. On the whole, the temperature is low in the north and high in the southeast, and the temperature is relatively stable without any abnormal phenomenon.
As shown in Figure 6, the spatial distribution of rainfall in the third period was almost the same. The high-value areas were distributed in the southeast of Qingdao, while the low-value areas were distributed in the north of Qingdao, with the least rainfall in the northeast. This is similar to the spatial distribution of air temperature, which is generally high in the south and low in the north. In 2016, precipitation in all districts generally dropped, and high-value areas moved to the eastern part of Qingdao, especially Jimo.

Firstly, through the comparative analysis of Figure 2 and Figure 5 and Figure 6, it is found that the vegetation coverage in Qingdao does not show the spatial distribution consistent with the temperature and precipitation and the obvious difference between the north and the south, and the situation is more complicated and changeable. Then correlation analysis was made on the air temperature and precipitation data and average vegetation coverage of each county region to obtain the correlation number table (Table 2). The results showed that the correlation coefficients between air temperature and
FVC and between precipitation and FVC were relatively small, indicating that although air temperature and precipitation had some influence on FVC change, but it was not significant.

**Table 2.** Correlation coefficient between vegetation coverage and precipitation and temperature in Qingdao.

|                        | FVC   |
|------------------------|-------|
| Average annual temperature | -0.358 |
| Annual precipitation    | -0.343 |

4.3.2. The combination influence of human and natural factors. The change of vegetation cover is influenced by natural factors and human factors. In this paper, the annual average temperature (X1), the annual precipitation (X2), total population (X3), rural population (X4), population density (X5), the rural labor force (X6), total GDP (X7), per capita GDP (by 8), the gross product of the primary industry (X9), the gross product of the secondary industry (X10), the gross product of the tertiary industry (X11), mechanical change of population (X12), a total of 12 impact indicators are selected and principal component analysis is carried out by SPSS software to calculate the correlation matrix and its characteristic values among each indicator, as well as its contribution rate and cumulative contribution rate.

It is found that there is a certain correlation between the indicators through the correlation analysis, which is a prerequisite for principal component analysis (Table 3).

Four principal components were extracted from the 12 components by calculation, and the cumulative contribution rate of the first four principal components reached more than 90%. It can be considered that these four principal components can reflect the main information of the original variable (Table 4).

**Table 3.** Correlation matrix of indexes.

|     | X1   | X2   | X3   | X4   | X5   | X6   | X7   | X8   | X9   | X10  | X11  | X12  |
|-----|------|------|------|------|------|------|------|------|------|------|------|------|
| X1  | 1    | 0.056| 0.068| 0.042| 0.109| -0.052| -0.099| -0.245| -0.399| -0.089| -0.093| 0.055 |
| X2  | 0.056| 1    | 0.128| -0.329| 0.215| -0.295| 0.394| 0.639| 0.143| 0.424| 0.353| 0.255 |
| X3  | 0.068| 0.128| 1    | 0.118| 0.923| 0.119| 0.8  | 0.428| -0.138| 0.789| 0.81  | 0.315 |
| X4  | 0.042| -0.329| 0.118| 1    | -0.249| 0.985| -0.16| -0.284| 0.646| -0.174| -0.168| -0.078 |
| X5  | 0.109| 0.215| 0.923| -0.249| 1    | -0.237| 0.806| 0.491| -0.404| 0.801| 0.819 | 0.374 |
| X6  | -0.052| -0.295| 0.119| 0.985| -0.237| 1    | -0.111| -0.192| 0.705| -0.123| -0.124| -0.064 |
| X7  | -0.099| 0.394| 0.8  | -0.16| 0.806| -0.111| 1    | 0.825| -0.144| 0.999| 0.998| -0.015 |
| X8  | -0.245| 0.639| 0.428| -0.284| 0.491| -0.192| 0.825| 1    | 0.104| 0.846| 0.793| 0.06  |
| X9  | -0.399| 0.143| -0.138| 0.646| -0.404| 0.705| -0.144| 0.104| 1    | -0.133| -0.191| 0.154 |
| X10 | -0.089| 0.424| 0.789| -0.174| 0.801| -0.123| 0.999| 0.846| -0.133| 1    | 0.994| 0.007 |
| X11 | -0.093| 0.353| 0.81 | -0.168| 0.819| -0.124| 0.998| 0.793| -0.191| 0.994| 1    | -0.043 |
| X12 | 0.055| 0.255| 0.315| -0.078| 0.374| -0.064| -0.015| 0.06  | 0.154| 0.007| -0.043| 1    |
Table 4. Eigenvalues and related contribution rates and the cumulative contribution rates from the PCA method.

| Principal component | Eigenvalue % | Rate of contribution % | Accumulating contribution rate % |
|---------------------|-------------|------------------------|----------------------------------|
| 1                   | 5.422       | 45.183                 | 45.183                           |
| 2                   | 2.549       | 21.238                 | 66.421                           |
| 3                   | 1.590       | 13.251                 | 79.671                           |
| 4                   | 1.290       | 10.752                 | 90.423                           |

Table 5. Rotate principal component load matrix.

| Annual average temperature | F1     | F2     | F3     | F4     |
|---------------------------|--------|--------|--------|--------|
| Annual precipitation      | -0.041 | -0.249 | 0.605  | 0.251  |
| Total population          | 0.485  | -0.104 | -0.558 | 0.409  |
| Rural population          | -0.332 | 0.889  | 0.266  | -0.018 |
| Population density        | 0.883  | -0.031 | 0.384  | 0.172  |
| Rural labor force         | -0.289 | 0.929  | 0.174  | -0.026 |
| Total GDP                 | 0.967  | 0.175  | -0.005 | -0.177 |
| Per capita GDP            | 0.817  | 0.114  | -0.482 | -0.037 |
| Gross product of the primary industry | -0.259 | 0.788  | -0.484 | 0.224  |
| Gross product of the secondary industry | 0.971 | 0.166  | -0.029 | -0.149 |
| Gross product of the tertiary industry | 0.964 | 0.153  | 0.384  | 0.172  |
| Mechanical change of population | 0.160 | 0.026  | 0.174  | -0.026 |

The six highest absolute values in the first principal component are total population, population density, total GDP, per capita GDP, gross product of the secondary industry, and gross product of the tertiary industry. These six indicators respectively represent the urbanization development process. The three highest absolute values of the second principal component are the number of rural population, rural labor force, and the total value of primary production, which represent the development level of rural areas. In the third principal component, the average annual temperature and annual rainfall are the two indexes with the largest load, which represent the influence of natural factors. In the fourth principal component, mechanical population variation accounted for the largest load, reflecting the influence of population mobility factors (Table 5).

According to the weight of the four principal components, it is found that urbanization factors play a dominant role, followed by rural development level, and the weight of temperature and precipitation factors is equal to that of population mobility factors. This indicates that urbanization is the main factor causing the change of vegetation cover in Qingdao, and climatic factors and population migration are also partly responsible.

5. Conclusions

Combined with spatial data and statistical data, through correlation analysis and principal component analysis, this paper discusses the influence of climatic factors and human factors on the change of vegetation coverage in Qingdao, and draws the following conclusions:

(1) From 2000 to 2016, the overall average vegetation coverage of Qingdao city showed a downward trend, with a decrease of 2%. However, there are differences in county units, and the changes in space are not uniform. From 2000 to 2008, the significant increase area of FVC was mainly distributed in the southwest of Qingdao, while the significant decrease and extremely significant decrease were mainly distributed in the central part of Qingdao. From 2008 to 2016, the decline of vegetation coverage was mainly distributed in the eastern coastal zone, and the significant increase was mainly in the Midwest and northwest of Qingdao, with the most significant decline in urban vegetation coverage.
(2) Correlation analysis and principal component analysis were conducted on the driving factors of vegetation cover change in Qingdao, and it was found that urbanization factors caused by human activities were the leading factors causing vegetation cover change in Qingdao, and they were negatively correlated. The contribution rate of rural development level is only the second, while the influence of temperature and precipitation is obviously weaker than that of human factors. The factors of population migration also had a certain influence on the change of vegetation cover in Qingdao.

References
[1] SUN H Y, WANG C Y, NIU Z, et al. Analysis of the vegetation cover change and the relationship between NDVI and environmental factors by using NOAA time series data [J]. Journal of Remote Sensing, 1998, 2 (3): 204 - 210.
[2] PUREVDORJ T, TATEISHI R, ISHIYAMA T, et al. Relationships between percent vegetation cover and vegetation indices [J]. International Journal of Remote Sensing, 1998, 19 (18): 3519 - 3535.
[3] ZHANG D H, REN Z Y, WANG X F, et al. MODIS Based Analysis of Dynamic Variation of Fractional Vegetation Coverage of the Loess Plateau of Shaanxi and Its Driving Forces [J]. Journal of Ecology and Rural Environment, 2013, 29 (01): 29 - 35.
[4] Wang J, Zhou W Q, Xu K P, et al. Spatiotemporal pattern of vegetation cover and its relationship with urbanization in Beijing-Tianjin-Hebei megaregion from 2000 to 2010 [J]. Acta Ecologica Sinica, 2017, 37 (21): 7019 - 7029.
[5] LIU X F, YANG Y, REN Z Y, et al. Changes of Vegetation Coverage in the Loess Plateau in 2000—2009 [J]. Journal of Desert Research, 2013, 33 (04): 1244-1249.
[6] YANG S T, LIU C M, YANG Z F, et al. Natural eco-environmental evaluation of West Route Area of Inter-basin Water Transfer Project [J]. Acta Geographic Sinica, 2002, 57 (1): 11 - 18.
[7] GAO S H, GUO J P, LIU L, et al. Study on Remote Sensing Interpretation of Vegetation Coverage and Calculation of Water and Soil Conservation Effect Coefficient in Northern Region of China [J]. Journal of Soil and Water Conservation, 2001, 15 (03): 65 - 67+88.
[8] LI M C, LIU D Y, GUO J. Interrannual NDVI variability in different seasons and its response to climatic variable in Tianjin area [J]. Ecology and Environmental Science, 2009, 18 (3): 979 - 983.
[9] CHEN Liding, HUANG Z L, GONG J, et al. The effect of land cover/vegetation on soil water dynamic in the hilly area of the loess plateau, China[J]. Catena, 2006, 70 (2): 0 - 208.
[10] MESSING I, CHEN Liding, HESSEL R. Soil conditions in a small catchment on the Loess Plateau in China [J]. Catena, 2003, 54 (1): 45 - 58.
[11] WANG Q, ZHANG B, DAI S P, et al. Analysis of the vegetation cover change and its relationship with factors in the Three-North Shelter Forest Program [J]. China Environmental Science, 2012, 32 (07): 1302 - 1308.
[12] MU S J, LI J L, CHEN Y Z, et al. Spatial differences of variations of vegetation coverage in Inner Mongolia during 2001-2010 [J]. Acta Geographica Sinica, 2012, 67(09): 1255 - 1268.
[13] SUN Y L, GUO P, YAN X D, et al. Dynamics of vegetation cover and its relationship with climate change and human activities in Inner Mongolia [J]. Journal of Natural Resources, 2010, 25 (3): 407 - 414.
[14] ZHANG Q Y, ZHAO D S, WU S H, et al. Research on vegetation changes and influence factors based on eco-geographical regions of Inner Mongolia [J]. Scientia Geographica Sinica, 2013, 33 (5): 594 - 601.
[15] LI H X, LIU G H, FU B J. Response of vegetation to climate change and human activity based on NDVI in the Three-River Headwaters region [J]. Acta Ecologica Sinica, 2011, 31 (19): 5495 - 5504.
[16] LI X M, REN Z Y, ZHANG C. Spatial-temporal Variations of Vegetation Cover in Chongqing City (1999-2010): Impacts of Climate Factors and Human Activities [J]. Scientia Geographica Sinica, 2013, 33 (11): 1390 - 1394.
[17] LIU L L, XU H M. Change of NDVI of Main Vegetations and Their Relationship with Meteorological Factors in Yellow River Basin [J]. Chinese Journal of Agrometeorology, 2007 (03): 334 - 337.

[18] FANG L, WANG W J, JIANG W G, et al. Spatial-temporal Variations of Vegetation Cover and Its Responses to Climate Change in the Heilongjiang Basin of China from 2000 to 2014 [J]. Scientia Geographica Sinica, 2017, 37 (11): 1745 - 1754.

[19] XIAO X, LI J Z, HAN B, et al. Spatial-temporal characteristics of vegetation coverage and its correlation with urbanization in traditional industrial area of Northeastern China [J]. Ecological Science, 2017, 36 (6): 71 - 77.

[20] DENG C H, BAI H Y, GAO S. Spatial-temporal Variation of the Vegetation Coverage in Qinling Mountains and Its Dual Response to Climate Change and Human Activities [J]. Journal of Natural Resources, 2018, 33 (03): 425 - 438.

[21] LI S J, LI X B, TAN M H. Impacts of rural-urban migration on vegetation cover in ecologically fragile areas: Taking Inner Mongolia as a case [J]. Acta Geographica Sinica, 2015, 70 (10): 1622 - 1631.

[22] G. Gutman, A. Ignatov. The derivation of the green vegetation fraction from NOAA/AVHRR data for use in numerical weather prediction models [J]. International Journal of Remote Sensing, 1998, 19 (8): 1533 - 1543.

[23] ZHAO S Y, GONG Z N, LIU X Y. Correlation analysis between vegetation coverage and climate drought conditions in North China during 2001-2013 [J]. Acta Geographica Sinica, 2015, 70(05):717 - 729.

[24] JI Z M, FANG L, ZHANG J, et al. Operation of principal component analysis in SPSS software and its application in water quality assessment [J]. Environmental Research and Monitoring, 2012, 25 (04): 68 - 73+57.