Effects of China's Ecological Restoration on Economic Development Based on Night-Time Light and NDVI Data

Qiang Li
China University of Geosciences Beijing
Xueyi Shi (shixueyi60@foxmail.com)
China University of Geosciences Beijing
Qing Qing Wu
Zhongnan University of Economics and Law

Research Article

Keywords: Panel data, Inverted U-shaped relationship, Regional coordination, Policy advices

Posted Date: March 10th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-249866/v1

Version of Record: A version of this preprint was published at Environmental Science and Pollution Research on July 28th, 2021. See the published version at https://doi.org/10.1007/s11356-021-15595-7.

Effects of China's ecological restoration on economic development based on Night-Time Light and NDVI data

Qiang Li[a], Xueyi Shi[b], Qingqing Wu[c]

[a] First author: School of Land Science and Technology, China University of Geosciences, Beijing 100083, China.

[b] Corresponding author: School of Land Science and Technology, China University of Geosciences, Beijing 100083, China.

E-mail addresses: shixueyi60@foxmail.com (X. Shi).

[c] Co-author: School of Finance, Zhongnan University of Economics and Law, Wuhan 430073, China.

Abstract: Correctly understanding and handling the relationship between economic development and environment protection is an eternal subject for human society. Based on the panel data of 31 provincial administrative units in China from 2000 to 2013, this study used Normalized Difference Vegetation Index (NDVI) and Night-Time Light data to characterize the effect of ecological restoration practices and economic development respectively, and made an empirical study on the impact of ecological restoration on economic development by means of trend analysis, panel regression model and sub-sample analysis. The results showed that the spatial distribution of Night-Time Light was high in the east and low in the west, and the NDVI in the northwest of the Hu Line was generally low, while the southeast was higher. During the 14 years from 2000 to 2013, the overall vegetation coverage showed an upward trend, and the area with stable night lights accounted for the largest proportion. The influence of NDVI on Night-Time Light presented an inverted U-shaped relationship, which meant that the negative influence of the former on the latter was not an inevitable result but its periodic performance. In the process of economic development, there was an optimal value of vegetation coverage. The increase in vegetation coverage had a negative impact on the economic development of the eastern region, but it was beneficial to the central and western regions. In the future, the government should strengthen protection and restoration of ecosystem, promote high-level protection of environment and high-quality development with efficient environmental and economic policies, and differentiate the relationship between development and ecology in the eastern, central and western regions.

Keywords: Panel data; Inverted U-shaped relationship; Regional coordination; Policy advices

1 Introduction

With the development of "social urbanization and economic industrialization" worldwide, the scale and speed of utilization and transformation of natural resources and environment have increased unprecedentedly, and the material wealth obtained from nature has been increasing continuously, which has promoted the rapid development of social economy in many regions. However, over-emphasis on economic benefits resulted in over-exploitation and utilization of resources, and ignoring the necessity of adopting environmental protection technical measures also led to environmental pollution and destruction (Zeng &Zhuang 2004). This kind of unsustainable development makes the contradiction between man and nature intensify, and the ecological environment is deteriorating (Li et al. 2020a). The influence and restriction of natural environment on the development of human society are becoming more obvious (Mao 1991).

In the development of human society, from the harmony between man and nature in ancient times, to the conquest and confrontation during the modern industrial revolution, then to the conscious adjustment in the contemporary era, the contradiction between environment and economic development has become the most prominent problem in social development since this century, and the most serious areas are mainly concentrated in developing countries with relatively backward economic development (Mao 1991). The cost of economic activity includes not only the consumption of various production factors, but also the destruction of resources and environment caused by external diseconomy. The existence of economic externality makes the feedback mechanism of interaction between economic activities and environment (Zhang &Chi 2001). The destroyed resources and environment have a restrictive effect on social and economic development,

and even endanger the survival of mankind. While a good ecology contains infinite economic value, which can continuously create comprehensive benefits and achieve sustainable economic and social development. Vigorously implementing major projects for the protection and restoration of important ecosystems is an effective way to improve the conditions of natural ecosystems such as forests, grasslands, deserts, rivers, lakes, wetlands and oceans, and to enhance the service functions of ecosystems (Ren et al. 2007, Wang et al. 2020).

Night-Time Light is a typical remote sensing data used to describe the intensity of economic activities on the surface (Ghosh et al. 2009), which is closely related to economic development (Chen &Nordhaus 2011a, Henderson et al. 2017). Since the data is not limited by statistical caliber, administrative unit and geographical boundaries, it can objectively and truly reflect the level of regional economic development (Chand et al. 2009), and it also provides the possibility to eliminate human interference and reduce statistical errors. At present, this data has been widely used in economic simulation (Li et al. 2013), poverty measurement (Yu et al. 2015), urbanization (Liu et al. 2012), etc. NDVI can reflect changes in vegetation coverage, productivity and health status (Noam et al. 2007, van Leeuwen et al. 2006), and is now increasingly used in ecological research (Cabello et al. 2012, Pettorelli et al. 2005). Human activities have a significant impact on vegetation coverage (Martínez &Gilabert 2009). Conversely, NDVI can also reflect the interference of human activities to a certain extent.

Previous studies mostly applied Night-Time Light data from socio-economic perspectives of urbanization, parameter spatialization and disaster assessment (Doll et al. 2006, Small et al. 2005, Sutton &Costanza 2002), while researches on NDVI mainly analyzed the impact of natural factors on vegetation distribution from perspective of natural conditions such as altitude, rainfall and

temperature (Chen &Pan 2002, Florinsky &Kuryakova 1996, Jiang et al. 2017, Li et al. 2020b). There were few literatures that combined Night-Time Light and NDVI data to study the impact of ecological environment variations on economic development. Based on provincial panel data of Night-Time Light reflecting economic development and NDVI representing ecological environment, we mainly studied: (1) The temporal and spatial variations of Night-Time Light and NDVI in China from 2000 to 2013. (2) The main driving factors of Night-Time Light variations in 31 provincial administrative units and sub-regions in Chinese mainland. (3) Exploring the relationship between economic development and ecological protection. (4) Putting forward suggestions for the coordinated development of economy and ecology to guide the practice of ecological restoration in different regions and the layout of economic development.

2 Materials and methods

2.1 Study area

China lies in the east of Eurasian land on the west of Pacific Ocean with an area of about 9.6 million square kilometers. The domain starts from the center of the Heilongjiang River at the north of Mohe river, then to the south is the Zengmu Reef in the south of the Nansha Islands. To the east is at the place where the Heilongjiang River and the Wusuli River meet, and to the west is Pamirs. There are over 5000 kilometers both from east to west and from north to south. The land border reaches 22.8 thousand kilometers with its mainland coastline of 18 thousand kilometers. The terrain is high in the west and low in the east, which is distributed in a ladder shape, and the combination of temperature and precipitation is diverse, forming a variety of climate. Provincial administrative divisions include 23 provinces, 5 autonomous regions, 4 municipalities and 2 special administrative

regions. Due to the particularity of Hong Kong, Macao and Taiwan in terms of socio-economic development and ecological protection, 31 provincial administrative units in mainland China were taken as the study areas. The location was shown in Fig.1.

As a typical developing country in the world, China has experienced rapid economic development since its reform and opening up, and its comprehensive strength has increased substantially, making it the world's second largest economy. However, due to the extensive pattern of economic development in the past, problems such as ecological damage and environmental pollution have become prominent, which has brought negative effects on economic development. The economy has shifted from high-speed growth to high-quality development, and the requirements for environmental protection and ecological safety are also increasing. Only by correctly handling the relationship between economic development and ecological restoration, developing towards the harmonious coexistence between man and nature, can better contribute Chinese wisdom and solutions to global sustainable development.

2.2 Data collection

Based on availability of data and actual situation of the study area, the provincial panel data in China from 2000 to 2013 were selected as research object. The definition and sources of variables were shown in Table 1.

Night-Time Light: The radiation signal generated by night lights and flames collected by DMSP/OLS sensor. DMSP/OLS sensor works at night, which can detect the low-intensity light from urban lights, even small-scale residential areas and traffic flows, and distinguish them from the dark rural background. It reflects the industrial production, commercial activities and energy

consumption more objectively. Therefore, DMSP/OLS night light images can be used to measure the development level of regional economy (Elvidge et al. 2009, Henderson et al. 2012).

NDVI：Based on the continuous time series of SPOT/VEGETATION NDVI satellite remote sensing data, the annual vegetation index data set since 2000 was generated by the maximum synthesis method. This data set effectively reflected the distribution and change of vegetation coverage on the spatial and temporal scales in various regions, and had important significance for monitoring vegetation change, rational utilization of vegetation resources (Tucker 1979).

According to Qin et al. (2019) and Shao et al. (2019), 9 indicators related to Night-Time Light were selected as control variables: (1) Capital formation rate: This indicator was used to reflect regional physical capital investment, measured by the ratio of provincial fixed assets investment to GDP. (2) Industrial structure: The upgrading and optimization of the industrial structure was an important driving force for economic progress and income growth. The ratio of added value of secondary industry to GDP was used to measure the impact of industrial structure on economic development. (3) Energy structure: It could reflect the dependence mode and extensive level of economic development, measured by the ratio of coal consumption to total energy consumption. (4) Human capital level: Economic development was inseparable from the support of talents. Cities with more universities could obtain more high-quality labor, and many college students stayed in the cities where they studied after graduation to work. Therefore, the ratio of the number of college students in each province to the total population was used to measure this indicator. (5) Trade openness: This index reflected the degree of regional utilization of domestic and international markets and the level of economic openness, and was measured by the ratio of regional total import and export to GDP. (6) City scale: Large-scale urban population meant huge economic factors and

local market potential. Urban population was used to reflect the real scale of a city. (7) Transportation status: As the infrastructure and important link of social economy, transportation was the basic need and prerequisite for development. Highway mileage was used to measure regional transportation facilities. (8) Inflation level: Moderate inflation was conducive to economic development, while hyperinflation would hinder the sound development of economy. The year-on-year growth rate of Consumer Price Index was used to measure the regional inflation. (9) Government expenditure: A certain degree of government intervention in economic activities would affect development and environment, and local general budget expenditures were used to measure regional government expenditures.

The correlation coefficient matrix shown in Table 2 reflected that there was no serious multicollinearity among variables.

2.3 Methods

2.3.1 Trend analysis

Unary linear regression could be used to analyze the variation trend of each grid point. Here, the slope of the least power linear regression equation of the multi-year value of each grid was used to express the inter-annual variation trend of NDVI and Night-Time Light (Stow et al. 2003), and the calculation equations were shown in Eqs. (1), (2) respectively.

$$k_{NDVI} = \frac{n\sum_{i=1}^{n}(i\times M_{NDVI,i})-\sum_{i=1}^{n} i\times\sum_{i=1}^{n} M_{NDVI,i}}{n\times\sum_{i=1}^{n} i^2-\left(\sum_{i=1}^{n} i\right)^2} \quad (1)$$

$$k_{Night-Time\ Light} = \frac{n\sum_{i=1}^{n}(i\times M_{Night-Time\ Light,i})-\sum_{i=1}^{n} i\times\sum_{i=1}^{n} M_{Night-Time\ Light,i}}{n\times\sum_{i=1}^{n} i^2-\left(\sum_{i=1}^{n} i\right)^2} \quad (2)$$

Among them, n is 14, i is the year serial number, $M_{NDVI,i}$ and $M_{Night-Time\ Light,i}$ are the NDVI and Night-Time Light values in the year i, respectively. k_{NDVI} and $k_{Night-Time\ Light}$

represent the slope of NDVI and Night-Time Light. When $k > 0$, it indicates that the vegetation coverage and economic development increased during the 14-year period from 2000 to 2013, while $k < 0$ means that the variation trend is decreasing, and the larger the absolute value of k, the more obvious the variation is. There is no unified standard for the division of variation trend k now (Cheng et al. 2017). Considering the overall distribution of NDVI and Night-Time Light in the study area, the k value for NDVI and Night-Time Light were divided into five levels by natural breakpoint method respectively. The five levels for NDVI were significantly degraded ($k_{NDVI} \leq -0.03$), slightly degraded ($-0.03 < k_{NDVI} \leq -0.01$), stable ($-0.01 < k_{NDVI} \leq 0.001$), slightly improved ($0.001 < k_{NDVI} \leq 0.01$) and significantly improved ($k_{NDVI} > 0.01$). And the five levels for Night-Time Light were significantly reduced ($k_{Night-Time\ Light} \leq -1.5$), slightly reduced ($-1.5 < k_{Night-Time\ Light} \leq -0.5$), stable ($-0.5 < k_{Night-Time\ Light} \leq 0.5$), slightly increased ($0.5 < k_{Night-Time\ Light} \leq 1$) and significantly increased ($k_{Night-Time\ Light} > 1$).

2.3.2 Panel regression model

The panel regression model was further introduced to quantitatively analyze the effect of NDVI on Night-Time Light. From the perspective of economics, there is a view that environmental protection and economic growth are in a contradictory relationship, that is, if we choose environmental protection, we must sacrifice economic growth at the expense; If we pursue economic growth, we must be prepared to accept the consequences of environmental degradation. On the one hand, the increase in NDVI means the improvement of vegetation coverage and ecological environment, which can provide good resources and environmental conditions for the sustained and stable development of economy, but on the other hand, it also means that it will occupy

part of the space of urbanization process and bring certain pressure to economic development. Therefore, the effect of NDVI on Night-Time Light is likely to be nonlinear. In order to verify this hypothesis, the primary and secondary terms of NDVI were included in the regression of the full-sample panel data as shown in Eq. (3) to accurately evaluate the mechanism of NDVI on Night-Time Light.

$$y_{it} = \beta_0 + \beta_i X_{it} + \beta_2 (X_{it})^2 + \Phi Z_{it} + \lambda_i + \eta_t + \varepsilon_{it} \quad (3)$$

In Eq. (3), y_{it} represents the Night-Time Light value of the province i in year t, X_{it} is the core independent variable, i.e. the NDVI value corresponding to the province i in year t. Z_{it} stands for the set of control variables, including 9 indicators listed in Table 1, such as capital formation rate, industrial structure, energy structure, human capital level, trade openness, city scale, transportation status, inflation level and government expenditure. β_0, β_1 and β_2 are the coefficients to be estimated, λ_i is the individual effect, η_t is the time effect and ε_{it} is the residual term.

2.3.3 Sub-sample analysis

China's economic development shows significant regional differences, and the development level in the eastern region is significantly higher than that in the central and western regions (Poncet 2003). Therefore, we further divided 31 provincial administrative units into three groups: the eastern region, the central region and the western region according to geographical and economic division basis, and conducted a regional heterogeneous study on the relationship between NDVI and Night-Time Light. The eastern region, which includes 11 provincial administrative units in Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan, is the

most developed region in economy and has been at the forefront in terms of development, transformation, reform and transition. The central region is composed of Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan. This area covers an area of about 1.028 million square kilometers, is rich in resources and has a solid industrial and agricultural foundation, and is the second echelon of economic development. There are 12 provincial administrative units in western region, including Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang, accounting for 70.6% of the country's area. Most areas are relatively backward and need to strengthen development. The specific division of the eastern, central and western regions were shown in Fig.1. And the panel regression model of sub-samples was shown in Eq. (4):

$$y_{it} = \beta_0 + \beta_1 X_{it} + \Phi Z_{it} + \lambda_i + \eta_t + \varepsilon_{it} \quad (4)$$

The variable connotation in Eq. (4) is the same as that in Eq. (3).Through Hausmann test, we found that all panel data regressions should adopt fixed effect model (Hausman 1978).

3 Results

3.1 Temporal and spatial variation characteristics of Night-Time Light and NDVI

It could be seen from the descriptive statistical results of the main variables in Table 3 that the mean value of Night-Time Light during the sample period was 5.503, the maximum was 42.43, and the minimum was 0.0124, indicating a large variation. The average value of NDVI was 0.659, and its standard deviation was 0.173 with a small fluctuation range.

From the perspective of temporal and spatial variations, the spatial distribution of Night-Time Light was higher in the east, followed by the central region, and generally lower in the west.

Moreover, Beijing-Tianjin-Hebei Urban Agglomeration, Yangtze River Delta and Pearl River Delta regions showed obvious characteristics of high concentration, while other regions were more scattered (Fig.2). By 2013, Night-Time Light value of most regions had been increased to a certain extent, especially in some provincial capitals in the central and southwestern regions, the areas with high concentration of night lights were constantly expanding. The spatial distribution of NDVI showed obvious geographic differentiation (Fig.3). Specifically, the NDVI value in the northwest region of the Hu Line was generally low, while that in the southeast region was generally high. In addition, from 2000 to 2013, NDVI values in most regions were on the rise, and the vegetation coverage rate increased significantly. According to Fig.2 and Fig.3, there was an obvious overlap between the areas where Night-Time Light increased in the Yangtze River Delta and the Pearl River Delta and the areas where NDVI decreased.

3.2 Dynamic trends of Night-Time Light and NDVI

During the 14 years from 2000 to 2013, the vegetation coverage showed an overall upward trend, and improved area was larger than degraded area (Fig.4 (a)). Areas with significantly improved were mainly distributed in the Loess Plateau, Northeast China Plain, Altai Mountains and Junggar Basin, while areas with slightly improved and stable were relatively large, accounting for 69.07% and 23.06% respectively. Slightly and significantly degraded areas were relatively small, accounting for only 0.47% and 0.01%, mainly concentrated in the central urban areas of provinces, especially the economically developed areas along the Yangtze River Delta. For Night-Time Light, the stable areas were the largest, accounting for 92.13%, while other types of areas were mostly scattered, with the significantly increased area accounting for 1.29%, mainly concentrated in the

eastern coastal areas. Areas with slightly and significantly reduced accounted for 4.45% and 0.04% respectively, mainly distributed in the northeast, northwest, Loess Plateau and other ecological function reserves, such as water and soil conservation and water source conservation function areas (Fig.4(b)).

3.3 Full sample regression analysis

Table 4 (1) and (2) respectively report the regression results of the fixed effects model and random effects model based on panel data of 31 provincial administrative units in China. In the regression results of the two different models, the first-order coefficients of NDVI were significantly positive, the regression coefficients were 27.359 and 36.822, and the quadratic coefficients were both significantly negative, the coefficients were -28.207 and -38.063 respectively, indicating that the influence of NDVI on Night-Time Light was not linear, but had an inverted U-shaped curve relationship. According to the regression results and the calculation formula $-\frac{\beta_1}{2\beta_2}$, the value of the inflection point was 0.48, that is, when the value of NDVI was less than 0.48, the influence of NDVI on Night-Time Light was positive, and when the NDVI value was greater than 0.48, the influence of NDVI on night light was negative.

For the control variables, the regression coefficients of industrial structure and energy structure were significantly negative, indicating that the increase in the proportion of the secondary industry and the proportion of coal consumption in total energy consumption would lead to a decrease in the value of Night-Time Light. While regression coefficients of human capital level, urban scale, inflation level and government expenditure were all significantly positive, indicating that these factors were conducive to the increase of Night-Time Light.

3.4 Analysis of regional heterogeneity

Table 5 (1), (2), (3) report the panel regression results of the eastern, central and western regions respectively. It could be seen that there were regional differences in the effects of NDVI on Night-Time Light. Specifically, the regression coefficient of NDVI in the eastern region was significantly negative at the level of 1%, with a value of -91.934, which indicated that Night-Time Light value would drop by 91.934% for each unit of increase in NDVI. In contrast, regression coefficients in the central and western regions were both positive, with values of 5.498 and 2.900 respectively, indicating that when NDVI increased by one unit, the Night-Time Light increased by 5.498% and 2.900% respectively. Three regions were also different in the direction and degree of influence by control variables. Night-Time Light variations in the eastern region were positively affected by human capital level, inflation level and government expenditure, and the coefficients were 2.968, 0.383 and 0.001 respectively. While industrial structure, energy structure and urban scale did not have significant impact on Night-Time Light variations. For the central region, all control variables affected Night-Time Light variations in this region, while Western Region was not affected by factors such as industrial structure, city scale, inflation level and government expenditure.

4 Discussion

4.1 Night-Time Light and its main driving factors

The scatter diagram drawn in Fig.5 intuitively reflects the influence of NDVI on Night-Time Light. It could be seen that the trend line presented an inverted U-shaped curve, which was

consistent with the results of the full sample benchmark regression (Table 4), indicating that the quadratic term of NDVI in the benchmark model could reflect the relationship between NDVI and Night-Time Light more accurately (Wooldridge 2007, Zhao &Wei 2015). The inverted U-shaped curve relationship between Night-Time Light and NDVI in the whole sample showed that the value of Night-Time Light increased first and then decreased with the increase of NDVI, and there was an optimal value of vegetation coverage, that is, the inflection point value of inverted U-shaped curve, which indicated that the effect of NDVI on Night-Time Light could be positive or negative. The relationship between them was mainly affected by human factors. In addition, it could be seen from Fig.4 that there was an obvious overlap between NDVI degradation and the increase of Night-Time Light, and the NDVI improvement area was also accompanied by the decrease of Night-Time Light to some extent. Therefore, it was necessary to formulate corresponding environmental protection policies to ensure that the effect of NDVI on Night-Time Light is positive.

Further combined with the results of sub-sample regression model (Table 5), the regression coefficient of NDVI in the eastern region was negative, which was on the right side of inflection point. The improvement of the ecological environment has a greater inhibitory effect on the social and economic development of the eastern region. While the regression coefficient of NDVI in the central and western regions was positive, which was on the left side of inflection point, and the improvement of ecological environment had a good role in promoting the economic development. The eastern region was densely populated with industries, the technology reserve for green development of enterprises was insufficient, and the system and mechanism for promoting environmental protection were imperfect (Wang &Luo 2012). The practice of large-scale ecological restoration would inevitably squeeze out the space for urbanization and bring certain pressure to

economic development. Considering that urbanization and industrialization in some areas of eastern region were still in the accelerated stage, it was quite arduous to achieve the dual goals of economic development and ecological restoration. The central and western regions, especially western region, had relatively low population and industrial agglomeration. As an important ecological security barrier in China, the government has always attached great importance to the ecological protection and construction in these regions, and a number of key ecological protection and construction projects had been launched and implemented successively (Fig.6, Fig.7). Forest and grass vegetation had been restored to a certain extent, soil erosion had been reduced, and environment of key project areas had been significantly improved (Bryan et al. 2018, Ouyang et al. 2016). These measures made the ecological bearing pressure of economic development in the central and western regions relatively small. How to further coordinate the relationship between regional economic development and ecological restoration required appropriate strategies based on the actual conditions of each region.

From the perspective of control variables (Table 4), the regression coefficient of industrial structure was significantly negative for the full sample. The higher the proportion of the secondary industry in GDP, the less conducive to social and economic development. The traditional pattern of "mass production, mass consumption and mass emissions" could no longer meet the needs of ecological civilization construction and green development. The tilt of industrial structure to the tertiary industry would improve the level of economic development (Ngai et al. 2007). Understanding and handling the relationship between development and environmental protection, matching factors such as resources, production and consumption, and changing the development mode from extensive to intensive were difficult problems faced by many enterprises.

4.2 Implications for policy making

The inverted U-shaped relationship between Night-Time Light and NDVI (Table 4, Fig.5) meant that a good ecological environment could promote economic development. If it exceeded the carrying capacity of resources and environment and can no longer be self-recovered, the damaged environment would inhibit economic development (Boulding &Staelin 1990, Pearce &Warford 1993). Only by adopting reasonable measures to enhance the coordination between development and ecological restoration, can the comprehensive improvement of economic and ecological benefits be promoted. China's environmental protection still lags behind economic development, the environmental carrying capacity has reached or approached the upper limit. It is urgent to protect and restore the ecosystem in the process of development.

For the eastern region, considering the negative impact of NDVI on economic development, it is necessary to promote the upgrading and transformation of enterprises, vertically integrate production, circulation, consumption, recycling, environmental protection and capacity building, horizontally couple the production processes of different industries, integrate production base and surrounding environment into unified management of the entire ecosystem, and strive for efficient utilization of resources and zero discharge of hazardous wastes outside the system. Use the principles of ecological economics and systems engineering methods to change the patterns of production and consumption, and tap the potential of all available resources. Develop ecologically efficient industries and build a landscape-friendly environment through environmental economic policies such as green taxation, green finance, and environmental resource value accounting (Magdoff 2012, Söderbaum 2015, Spash 2013). In this process, give full play to the role of market mechanisms, promote high-level protection of the ecological environment and high-quality

economic development with efficient environmental economic policies (Beckerman 1992). For the central and western regions, NDVI has a positive effect on Night-Time Light. Therefore, more attention should be paid to ecological restoration in these areas. The advantage of the central region lies in the heavy industry and planting industry, and this region should focus on rational exploitation of resources and treatment of three wastes. Comprehensively consider the bearing capacity of water resources, animal and plant resources and soil resources, and promote the construction of ecological civilization with systematic thinking, holistic concept and scientific theory, and improve the overall ecosystem function by implementing major biodiversity conservation projects, promoting grassland forest, rivers and lakes to cultivate, improving the farmland fallow rotation system and the red line supervision system of nature reserves and ecological protection, and carrying out monitoring and evaluation of the effectiveness of ecosystem protection (Jian 2011).

While rationally dividing labor in the eastern, central and western regions (Ben-David 1993), the inter-regional ecological compensation mechanism should also be further improved (Kolinjivadi et al. 2014, Lyle et al. 2015, Yang et al. 2013). As the central and western regions sacrificed certain economic development to create ecological service value, the eastern region has benefited from this and needs to compensate the former economically. The allocation and utilization of ecological protection funds should give a certain inclination to underdeveloped provinces, nature reserves, water source areas and important ecological function areas, and take the lead in supporting regional and basin-based environmental protection and pollution prevention projects with significant ecological effects. Follow the principle of "who benefits, who compensates", encourage ecological compensation between downstream and upstream areas, development and protection areas, ecological benefit and protection areas, and accelerate the construction of horizontal ecological

compensation mechanisms (Jia &Gao 2015).

4.3 Uncertainties and limitations

Panel regression model can not only control the unobservable individual heterogeneity including individual effects that do not change with time and time effects that occur in a specific year, but also describe and analyze the dynamic adjustment and deal with error components (Baum 2006). However, there were some shortcomings in the timeliness of data, Night-Time Light data used during the 14 years from 2000 to 2013 were mainly derived from DMSP/OLS lighting data of the US National Defense Meteorological Satellite, and this kind of data would not be released to the public since 2014. Moreover, the data has some defects such as radiation saturation, low spatial resolution and discontinuity of multi-sensor, which greatly hinders and weakens the accuracy of quantitative analysis and reliability of conclusions (Donaldson &Storeygard 2016, Wang &Huang 2018). How to develop scientific and reasonable methods to correct the time series of data such as DMSP/OLS and NPP/VIIRS from different satellites, and unify the statistical caliber of control variables would be the key issues to be solved in further research (Chen &Nordhaus 2011b). In addition, the coordinated development of economy and environment is a complex issue, and the causes and forms of environmental changes are diverse. NDVI can reflect the basic trend of vegetation variations in ecological environment, so it has certain reference value to use NDVI to characterize the effects of ecological restoration. However, this indicator can not fully reflect the problems of air pollution, water quality deterioration, soil salinization and so on. It is necessary to further seek more accurate and objective factors to reflect the effect of ecological restoration, so as to make the analysis of the impact of ecological restoration on economic development more

scientific.

5 Conclusions

Our analysis showed that the influence of NDVI on Night-Time Light presented an inverted U-shaped curve relationship, and the value of Night-Time Light showed a trend of rising first and then falling with the increase of NDVI. There was an optimal value for NDVI, that is, the inflection point value, 0.48. The NDVI value of the eastern region was on the right side of inflection point, and the increase of vegetation coverage would have a certain negative impact on economic development, while the central and western region were on the left side of inflection point, the improvement of vegetation coverage was conducive to the economic development of these regions. In the future, the government should strengthen the protection and restoration of ecosystems, promote high-level protection of ecology and high-quality development with efficient environmental and economic policies, differentially handle the relationship between ecological restoration and economic development in the eastern, central and western region, improve the inter-regional ecological compensation mechanism, and improve the level of regional linkage and coordinated development. The negative impact of NDVI on Night-Time Light is not an inevitable result but its periodic performance, when NDVI is at different stages, it is of great significance to examine its influence mechanism and logic on economic development for correctly handling the relationship between ecological restoration and economic development, and it is also the focus of future research.

Acknowledgements

This work was supported by the Charity Special Project of Ministry of Land and Resources of the People's Republic of China [grant number 201411007]. We thank our colleagues for their insightful comments on the earlier version of this manuscript. Thanks are also given to the anonymous reviewers for their constructive comments.

Ethical Approval

Not applicable

Consent to Participate

Not applicable

Consent to Publish

Not applicable

Authors Contributions

Xueyi Shi, Qiang Li, QingQing Wu have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version.

Funding

The work was supported by the Charity Special Project of Ministry of Land and Resources of the People's Republic of China [grant number 201411007].

Competing Interests

The authors declare that they have no competing interests.

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

References

Baum CF (2006): An Introduction to Modern Econometrics Using Stata. Stata Press books

Beckerman W (1992): Economic growth and the environment: Whose growth? whose environment? World Development

Ben-David D (1993): Equalizing Exchange: Trade Liberalization and Income Convergence. Quarterly Journal of Economics 108, 653-679

Boulding W, Staelin R (1990): Environment, Market Share, and Market Power. Management Science 36, 1160-1177

Bryan BA, Gao L, Ye Y, Sun X, Connor JD, Crossman ND, Stafford-Smith M, Wu J, He C, Yu D, Liu Z, Li A, Huang Q, Ren H, Deng X, Zheng H, Niu J, Han G, Hou X (2018): China's response to a national land-system sustainability emergency. Nature 559, 193-204

Cabello J, Fernández N, Alcaraz-Segura D, Oyonarte C, Piñeiro G, Altesor A, Delibes M, Paruelo JM (2012): The ecosystem functioning dimension in conservation: insights from remote sensing. Biodiversity and Conservation 21, 3287-3305

Chand TRK, Badarinath KVS, Elvidge CD, Tuttle BT (2009): Spatial characterization of electrical power consumption patterns over India using temporal DMSP‐OLS night‐time satellite data. International Journal of Remote Sensing 30, 647-661

Chen X, Pan W (2002): Relationships among phenological growing season, time-integrated normalized difference vegetation index and climate forcing in the temperate region of eastern China. International Journal of Climatology 22, 1781-1792

Chen X, Nordhaus WD (2011a): Using luminosity data as a proxy for economic statistics. Proceedings of the National Academy of Sciences 108, 8589

Chen X, Nordhaus WD (2011b): Using luminosity data as a proxy for economic statistics. Proceedings of the National Academy of Sciences of the United States of America 108, 8589-8594

Cheng F, Liu S, Yin Y, Lv Y, An N, Liu X (2017): The dynamics and main driving factors of coastal vegetation in Guangxi based on MODIS NDVI. Acta Ecologica Sinica 37, 788-797

Doll CNH, Muller J-P, Morley JG (2006): Mapping regional economic activity from night-time light satellite imagery. Ecological Economics 57, 75-92

Donaldson D, Storeygard A (2016): The View from Above: Applications of Satellite Data in Economics. Journal of Economic Perspectives 30, 171-198

Elvidge CD, Sutton PC, Ghosh T, Tuttle BT, Baugh KE, Bhaduri B, Bright E (2009): A global poverty map derived from satellite data. Computers & Geosciences 35, 1652-1660

Florinsky IV, Kuryakova GA (1996): Influence of topography on some vegetation cover properties. CATENA 27, 123-141

Ghosh T, Anderson S, Powell R, Sutton P, Elvidge C (2009): Estimation of Mexico's Informal Economy and Remittances Using Nighttime Imagery. Remote Sensing

Hausman JA (1978): Specification Tests in Econometrics. Econometrica 46

Henderson, Vernon J, Storeygard, Adam, Weil, David N (2012): Measuring Economic Growth from Outer Space. American Economic Review

Henderson V, Squires T, Storeygard A, Weil D (2017): The Global Distribution of Economic Activity: Nature, History, and the Role of Trade. Quarterly Journal of Economics 133

Jia R, Gao G (2015): Study on establishing horizontal ecological compensation system among regions. Macroeconomics, 13-23

Jian S (2011): Research Advances and Trends in Ecosystem Services and Evaluation in China. Procedia Environmental Sciences 10, 1791-1796

Jiang L, Guli·Jiapaer, Bao A, Guo H, Ndayisaba F (2017): Vegetation dynamics and responses to climate change and human activities in Central Asia. Science of The Total Environment 599-600, 967-980

Kolinjivadi V, Adamowski J, Kosoy N (2014): Recasting payments for ecosystem services (PES) in water resource management: A novel institutional approach. Ecosystem Services 10, 144-154

Li Q, Shi X, Wu Q (2020a): Effects of Protection and Restoration on Reducing Ecological Vulnerability. Science of The Total Environment, 143180

Li Q, Shi X, Wu Q (2020b): Exploring suitable topographical factor conditions for vegetation growth in Wanhuigou catchment on the Loess Plateau, China: A new perspective for ecological protection and restoration. Ecological Engineering 158, 106053

Li X, Xu H, Chen X, Li C (2013): Potential of NPP-VIIRS Nighttime Light Imagery for Modeling the Regional Economy of China. Remote Sensing

Liu Z, He C, Zhang Q, Huang Q, Yang Y (2012): Extracting the dynamics of urban expansion in China using DMSP-OLS nighttime light data from 1992 to 2008. Landscape and Urban Planning 106, 62-72

Lyle G, Bryan BA, Ostendorf B (2015): Identifying the spatial and temporal variability of economic opportunity costs to promote the adoption of alternative land uses in grain growing agricultural areas: An Australian example. Journal of Environmental Management 155, 123-135

Magdoff F (2012): Harmony and Ecological Civilization: Beyond the Capitalist Alienation of Nature. Monthly Review 64, 1-9

Mao H (1991): Study on coordinating development of economic, social growth with population, resources and environment at county level. Geographical Research 46, 385-395

Martínez B, Gilabert MA (2009): Vegetation dynamics from NDVI time series analysis using the wavelet transform. Remote Sensing of Environment 113, 1823-1842

Ngai, L., Rachel, Pissarides, Christopher, A. (2007): Structural Change in a Multisector Model of Growth. American Economic Review

Noam L, Shmida A, Oded L, Hagit T, Kark S (2007): Predicting Mountain Plant Richness and Rarity from Space Using Satellite-Derived Vegetation Indices. Diversity and Distributions 13, 692-703

Ouyang Z, Zheng H, Xiao Y, Polasky S, Liu J, Xu W, Wang Q, Zhang L, Xiao Y, Rao E, Jiang L, Lu F, Wang X, Yang G, Gong S, Wu B, Zeng Y, Yang W, Daily GC (2016): Improvements in ecosystem services from investments in natural capital. Science 352, 1455

Pearce DW, Warford JJ (1993): World without end economics, and sustainable development. Oxford University Press, New York

Pettorelli N, Vik JO, Mysterud A, Gaillard J-M, Tucker CJ, Stenseth NC (2005): Using the satellite-derived NDVI to assess ecological responses to environmental change. Trends in Ecology & Evolution 20, 503-510

Poncet S (2003): Measuring Chinese domestic and international integration. China Economic Review 14, 1-21

Qin M, Liu X, Li S (2019): The impact of urban sprawl on regional economic growth — empirical researches based on DMSP night-time light data. China Economic Quarterly 18, 527-550

Ren H, Shen W-J, Lu H-F, Wen X-Y, Jian S-G (2007): Degraded ecosystems in China: status, causes, and restoration efforts. Landscape and Ecological Engineering 3, 1-13

Shao S, Li x, Cao J (2019): Urbanization promotion and haze pollution governance in China. Economic Research Journal 54, 148-165

Small C, Pozzi F, Elvidge CD (2005): Spatial analysis of global urban extent from DMSP-OLS night lights. Remote Sensing of Environment 96, 277-291

Söderbaum P (2015): Varieties of ecological economics: Do we need a more open and radical version of ecological economics? Ecological Economics 119, 420-423

Spash CL (2013): The shallow or the deep ecological economics movement? Ecological Economics 93, 351-362

Stow D, Daeschner S, Hope A, Douglas D, Petersen A, Myneni R, Zhou L, Oechel W (2003): Variability of the Seasonally Integrated Normalized Difference Vegetation Index Across the North Slope of Alaska in the 1990s. International Journal of Remote Sensing 24, 1111-1117

Sutton PC, Costanza R (2002): Global estimates of market and non-market values derived from nighttime satellite imagery, land cover, and ecosystem service valuation. Ecological Economics 41, 509-527

Tucker CJ (1979): Red and photographic infrared linear combinations for monitoring vegetation. Remote Sensing of Environment 8, 127-150

van Leeuwen WJD, Orr BJ, Marsh SE, Herrmann SM (2006): Multi-sensor NDVI data continuity: Uncertainties and implications for vegetation monitoring applications. Remote Sensing of Environment 100, 67-81

Wang J, Luo C (2012): Orientation of Eastern 10 Provinces' Economic Developing Strategies and Their Prosepcts. Reform, 5-18

Wang J, Ying L, Zhong L (2020): Thinking for the transformation of land consolidation and ecological restoration in the new era. Journal of Natural Resources 35, 26-36

Wang X, Huang l (2018): Night light data and its application in economic research. Economic Perspectives, 75-87

Wooldridge J (2007): Introductory Econometrics: A Modern Approach South-Western College Pub, Cincinnati, Ohio

Yang W, Liu W, Viña A, Luo J, He G, Ouyang Z, Zhang H, Liu J (2013): Performance and prospects of payments for ecosystem services programs: Evidence from China. Journal of Environmental Management 127, 86-95

Yu B, Shi K, Hu Y, Huang C, Chen Z, Wu J (2015): Poverty Evaluation Using NPP-VIIRS Nighttime Light Composite Data at the County Level in China. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 8, 1217-1229

Zeng L, Zhuang D (2004): Study on the social-economic development and resources environment change of Hainan island in the past 50 years. China Population,Resources and Environment 1, 75-79

Zhang X, Chi T (2001): Differentiating and analysis of the coordination degree between economic development and environment of provinces (regions) in China. Geographical Research 20, 506-515

Zhao Y, Wei H (2015): The Government Intervention, the Division of Labor of the Function of the Space of the City Group,and the Difference in District: On the Effectiveness of Regional Policy in China. Management World, 14-29+187

Figures

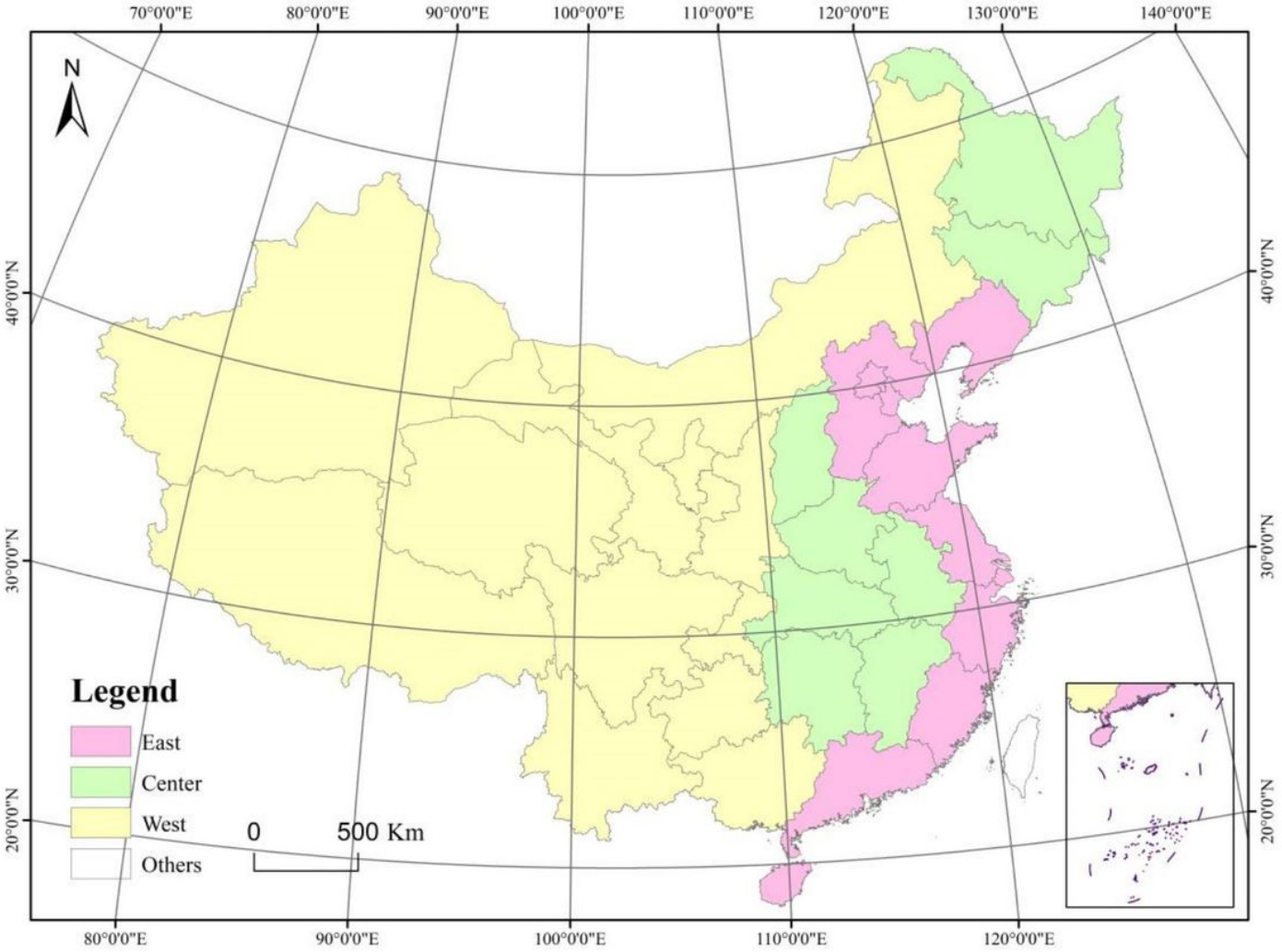

Figure 1

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

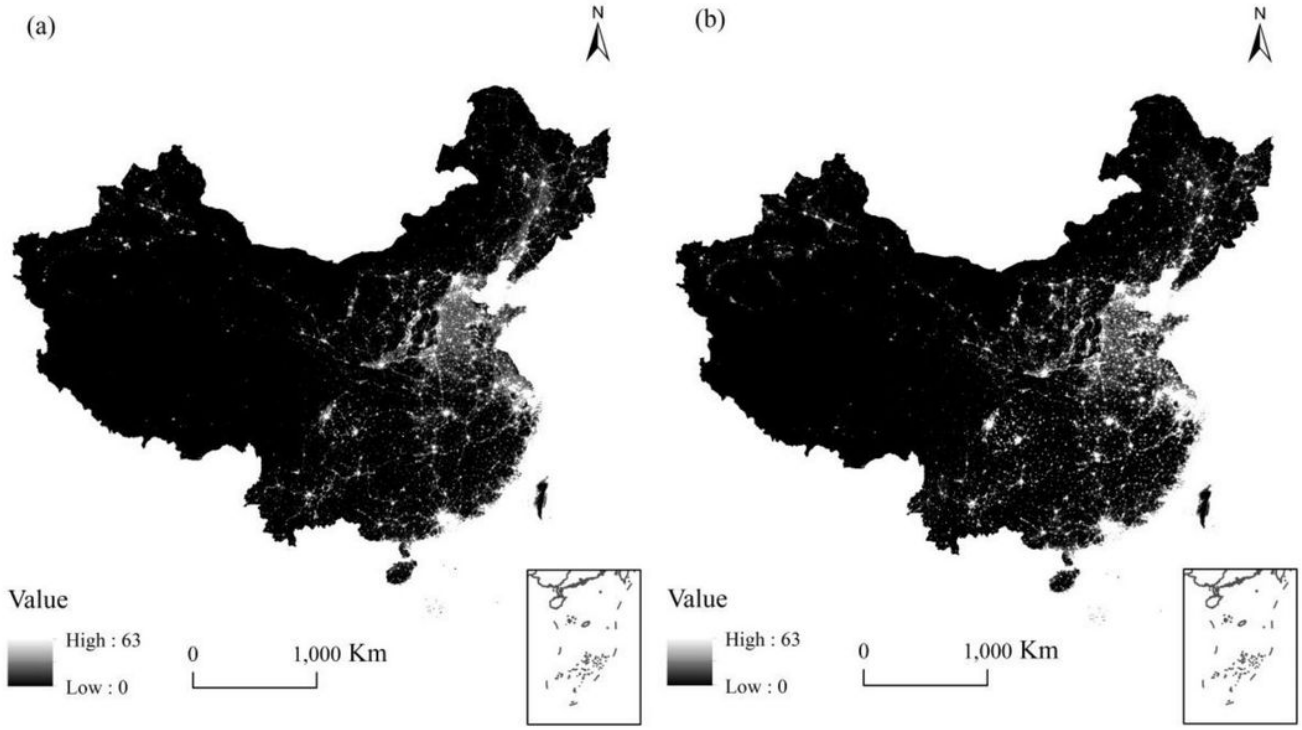

Figure 2

Distribution of Night-Time Light in China in 2000 (a) and 2013 (b). Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

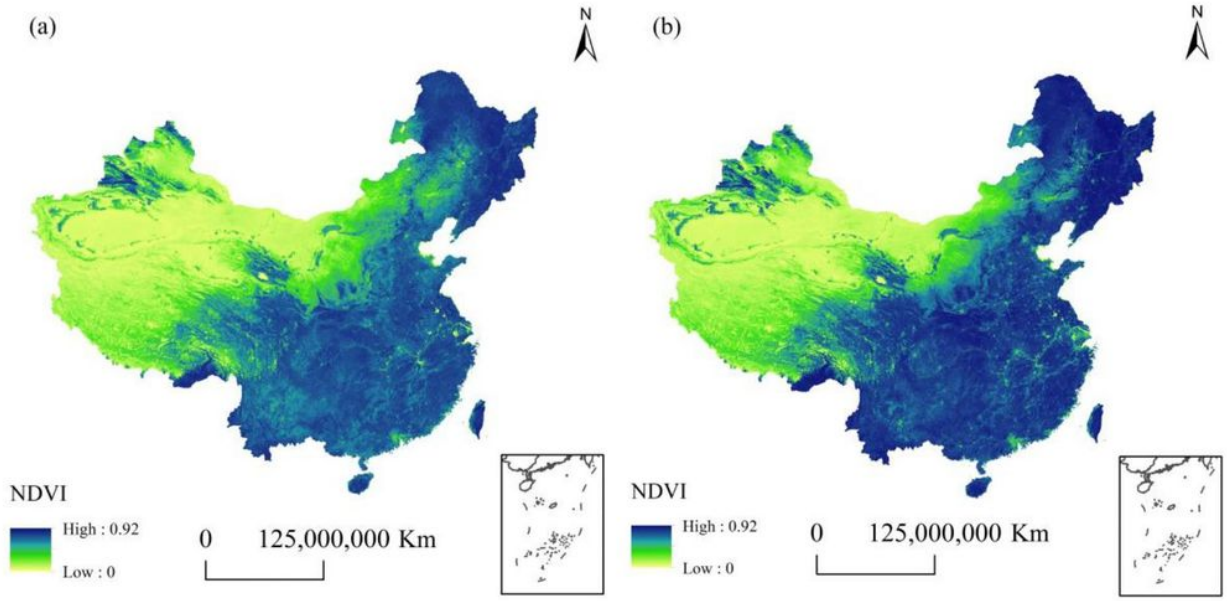

Figure 3

Distribution of NDVI in China in 2000 (a) and 2013 (b). Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

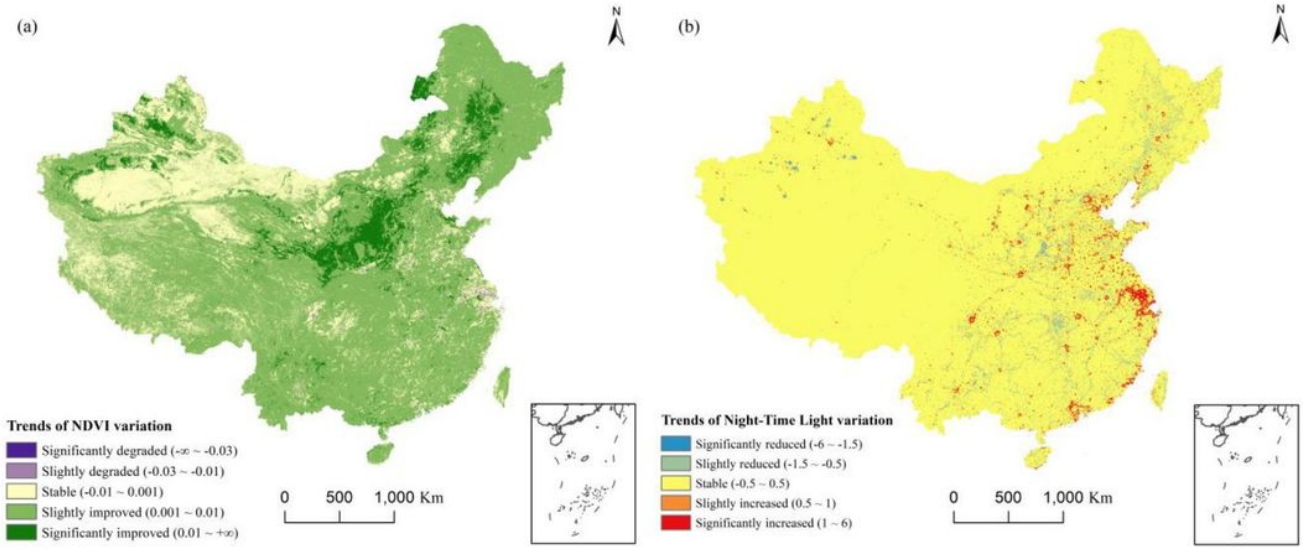

Figure 4

Trends of NDVI (a) and Night-Time Light (b) variation in China from 2000 to 2013. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

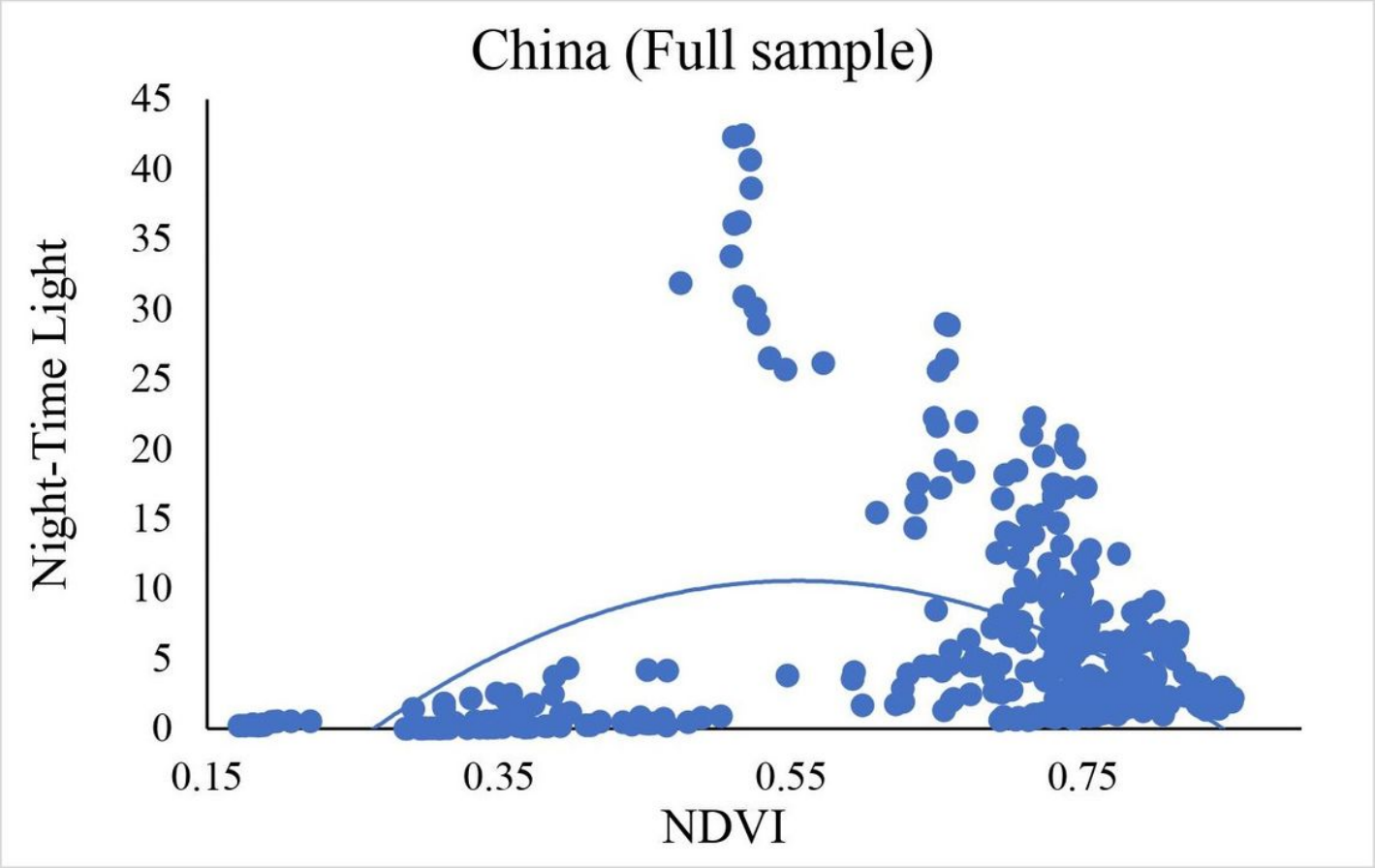

Figure 5

Scatter fitting of NDVI and Night-Time Light for China.

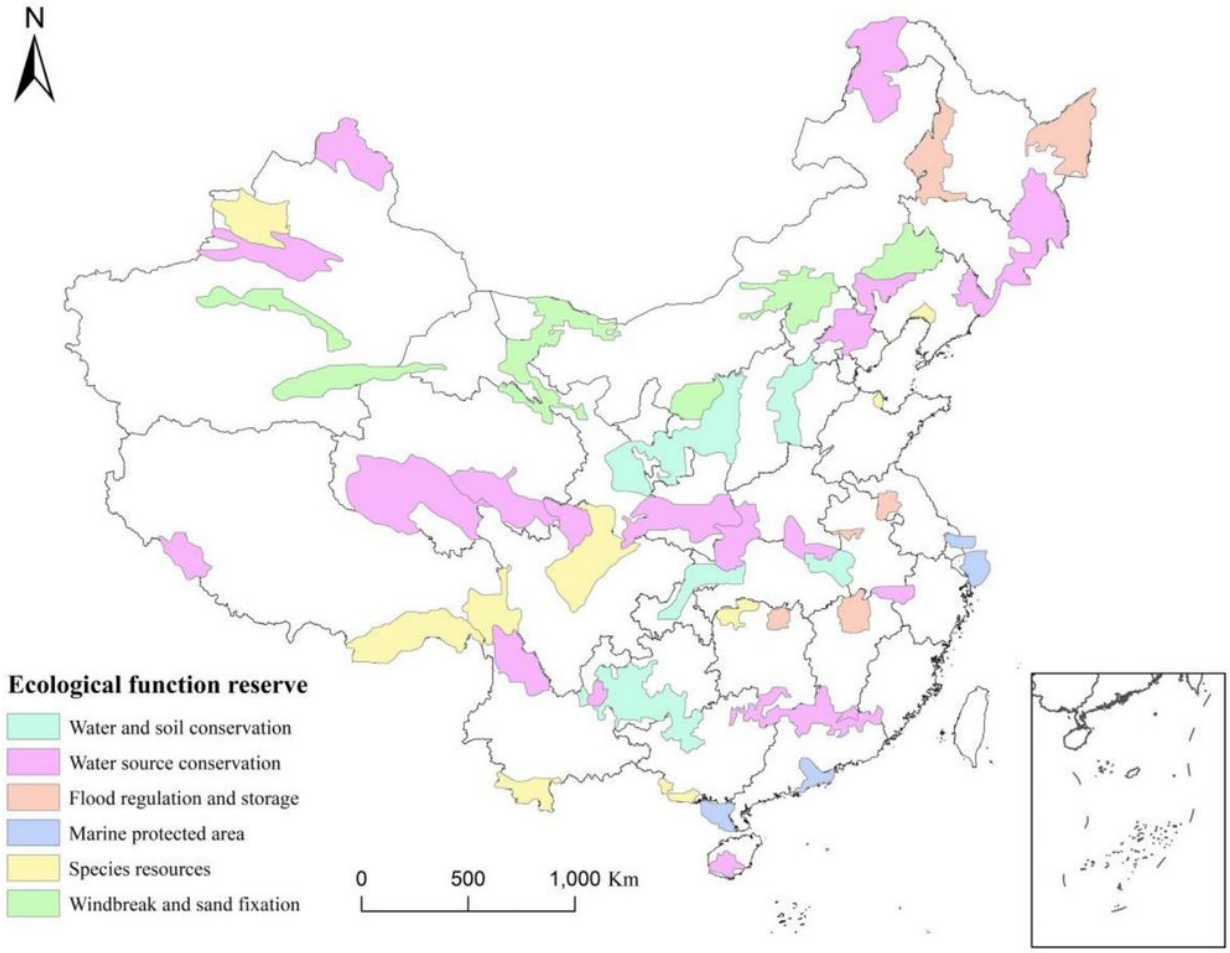

Figure 6

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

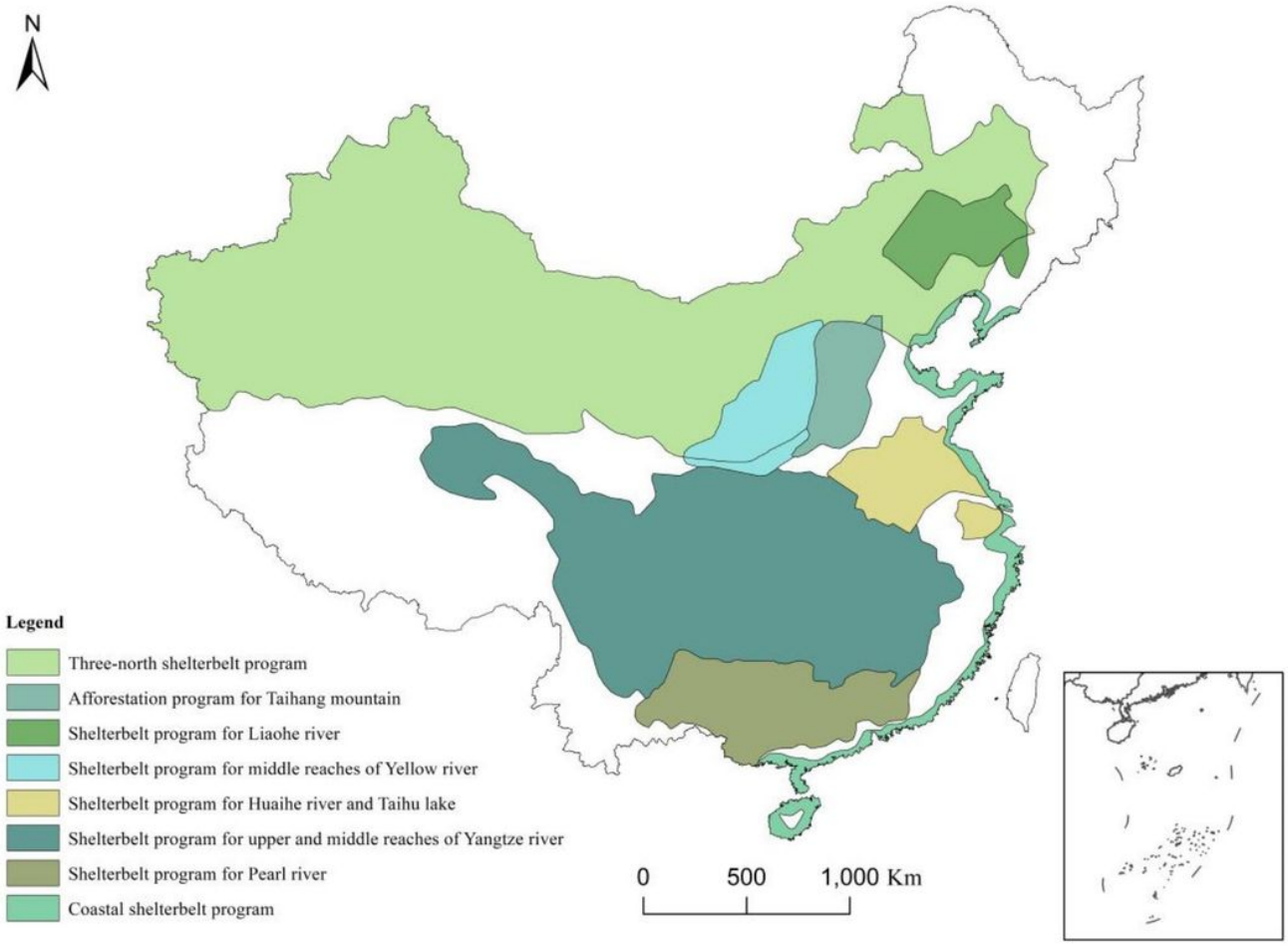

Figure 7

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

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Tables.docx