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Analysis of decoupling between land use degree and ecosystem service intensity in China

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ABSTRACT

Scientifically exploring the decoupling relationship between land use degree and ecosystem service intensity can effectively reveal the interference degree of land use change in the ecosystem, and provide a scientific basis for land use policy-making and ecosystem protection. However, previous studies lack specific research on the decoupling relationship between land use and ecosystem service intensity at the county level in China. In order to make up for this deficiency, combined with the remote sensing monitoring data of China's land use status from 2000 to 2015 and the vegetation coverage index, the spatial and temporal pattern characteristics of China's county scale ecosystem service intensity and land use degree from 2000 to 2015 were measured respectively by using the measurement methods of ecosystem service intensity and land use degree, and the decoupling relationship between the two was detected by using the decoupling analysis theoretical framework. The results showed the followings. (1) During the study period, the intensity of ecosystem services in China showed significant spatial heterogeneity, and the intensity of ecosystem services in Southeast China was significantly higher than that in Northwest China; the ecosystem service intensity in plain areas, urban agglomerations and the surrounding areas of big cities is significantly lower than that in mountainous and hilly areas. (2) China's land use degree continued to increase during the study period. The land use degree in the southeast was significantly higher than that in the northwest. The distribution of land use degree in the southeast was "high and low", and the distribution of land use degree in the northwest was "low, medium, and high". (3) The results of the decoupling analysis show that strong decoupling and expanding negative decoupling are the main relationship types between land use and ecosystem service intensity in China. The former is a dilemma, and the latter is a win-win model. The study found that the interference of land use at different stages on the intensity of ecosystem services showed significant differences. The results can provide scientific guidance for the formulation of land use and ecosystem management policies.

Keywords: Ecosystem Service Intensity; Land Use Degree; Space-time Relationship; Decoupling Analysis; China

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Land use/land cover change has been recognized as an important component and one of the main causes of global change, and will continue to play an important role in global change[1,2]. Since the 1990s, China's rapid urbanization has accelerated the process of China's land use transformation. At the same time, it has seriously disturbed the sustainable supply of ecosystem services, triggered a series of problems such as land degradation and biodiversity loss, and then brought great challenges to China's ecological civilization construction and sustainable development. At present, the increasingly serious contradiction between man and land forces human beings to effectively coordinate the relationship between land use and the ecosystem. How to scientifically assess the disturbance degree of land use change to the ecosystem, effectively alleviate the deterioration of the ecosystem, and formulate effective ecosystem protection strategies is a hot topic discussed by Chinese government decision-makers and urban planners. In this context, scientific exploration of the decoupling relationship between land use change and ecosystem services is of great significance for formulating effective ecosystem protection and land use policies.

Ecosystem services research mainly focuses on ecosystem services evaluation, trade-offs, and analysis of influencing factors, supply and demand analysis, scenario prediction, and optimal regulation[3-6]. Previous studies have done a lot of empirical research on ecosystem services at different time and space scales based on the value method, material method, and energy method[7-9], but it is difficult to compare the results of ecosystem services evaluation based on different research scales and different research objectives, It is more difficult to incorporate into the national scale ecosystem protection and land use decision-making[10]. Among them, the value quantity assessment method mainly measures the use value and non-use value of ecosystem services by assigning value quantity coefficients to different ecosystem types[11]. The determination of ecosystem value equivalent coefficient based on expert knowledge lacks consideration of spatial heterogeneity of ecosystem services, resulting in subjectivity and uncertainty in ecosystem service assessment[12]. However, ecosystem service assessment based on material quality and energy is often difficult to conduct large-scale and long-time series comparative analysis due to the difficulty in obtaining assessment data[8]. In view of this, this paper introduces the ecosystem service intensity to measure the national county scale ecosystem service supply capacity, so as to enrich China's ecosystem service measurement methods[10,12]. Ecosystem service intensity can be used to characterize the intensity that nature and the ecosystem provide ecological products, support functions, regulation functions, and other ecological benefits to humans[12,13]. The introduction of the concept of ecosystem service intensity effectively integrates various ecosystem functions and provides a new perspective and method for ecosystem service measurement.

Previous studies have comprehensively explored the impact of land use change on ecosystem services from the aspects of quantitative change of land use[13,14], change of land use mode[15], change of land use pattern[16], comprehensive dynamic degree of land use[17,18] and degree of land use[19,20]. Specifically, previous studies on the relationship between land use and ecosystem services were mostly limited to local areas. Due to different research methods and scales, the relationship between land use and ecosystem services showed great differences. Some studies believe that the increase in land use will lead to the deterioration of ecosystem services. However, some studies have reached the opposite conclusion[21,22]. How use affects ecosystem services has not been determined. The impact of land use degree on ecological services is not a simple linear relationship. The existing studies usually use the elastic analysis method to detect the relationship between the two, and rarely use the decoupling analysis method to conduct a comprehensive study on the relationship between the land use degree of county units and ecosystem services[19,23]. The decoupling analysis method can be used to analyze the response relationship between two or more elements, and can effectively reveal the impact of land use change on ecosystem services. Based on this, this paper uses decoupling analysis to explore the decoupling relationship between the land use degree of county units and the intensity of ecosystem services in China, and effectively explain the interference of land use change on ecosystem services, in order to provide scientific reference for the formulation of land use policies and the protection of ecosystems in China.

Based on the remote sensing monitoring data of China's land use status from 2000 to 2015 and the vegetation coverage index, this paper uses the measurement methods of ecosystem service intensity and land use intensity to measure the spatial-temporal distribution pattern characteristics of China's county scale land use intensity and ecosystem service intensity from 2000 to 2015 and explores the decoupling relationship between them with the help of the theoretical framework of decoupling analysis. Specifically, the previous studies were supplemented and improved from the following three aspects: (1) based on the measurement method of ecosystem service intensity and land use degree, the spatial-temporal distribution characteristics of ecosystem service intensity and land use degree of county units in China from 2000 to 2015 were measured; (2) based on the spatial matching relationship between ecosystem service intensity and the change of ecosystem service intensity, this paper explores the spatial evolution characteristics of ecosystem service intensity in China; (3) based on the decoupling analysis method, the impact of land use change on ecosystem services change was analyzed. This paper intends to solve the following three problems. (1) what are the spatiotemporal distribution characteristics of ecosystem service intensity and land use degree? (2) What is the decoupling relationship between ecosystem service intensity and land use degree? (3) How to support the application of relevant policies?

1. Research methods and data sources

1.1 Data source

The remote sensing monitoring data of land use in China in 2000, 2005, 2010, and 2015 came from the resource and environmental science data center of the Chinese Academy of Sciences (http://www.resdc.cn), resolution of 1,000 m × 1,000 m is currently the most accurate remote sensing monitoring data product for land use in China and has played an important role in national land resource survey, hydrology and ecological research[24,25]. The data production and production in 2000, 2005, and 2010 were mainly based on Landsat TM/ETM remote sensing images of various periods. The data in 2015 were updated on the basis of 2010 data. Based on Landsat 8 remote sensing images, they were generated through manual visual interpretation, and the data accuracy was higher than 90%[24,25]. Land use types include 7 primary types, cultivated land, forest land, grassland, water area, construction land, unused land, and wetland. The administrative boundary data is from China National Geographic Information Center (NGCC) (http://ngcc.sbsm.gov.cn/). The spatial distribution data sets of normalized difference vegetation index (NDVI) of China in 2000, 2005, 2010, and 2015 are also from the resource and environmental science data center of the Chinese Academy of Sciences (http://www.resdc.cn)[26]. Due to the lack of data, Hong Kong, Macao, and Taiwan are excluded.

1.2 Research methods

1.2.1 Ecosystem service intensity

Based on the theoretical framework of ecosystem service value measurement proposed by Costanza *et al*.[13], Xie *et al*.[14] revised the classification and equivalent table of China's ecosystem on the basis of the knowledge of more than 700 ecologists and experts and in combination with the characteristics of China's ecosystem. However, the equivalent factor proposed by Xie *et al*.[14] is a national equivalent means of ecosystem service value, which lacks the expression of spatial heterogeneity of ecosystem service value in China. Previous studies have corrected ecosystem service value based on biomass, but biomass and ecosystem function are not completely positively correlated, especially in areas with vast water areas[27,28]. For example, aquatic ecosystems contain very little biomass, but aquatic ecosystems play an important role in water purification, waste treatment, and climate regulation. Chen *et al*.[29] proposed a correction method based on the biomass of cultivated land to compensate for the deviation caused by the correction based on the regional biomass. Based on this, this paper improves the previous studies and believes that it is more reasonable to correct the equivalent table of ecological service values proposed by Xie *et al*.[14] based on the biomass on cultivated land. Based on equations (1) and (2), the correction coefficient of the ecosystem service value of each county unit is estimated, and the calculation formula is as follows:

$$f = \frac{NDVI - NDVI_{\min}}{NDVI_{\max} - NDVI_{\min}} \tag{1}$$

$$F_k = \frac{f_k}{\bar{f}} \quad (2)$$

Where: F_k is the correction coefficient of ecosystem service value of the kth county unit; f_k is the average biomass of cultivated land in the k county unit; $\bar{f}$ is the average biomass of cultivated land in China. Because there is no cultivated land in some counties in Northwest China, this paper obtains the correction coefficient by taking the mean value of the surrounding counties.

Based on the equivalent table proposed by Xie *et al.*[14] (equation 3), the standardized mean value of ecosystem function of each land type (equation 4) is taken as the ecosystem service intensity value per unit area of the land type (**Table 1**). Since there is no one-to-one matching between land use types and ecosystem types, according to previous studies, the closest ecosystem service intensity value of each land use type is selected for the assignment[18,30], and the county ecosystem service intensity in China is measured according to equation 5. The calculation formula is as follows:

$$w_{ij} = \left(\frac{I_{ij} - I_{ij-\min}}{I_{ij-\max} - I_{ij-\min}} \right) \times 100 \quad (3)$$

$$w_i = \sum_{j=1}^{m} w_{ij} / m \quad (4)$$

$$ESI_k = \sum_{i=1}^{n} w_i S_{ik} F_k / \sum_{i=1}^{n} S_{ik} \quad (5)$$

Where: w_{ij} is the equivalent factor of j ecosystem service value after i land type standardization, and its score is between 0 and 100; $I_{ij-\max}$ and $I_{ij-\min}$ are the maximum and minimum values of j ecosystem function types provided by land types respectively; w_i is the ecosystem service intensity of the i land use type; m (m = 1, 2, 3, …, 9) is the number of ecosystem function types; ESI is ecosystem service intensity; S_i is the area of soil type i (hm^2); n is the type of regional land use.

Table 1. The standardized equivalent weighting factor of ecosystem services value per hectare for each land type.

Primary type	Secondary type	Woodland	Grassland	Cultivated land	Wetland	Waters	Unused land	Land used for building
Supply services	Food production	33. 00	43. 00	100. 00	36. 00	53. 00	2. 00	0. 00
	Raw material production	100. 00	12. 00	13. 00	8. 00	12. 00	1. 34	0. 00
Regulation service	Gas conditioning	100. 00	35. 00	17. 00	56. 00	12. 00	1. 39	0. 00
	Climate regulation	30. 00	12. 00	7. 00	100. 00	15. 00	0. 96	0. 00
	Hydrological regulation	22. 00	8. 00	4. 00	72. 00	100. 00	0. 37	0. 00
	Waste disposal	12. 00	9. 00	9. 00	97. 00	100. 00	1. 75	0. 00
Support services	Soil conservation	100. 00	56. 00	37. 00	50. 00	10. 00	4. 23	0. 00
	Maintain biodiversity	100. 00	41. 00	23. 00	82. 00	76. 00	8. 87	0. 00
Cultural Services	Provide aesthetic landscape	44. 00	19. 00	4. 00	100. 00	95. 00	5. 12	0. 00
	w	60. 08	26. 00	23. 69	66. 64	52. 52	2. 89	0. 00

1.2.2 Land use degree

Land use degree Lui can be used to reflect the depth and breadth of land use, and then reveal the natural balance maintenance state of land resources natural complex under the interference of human social system[31]. In order to quantitatively evaluate the land use degree, Liu[31] proposed that the land use degree is divided into four levels according to the natural balance of the land natural complex under the influence of social factors, and the land use degree of each land use type is assigned (D_i). For example, construction land such as towns, residential areas, and other construction land is defined as the highest level of land use, and the value is 4; the land use mode that is in the original state, naturally developed and not interfered by human factors is defined as the lowest level, with a value of 0, so as to give a quantitative expression of the utilization degree of the excavated land. Li *et al.*[20] refined the assignment of utilization degree of different land types proposed by Liu[31]. For example, the unused land with less human interference and input-output is assigned as 0, the urban construction land with strong human interference and input-output is assigned as 10, the rural residential area is assigned as 8, and the cultivated land is assigned as 7, realizing a more accurate assessment of land use. For the specific assignment, please refer to the research of Li *et al*.[20] The calculation formula is as follows:

$$LUI = \sum_{i=1}^{n} \frac{S_i}{\sum_{i=1}^{n} S_i} \times D_i \tag{6}$$

Where: D_i is the land use degree assignment of land type i.

1.2.3 Decoupling analysis

The decoupling analysis method has been widely used in the fields of agriculture, transportation, energy, construction land expansion and carbon emissions, but few studies have measured the relationship between land use and ecosystem services based on the decoupling method. This paper uses the decoupling analysis method to study the relationship between the two. According to the development and enrichment of decoupling theory by Tapio[32] and OECD[33], the theoretical framework of decoupling is divided into eight logical possibilities, including strong decoupling, strong negative decoupling, weak decoupling, expansion connection, expansion negative decoupling, recession decoupling, recession connection, and weak negative decoupling. Referring to previous studies, taking 1.2 and 0.8 as the critical values of decoupling elasticity, the change rate of ecosystem service intensity ($\%\Delta ESI$) is divided by the rate of land use change ($\%\Delta LUI$) to construct the decoupling index[34]. Where $DI > 1.2$, $\%\Delta ESI > 0$, $\%\Delta LUI > 0$, expansion negative decoupling; $0.8 < DI < 1.2$, $\%\Delta ESI > 0$, $\%\Delta LUI > 0$, expansion connection; $0 < DI < 0.8$, $\%\Delta ESI > 0$, $\%\Delta LUI > 0$, weak decoupling; $DI < 0$, $\%\Delta ESI < 0$, $\%\Delta LUI > 0$, strong decoupling; $DI > 1.2$, $\%\Delta ESI < 0$, $\%\Delta LUI < 0$, recession decoupling; $0.8 < DI < 1.2$, $\%\Delta ESI < 0$, $\%\Delta LUI < 0$, fading connection; $0 < DI < 0.8$, $\%\Delta ESI < 0$, $\%\Delta LUI < 0$, weak negative decoupling; $DI < 0$, $\%\Delta ESI > 0$, $\%\Delta LUI < 0$, strong negative decoupling. Refer to[32] for the meaning of each type, and the calculation formula is as follows:

$$DI_{t2-t1} = \frac{\%\Delta ESI}{\%\Delta LUI} = \frac{(ESI_{t2} - ESI_{t1})/ESI_{t1}}{(LUI_{t2} - LUI_{t1})/LUI_{t1}} \tag{7}$$

Where: DI_{t2-t1} represents the decoupling index from $t1$ to $t2$; ESI_{t1} and ESI_{t2} represent ecosystem service intensity index in $t1$ and $t2$ respectively; LUI_{t1} and LUI_{t2} represent land use index in $t1$ and $t2$ respectively.

2. Result analysis

2.1 Spatial and temporal distribution of ecosystem service intensity in China from 2000 to 2015

From 2000 to 2015, the spatial distribution pattern of China's ecosystem service intensity remained basically stable. On the whole, the ecosystem service intensity in the south of Qinling Mountains Huaihe River was significantly better than that in the north. The ecosystem service intensity in the eastern monsoon region was higher than that in the Qinghai Tibet high cold region and the northwest arid region (**Figure 1**). The intensity of ecosystem services in the Northwest Economic Zone (Xinjiang, Tibet, Qinghai, Gansu, and Ningxia) and some provinces in the middle reach of the Yellow River Economic Zone, including Inner Mongolia and Shanxi, is relatively low; the Huang Huai Hai Plain in the eastern monsoon region (including Beijing, Hebei, Tianjin, Shandong, Jiangsu, the eastern part of Henan and the northern part of Anhui), the Sichuan Basin, the economic zone in the middle reaches of the Yangtze River (Hubei, Hunan, and Jiangxi), the Yangtze River Delta (Shanghai, the southern part of Jiangsu, the eastern part of Anhui and the northern County of Zhejiang) and the Pearl River Delta (Guangdong), as well as the Liaoning coastal economic belt, the central and southern city clusters of Liaoning along the Harbin Dalian line in the northeast The ecosystem service intensity of Shenyang Economic Zone and Harbin Changcheng city group is also low. The low intensity of ecosystem services in the Northwest Economic Zone and the middle reaches of the Yellow River Economic Zone is mainly due to poor natural conditions, insufficient rainfall, dry climate, widespread deserts, fragile ecological environment, and low overall resource and environmental carrying capacity; the low-value areas of ecosystem service intensity in the eastern monsoon region are caused by social and economic development. These areas have superior natural conditions, convenient transportation, a strong economic agglomeration effect, and an obvious pulling effect on the population. Social and economic development and population agglomeration are the main reasons for the low ecosystem service intensity in these areas.

In order to further analyze the ecosystem service intensity and its spatial matching, based on the spatial distribution of China's County Ecosystem service intensity index, three-level areas (low level, medium level, and high level) are divided into 0–25, 25–50 and ≥50, and then based on the changes of ecosystem service intensity, they are divided into five horizontal zones of <0.50, 0.50–0, 0–0.25, 0.25–0.75, and ≥0.75 (high-speed deterioration, low-speed deterioration, low-speed improvement, medium speed improvement, and high-speed improvement) can be combined to obtain 15 zoning combination types (**Figure 2**). The low-level and deteriorating regions are mainly distributed in some counties in Northwest China, such as Qinghai, Tibet, Xinjiang, and Inner Mongolia; the regions with low level and continuous improvement are mainly distributed in some areas of the Loess Plateau and some counties of Xinjiang; the regions with deteriorating medium level are mainly distributed in the transitional counties of the second and third ladder in China, the counties around the Sichuan Basin, the North China Plain, and the southeast.

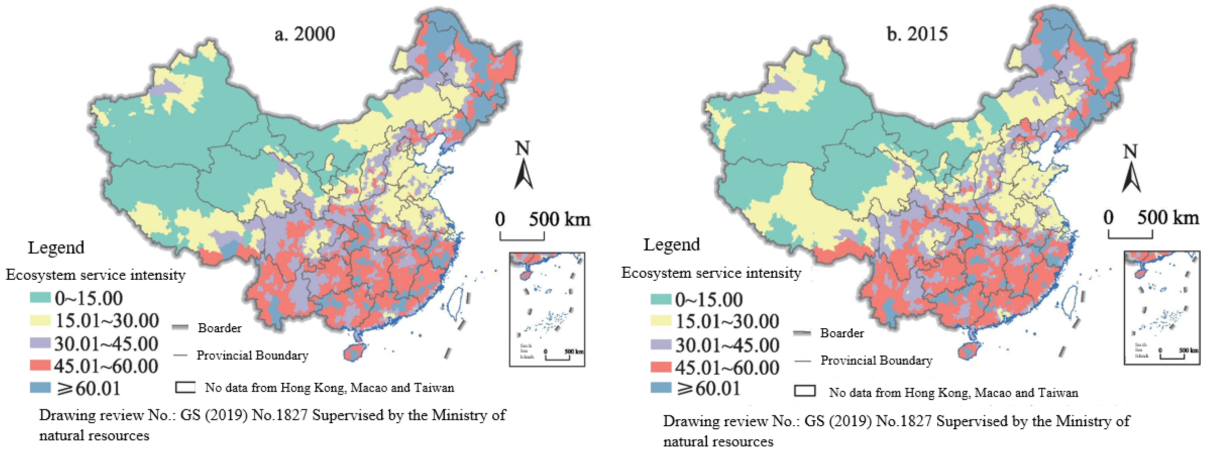

Figure 1. Spatial distribution of ecosystem services intensity at the county level in China in 2000 and 2015.
Note: this drawing is based on the standard map downloaded from the standard map service system of the Ministry of natural resources. The base map is unchanged, the same below.

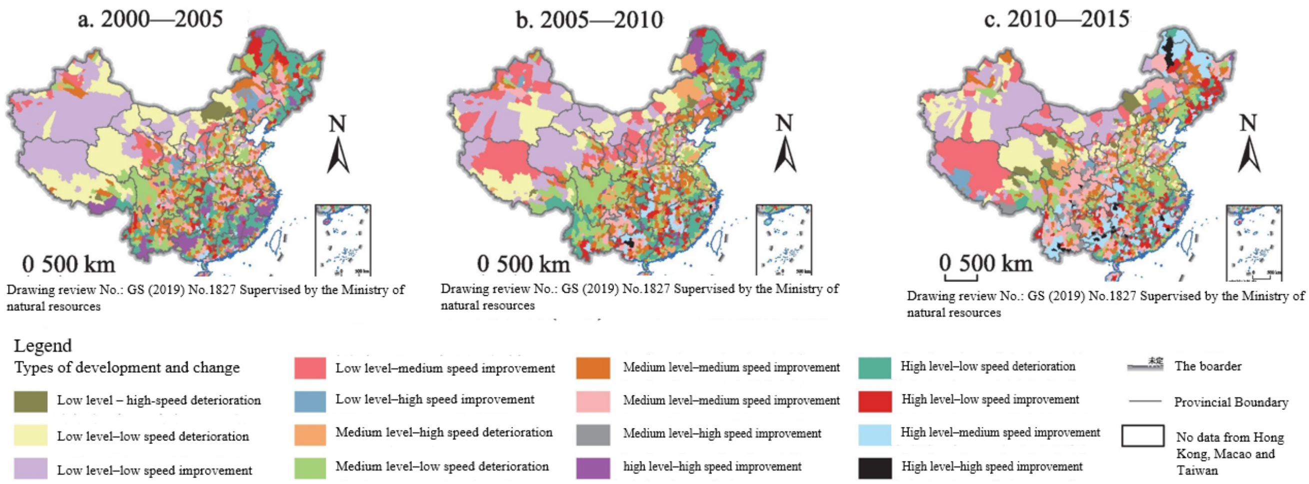

Figure 2. Development types of ecosystem services intensity at the county level in China from 2000 to 2015.

Some large cities and surrounding areas of urban agglomerations (Urban Agglomerations in the middle reaches of the Yangtze River, urban agglomerations in the Yangtze River Delta and urban agglomerations in the Pearl River Delta); the high-level improvement areas are mainly concentrated in the greater Hinggan Mountains, Changbai Mountains, Taihang Mountains, Wushan mountain, Xuefeng mountain and Wuyi Mountain; high level deterioration areas are mainly distributed in the surrounding areas of these mountains.

2.2 Spatial and temporal distribution of land use degree in China from 2000 to 2015

In terms of time scale, China's land use degree showed a continuous increasing trend from 2000 to 2015, from 1.97 in 2000 to 2.01 in 2015. With the rapid growth of China's economy and population, the impact of human activities on the natural complex of land use has become more and more intense. In terms of spatial scale, the land use degree in the eastern monsoon region is significantly higher than that in the northwest arid region and the Qinghai Tibet alpine region, and the overall spatial pattern of "high in the southeast and low in the northwest" has not changed significantly. The land use degree distribution in the southeast region is "high and low", and the land use degree in the northwest region is "low, medium and high". The low value areas of land use degree in the eastern monsoon region are mainly distributed in mountainous and hilly areas, while the high value areas of land use degree are mainly distributed in the Huang Huai Hai Plain, the Yangtze River Delta, the Sichuan Basin, the middle reaches of the Yangtze River, the Pearl River Delta and the central and southern part of the northeast region; the high value areas of land use degree in the northwest arid region and the Qinghai Tibet high cold region are mainly distributed in Xining, Lhasa, Urumqi and other provincial capitals (**Figure 3**).

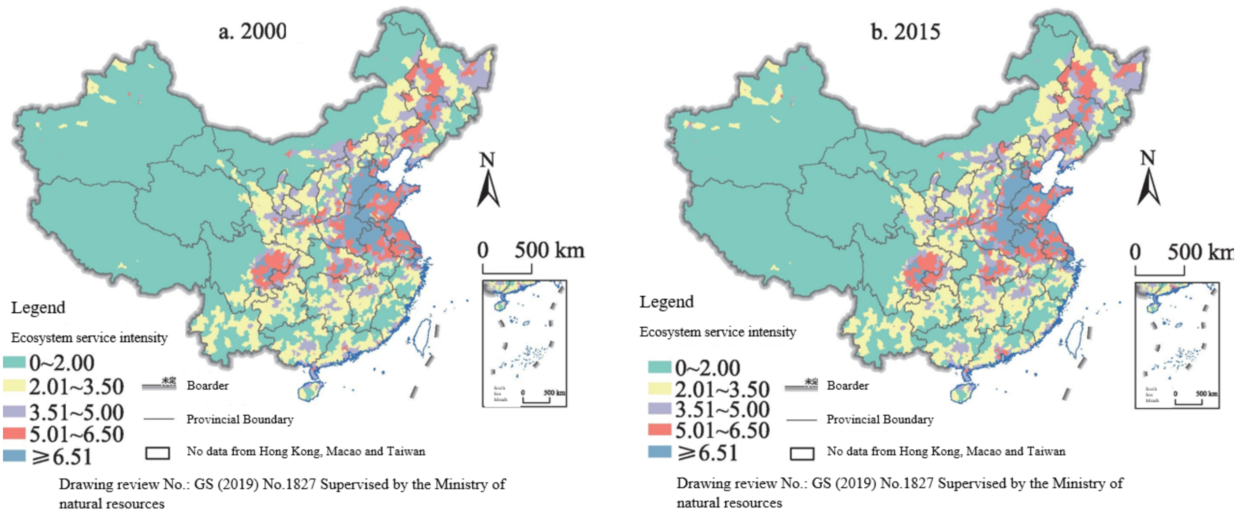

Figure 3. Spatial distribution of land use intensity at the county level in China in 2000 and 2015.

2.3 Analysis of decoupling between land use degree and ecosystem service intensity in China from 2000 to 2015

In order to fully reveal the relationship between ecosystem service intensity and land use degree, the scatter diagram between ecosystem service intensity and land use degree is first analyzed (**Figure 4**). From the scatter diagram of four time points from 2000 to 2015, it can be seen that there is not a simple linear relationship between land use degree and ecosystem service intensity. Ecosystem service intensity increases with the increase of land use degree and decreases with the increase of land use degree after reaching the threshold. In the primary stage of land use, it is mainly from unused land (low ecosystem service supply potential) to forest land, grassland, cultivated land and other land use types (high ecosystem service supply potential), so as to promote the improvement of the overall ecosystem service intensity. With the increase of land use, the transformation of land use types mainly occurs between land use types such as forest land to cultivated land, grassland to cultivated land, forest land to construction land, grassland to construction land, which will inevitably lead to the reduction of the overall ecosystem service intensity. The results of Pearson correlation analysis between ecosystem service intensity and land use degree showed that the correlation coefficient between them was -0.519 in 2000, p = 0.000; in 2005, the correlation coefficient between them was -0.526, p = 0.000; in 2010, the correlation coefficient between the two was -0.546, p = 0.000; in 2015, the correlation coefficient between the two was -0.571, p = 0.000. On the whole, it can be seen that there is a negative correlation between ecosystem service intensity and land use degree, but the increase in land use degree in local areas will lead to an increase of ecosystem service intensity.

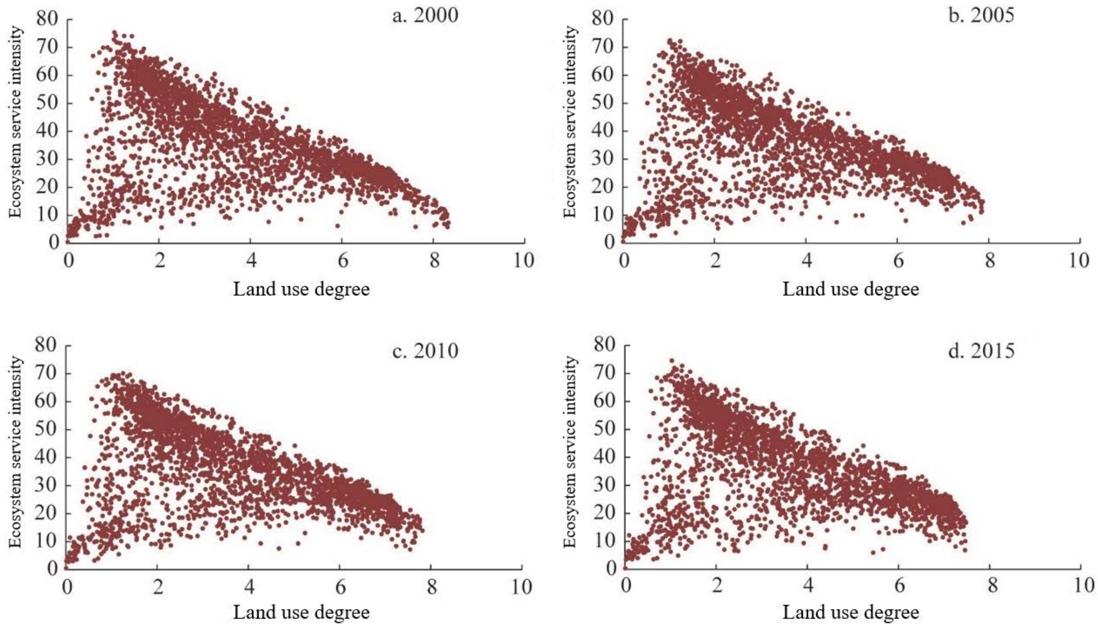

Figure 4. Scatter plot of *ESI* and *LUI* in China from 2000 to 2015.

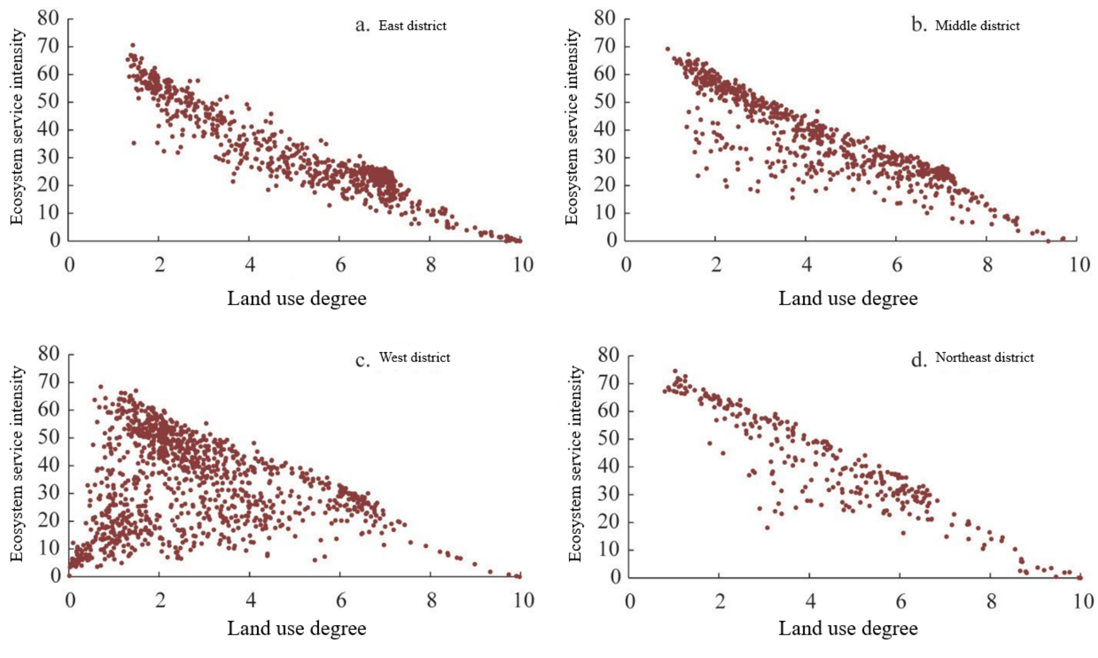

Figure 5. Scatter plot *ESI* and *LUI* in different regions of China in 2015.

In order to further explain the relationship between ecosystem service intensity and land use degree in different regions of China, the scatter map of ecosystem service intensity and land use degree in eastern, central, Western and Northeast China in 2015 is further analyzed (**Figure 5**). It is obvious that there is a significant negative correlation between ecosystem service intensity and land use degree in eastern, central and Northeast China. Among them, the increase of land use degree in the eastern region will lead to the most significant decrease in ecosystem service intensity. On the contrary, the increase in land use degree in most counties and regions in the northwest region will promote the increase of ecosystem service intensity, and only a few counties and regions will promote the decrease of ecosystem service intensity. The scatter plots of ecosystem service intensity and land use degree in different regions reveal that the impact of land use degree on ecosystem service intensity has significant regional differences.

Based on Equation (7), the spatial distribution characteristics of the decoupling index of land use degree and ecosystem service intensity between 2000–2005, 2005–2010, and 2010–2015 are obtained (**Figure 6**). Statistics on the proportion of counties with different logic types are shown in **Table 2**. Among the eight decoupling types in 2000–2005, 2005–2010 and 2010–2015, the strong decoupling type accounted for the highest proportion, 33.68%, 36.85% and 41.90% respectively, showing a gradually increasing trend. The strong decoupling type represents that the increase of land use will lead to the decrease of ecosystem service intensity. This development model is in a dilemma. From 2000 to 2005, the types of strong decoupling were mainly distributed in Zhejiang, Fujian, Hunan, Guangxi, Yunnan, most of the northeast and some of the central and western regions; from 2005 to 2010, it was mainly distributed in Shandong, Jiangsu, Zhejiang, Guangdong, the eastern part of Inner Mongolia and some parts of the central and western regions; from 2010 to 2015, it was mainly distributed in Henan, the middle and lower reaches of the Yangtze River, the Bohai Rim and some parts of the central and western regions. The second is the expansion negative decoupling type, which accounts for 20.69%, 29.86%, and 35.90% respectively in the three research periods, and also shows a gradually increasing trend. The expansion negative decoupling type represents that the increase of land use degree will lead to the increase of ecosystem service intensity, and the increase of ecosystem service intensity is higher than the increase of land use degree, which is a win-win development model. From 2000 to 2005, the types of expansion negative decoupling were scattered throughout the country; from 2005 to 2010, it was mainly distributed in the central and western regions; from 2010 to 2015, it is mainly distributed in Southwest China and Northeast China. The second is the strong negative decoupling type, accounting for 16. 58%, 15.60%, and 6.95% respectively, showing a gradually decreasing trend. The strong negative decoupling type represents that the reduction of land use in these areas has led to the improvement of ecosystem service intensity. This type is a sustainable development type, which is mainly distributed in the central and western regions and Northeast of China. The recession decoupling type is also an important decoupling logic type, accounting for 12.82%, 13.66%, and 3.34% respectively in 2000–2005, 2005–2010, and 2010–2015. The reduction of land use degree of this type of county unit leads to the reduction of ecosystem service intensity, and the reduction of ecosystem service intensity is higher than the reduction of land use degree. This type is an unsustainable development type.

3. Conclusion and discussion

3.1 Conclusion

Based on the measurement method of ecosystem service intensity and land use degree, this paper analyzes the temporal and spatial distribution characteristics of ecosystem service intensity and land use degree in China from 2000 to 2015, and makes an in-depth study on the decoupling relationship between the change of land use degree and the change of ecosystem service intensity in combination with the decoupling theoretical model, the conclusions are as follows: (1) from 2000 to 2015, the spatial distribution of ecosystem service intensity in China has significant spatial heterogeneity. The ecosystem service intensity in Northwest China is significantly lower than that in eastern China. The ecosystem service intensity in plain areas with economic agglomeration and population agglomeration is significantly lower than that in mountainous and hilly areas, it can be seen that the spatial pattern of the supply potential of China's ecosystem service intensity is formed under the combined action of natural geographical factors and socio-economic factors.

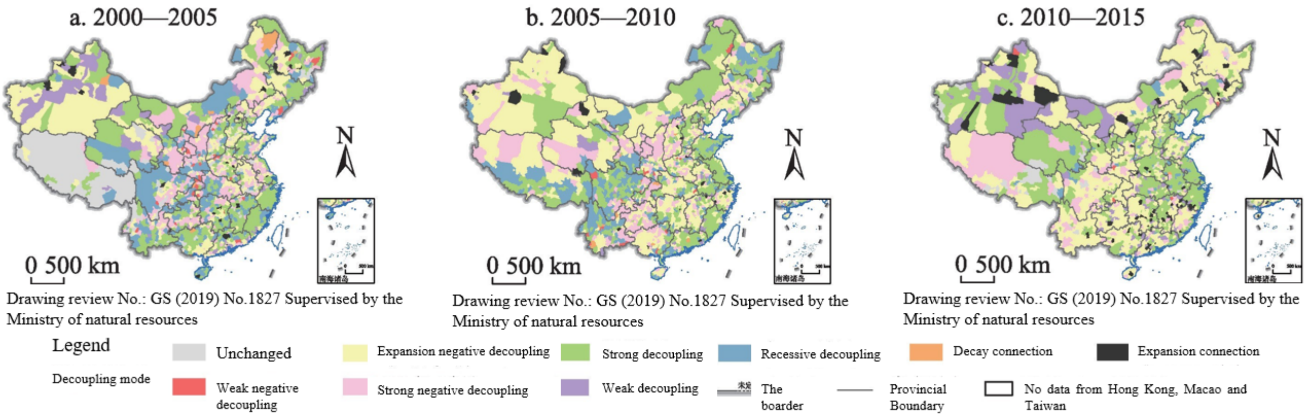

Figure 6. Spatial distribution of decoupling patterns at the county level in China from 2000 To 2015.

Table 2. Logical possibilities statistics (%)

Decoupling category	2000–2005	2005–2010	2010–2015
Unchanged	9.59	0.25	3.86
Expansion negative decoupling	20.69	29.86	35.90
Expansion connection	1.37	0.84	2.39
Weak decoupling	3.76	1.83	5.30
Strong decoupling	33.68	36.85	41.90
Recessive decoupling	12.82	13.66	3.34
Decay connection	0.46	0.42	0.07
Weak negative decoupling	1.05	0.70	0.28
Strong negative decoupling	16.58	15.60	6.95

(2) From 2000 to 2015, China's land use degree gradually increased, and the overall spatial pattern of "high in the southeast and low in the northwest" has not changed significantly. The distribution of land use degrees in the southeast is "high and low", and the land use degree in the northwest is "low, medium, and high". The degree of land use in economic and population concentrated areas is significantly higher than that in mountainous and hilly areas. Natural geographical factors are always important factors that restrict human interference with the natural balance of the land use system.

(3) The disturbance of land use at different stages on ecosystem service intensity is significantly different in time and space. The decoupling analysis results show that the increase in land use will lead to an increase or decrease in ecosystem service intensity. Strong decoupling and expansion negative decoupling is the main relationship types between land use degree and ecosystem service intensity in China. The former is a dilemma, and the latter is a win-win model.

3.2 Discussion

Compared with previous studies, it can be found that the spatial distribution characteristics of land use degree and ecosystem service intensity are both correlated and differentiated, mainly from east to west and north to south. The correlation between the East and the west is caused by the natural attribute of land use, while the differentiation between the north and the south is caused by the social attribute of land use[35]. The relationship between land use degree and ecosystem service intensity in this paper is basically consistent with the previous research results, showing a negative impact in general and a positive impact in local areas[19]. Based on the above research results, it can be found that there are significant differences in the decoupling degree between land use and ecosystem service intensity in different regions. Based on this, this paper proposes differentiated control policies. For strong decoupling regions, such regions are in a dilemma. The increase of land use activities will lead to the decrease of ecosystem service intensity. The rapid development of urbanization and industrialization leads to the continuous increase in land use. The excessive increase in land use will inevitably lead to the deterioration of the ecosystem. Coordinating the relationship between land use, socio-economic development, and ecosystem protection is an effective way to promote sustainable land use and ecosystem protection. The degree of land use cannot explain whether the land use is reasonable, but the intensity of ecosystem services can be used as a scientific indicator to evaluate whether the land use is reasonable[36]. It is necessary to explore new mechanisms of land management, innovate new models of economical and intensive land use, improve the intensive degree of land use, increase the proportion of ecological land, strictly control the increment of construction land, form a forced mechanism, and alleviate the deterioration of the ecosystem in the process of increasing land use by optimizing the overall land use structure and layout. For the win-win type of expansion and negative decoupling, on the premise of protecting the ecological environment, we should speed up economic development, fully release land dividends and ecological dividends, form a situation of ecological environment protection and economic development, and achieve benign interaction and coordinated development. The strong negative decoupling type is a sustainable development type. It is necessary to promote the reuse of inefficient wasteland, increase input and output, and improve land use efficiency according to the specific regional conditions. The recession decoupling type is also an unsustainable development type. The degree of ecosystem services and land use are reduced at the same time, and the degree of reduction of ecosystem services is higher than that of land use. For this type, it is urgent to optimize the land use structure and layout, alleviate the current low efficiency, disorder, and extensive land use, and alleviate the deterioration of the ecosystem.

Based on the decoupling analysis method, this paper discusses the relationship between land use degree and ecosystem service intensity. The results show that the current land use degree in China has a negative and positive impact on ecosystem service intensity, and the negative impact is greater than the positive impact. The research results can provide scientific guidance for the sustainable use of land resources, land use planning, and ecosystem protection. Limited to the availability of county-level data, this paper introduces ecosystem service intensity to measure the supply capacity of ecosystem services in China and corrects it in combination with vegetation coverage. However, the spatial differences in ecosystem service types and intensity caused by the diversity of the ecosystem itself and environmental conditions are still inadequately considered. In addition, only the relationship between ecosystem service intensity and land use degree is discussed, and the decoupling relationship between ecosystem service intensity and land use change speed (comprehensive dynamic degree of land use), land use structure (land use diversity index), natural factors (altitude, climate, topography, etc.). And socio-economic factors (population density and economic development) are not discussed. Future research can comprehensively consider the decoupling relationship between land use factors, natural factors, and socio-economic factors, and the intensity of ecosystem services. In addition, the impact of the global telecoupling and local coupling systems formed by the implementation of China's land use policies, ecosystem policies, and regional development strategies on the intensity of ecosystem services in China is also the focus of future research[37].

Conflict of interest

The authors declared no conflict of interest.

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