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Research Article

Analysis of Harmonious Development of Eco-Economic System in the Second Green Isolation Area in Beijing

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The construction of green isolation areas is an important means to prevent the sprawl of central urban areas, guide the rational layout of urban green spaces, and protect the ecological environment. However, with the continuous construction advancement of green isolation areas in Beijing, the problems of mutual restriction between ecology and economy are increasingly prominent, but few studies are devoted to such problems. Taking the second green isolation area of Beijing in 2000, 2010, and 2020 as the research objects, the kilometer grids were taken as the basic research units, and the land cover data and GDP data were placed in the unified spatial coordinate system by GIS software; also, the equivalent factor method was adopted to calculate the ecological service value (ESV) of the research region, and the eco-economic harmony degree (EEH) was calculated using the ratio of ESPpr to GDPpr. This research innovatively used the kilometer grid as the basic research unit to study the second green isolation area in Beijing and compared the harmony degree between the second green isolation area and the overall ecological, economic system of Beijing, so as to dynamically compare the ecological environment changes in the second green isolation area during the study period and the degree of mutual influence in the process of economic development. The study found that the construction of the second green isolation area improved the harmony of the eco-economic system in a certain area, but it failed to effectively curb the spread of construction land in the urban area of Beijing. The research results can provide scientific guidance for the coordinated planning of the ecological economy in the second green isolation area.

1. Introduction

The construction of green space in big cities' fringe area is one of the hot topics in recent years. With the continuous advancement of the urbanization process across the world, the uncontrolled sprawl of urbanized areas has become a common problem at the stage of incremental urbanization, resulting in urban problems such as disorderly land use hindering social development, damage to the economic, ecological, and cultural environment, and lower land utilization rate [1, 2]. In order to explore sustainable urban development and guard against disorderly urban sprawl, scholars put forward a practical approach to build an urban green belt for dealing with disorderly urban sprawl [3, 4]as early as in the 19th century. The construction of green belts surrounding the cities became a practical method to solve problems such as urban sprawl. In London, Moscow, Frankfurt, and Seoul, green belts were built successively, helping to alleviate the problems of land use and ecological issues caused by disorderly urban sprawl to a certain extent [5].

The concept of green isolation area refers to a "green belt surrounding the city" [6, 7] which, on the basis of the conception of "green space planning in the urban fringe area" [8, 9], was proposed to protect the urban ecological and cultural environment, improve the quality of economic development, raise the land use, and curb the disorderly growth of cities [6, 7]. "Urban green belt" is a kind of common spatial form in the planning of urban fringe green isolation areas. The "four-layer territorial circle" proposed in the famous Greater *London Planning* was regarded as the first application of "urban green belt" in the metropolitan

area. Then, the idea of building urban green isolation areas was widespread to the world in various forms [10].

In China, the construction concept of the green isolation belt in Beijing was initiated in *Beijing Urban Master Plan* in 1958, and the pilot construction was proposed in *Beijing Urban Master Plan (1991-2010)* in 1993. As more emphasis was put on the sustainable development of the capital after 2000, the green isolation belt in the capital began to enter a large-scale construction stage [11]. At present, preliminary results have been achieved in the construction of the first green isolation area (hereinafter referred to as "the first green isolation area") in Beijing, and the construction of the second green isolation area (hereinafter referred to as "the second green isolation area") has been accelerated. After over ten years of unremitting efforts, great achievements have been made in the construction of green isolation area, contributing a lot to the protection of the urban ecological and cultural environment, optimization of urban and rural spatial function planning, coordinated development of urban and rural areas, and promotion of high-quality urban development [12].

Undoubtedly, the construction of the first and second green isolation areas also caused many problems. The construction of the first green isolation area has been basically completed, which, however, has not hindered the spread of construction land in Beijing. The country parks initially planned and constructed are now renamed as urban parks. But the more serious problem is that, during the construction of the first green isolation area, there was a huge conflict between the high cost of green space construction and economic development, which made the construction of the green space in the first green isolation area highly dependent on the profitable land economy. On a comparative basis, the land price of the second green isolation area is far less than that of the first green isolation area, which makes the construction of the second green isolation area more difficult and more complicated. Coupling with the construction of the second green isolation area, the inharmony and nonsustainability of development arising from the mutual restriction of ecology and economy becomes increasingly prominent. The land use is highly mixed and dynamic [13, 14]; the implementation cost of green spaces is too high, resulting in conflict with economic development [15]. These problems for the second green isolation area not only make it difficult to maintain sustainable development but also make it harder to increase the green spaces and implement the planning due to lower land price than the first green isolation area. Yet, there are few related pieces of research on the problems faced by the second green isolation area, especially on the degree of harmony of ecological and economic systems.

Therefore, from the perspective of the ecological and economic harmony, the degree of ecological and economic system coordination (EEH) was taken as an important indicator to measure the balance of ecological and economic development of the second green isolation area so as to perform in-depth analysis and research and fill the research gap in this area, thus providing a scientific basis for promoting the coordinated development of the ecological economy in the second green isolation area. Taking the kilometer grids as the basic research unit, this study compared the harmonious development of the second green isolation area with the overall eco-economic system of Beijing so as to dynamically compare the degree of mutual influence between the ecological environment change and the economic development process in the second green isolation area during the study period, which can not only provide a new research perspective and regulation approach for the spatial optimization of the second green isolation area but also lay an important basis for boosting the EEH planning in the second green isolation area.

2. Overview of Theories

2.1. Research Area. In the construction of green isolation areas in various cities in China, the construction of green isolation areas in the capital—the first and second green isolation areas, set an important example, which also witnessed the serious conflict between ecological and economic development. The main reason for studying the second green isolation area instead of the first green isolation area is that the second green isolation area of Beijing is an important green space for Beijing to curb the spread of central urban areas and to prevent the continuous development of new towns; with a total area of about 910 square kilometers, it extends from the first green isolation area to 1,000 meters outside the Sixth Ring Road. The second green isolation area encompasses 10 districts including Chaoyang District, Haidian District, Fengtai District, Daxing District, Changping District, Tongzhou District, Shunyi District, Mentougou District, Fangshan District, and Shijingshan District, containing 61 townships and towns and 470 village-level units, which have missions of accommodating the depopulation of central urban areas, serving to guarantee the development of urban subcenters and new towns, and promoting the integrated development of urban and rural areas. Compared with the first green isolation area, the second green isolation area has a wider scope, and its planned green space construction volume is much higher than that of the first green isolation area (as shown in Figure 1). The park green space built in the first green isolation area accounted for a small proportion of all land types and had a limited impact on the ecological and economic coordination of the region. Therefore, the research value of the first green isolation area is lower than that of the second green isolation area.

In the construction of green isolation areas in various cities in China, the construction of the first and second green isolation areas of Beijing set an important example and also witnessed serious conflict between ecological and economic development. At present, it is at a crucial period that preliminary results have been made in the construction of the first green isolation area, and the second green isolation area urgently needs to accelerate the step of sustainable construction but has encountered the bottleneck. Pursuant to *Beijing Master Plan (2016-2035)*—the latest edition of Beijing's general plan, the goal of reducing urban capacity, increasing green spaces, and improving quality has been

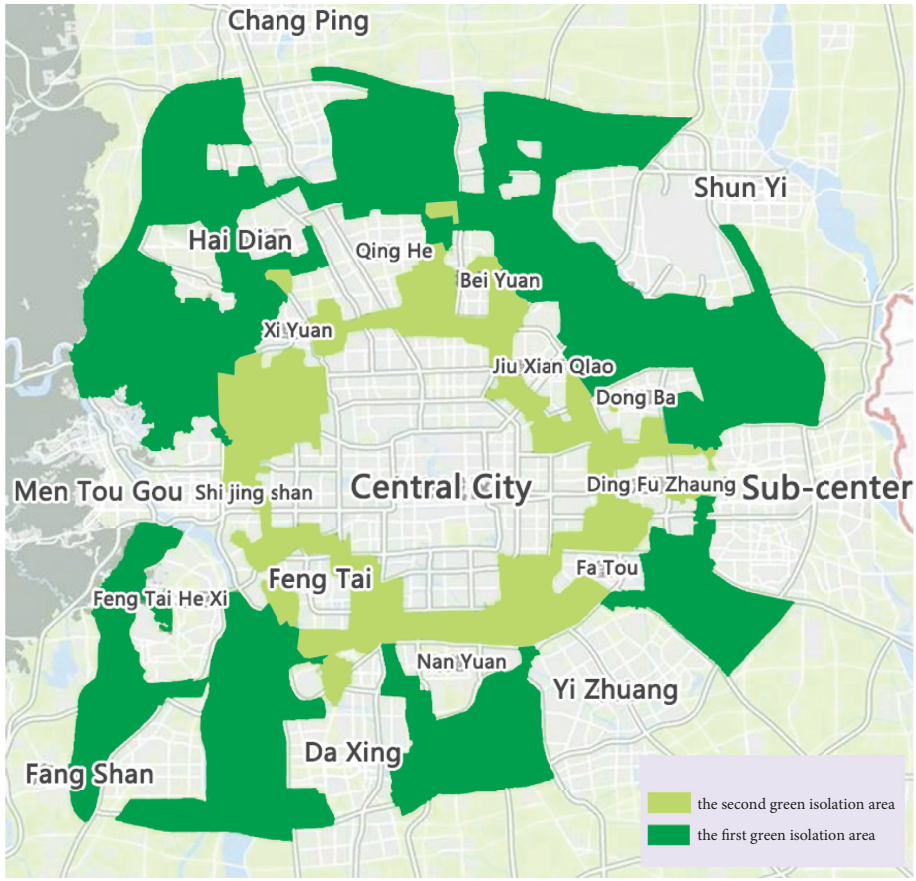

Figure 1: Scope of the first and second green isolation areas [16].

presented to implement the strategy of guaranteeing capital development and strengthening social and ecological resilience. Under this background, the implementation conditions and development situation of the second green isolation area are more complicated. Therefore, it is imperative to ensure the harmony between green space growth and urban-rural development for eco-economic harmonious development.

2.2. Research on the Development of Green Isolation Areas. In the global context, most of the research on green isolation areas was devoted to the historical evolution and implementation effectiveness. Despite the fact that some scholars carried out research on the role of land ownership [17, 18] and market transaction standard system [19] from the dimension of application, there is still a lack of research on the EEH in general. At present, there are some mature cases of green isolation areas abroad— London, Moscow, Frankfurt, Seoul, and Tokyo, etc. [20–22]. The construction of green isolation areas in China is still in the exploratory stage. Domestic researches on green isolation areas mainly focus on two aspects: the theory of constructing green belts surrounding the city and learning from western countries on existing governance experience of green belts surrounding the city [23–26]; evaluation of implementation effect of green isolation belts based on various sci-tech means [27–31]. On the whole, there are shortcomings of insufficient research and simple research perspectives—a large number of research works are still devoted to evaluation and analysis of the construction implementation effects.

However, green isolation areas, especially the second green isolation areas, are faced with high complexity in construction, such as the mixture of land ownership and land use function, continuous conflict between ecological and economic development, lack of implementation path for each planning, and complicated management rights, etc. Among them, the conflict between ecological and economic development is the most prominent, leading to a series of problems, such as difficulty in site selection for supplementing green spaces and in promoting urban capacity reduction. Since 2018, under the background of reducing the "noncapital function" and realizing the goal of "reducing urban capacity, improving quality and increasing green spaces" of Beijing, the second green isolation area, as an area that plays a key role in maintaining the ecological process safety of Beijing, urgently needs to solve the problems such as green space supplement and unclear eco-economic development. Yet, little response has been made from relevant research on the second green isolation area. In recent years, some scholars carried out research [32, 33] on the ecosystem, landscape service, and construction site selection of outskirt parks in the second green isolation area from the perspective of ecological protection, and also put forward solutions from

a spatial perspective, but these researches failed to integrate ecological and economic systems. Therefore, the research on the EEH in green isolation areas and the in-depth analysis of the ecological and economic systems not only play an active role in alleviating the persistent conflict of eco-economic development but also make up the insufficient EEH from the space category, thus providing scientific practical guidance for the optional green space supplement and reduction.

3. Research Methods

3.1. Research Units and Data Sources

3.1.1. Research Units. In previous EEH research, administrative units such as provinces, counties, and townships (subdistricts) were taken as the basic research units, which were not of practical guiding significance to the problems faced by the second green isolation area, such as the difficulty of spatial positioning in reducing urban capacity and increasing green spaces. As an advanced and mature data distribution technology at present, the kilometer grid data distribution processing technology could transform data from administrative divisions to kilometer grids, ensuring that EEH in this research can be effectively placed in relatively accurate space. Therefore, kilometer grids [34] were taken as main basic units of EEH research, and township (subdistrict) administrative units were taken as the basic units of analyzing the EEH spatial pattern, with the administrative divisions based on the *Basic Geographical Map of Beijing Administrative Boundaries (2020 Edition)*. For the purpose of mapping and subsequent analysis, ArcGIS 10.2 software was used to transform the administrative boundary into vector data and project to WGS 1984 geographic coordinate system. In addition, since the second green isolation area is not strictly demarcated according to the administrative boundary, the township (subdistrict) administrative boundary was referenced to delimit the research scope, incorporating the second green isolation area and some surrounding towns (subdistricts) into 3,164 basic units. Notwithstanding Beijing's green isolation areas entered into a large-scale construction stage since the 1990s, the pace of accelerating construction of the second green isolation area started around 2003, so 2000, 2010, and 2020 were selected as the research periods herein.

3.1.2. Data Sources. The data hereto contain administrative boundary vector data, GDP data, and land cover data in the corresponding research period. Among them, the administrative boundary vector data are the transformation results of the research team based on the *Basic Geographical Map of Beijing Administrative Boundaries (2020 Edition)*, and the basic data are derived from "Tianditu Beijing" (https://beijing.tianditu.gov.cn/). GDP data within the research scope are mainly sourced from national science and technology basic condition platform—the National Earth System Science Data Center (http://www.geodata.cn), and the vector data of the national GDP kilometer grids are prepared by WGS 1984 geographic coordinate system. The land cover data are mainly sourced from the global land cover data product service website of the National Geomatics Center of China (DOI: 10.11769). The three-period land use data provided by GlobeLand30, a global land cover data product provided by the National Geomatics Center of China, are the global land cover data of a spatial resolution 30 m $*$ 30 m, with data types divided into farmland, forest land, grassland, shrub land, wetland, water body, tundra, artificial surface, bare land, glacier, and permanent snow cover, based on the WGS 1984 geographic coordinate system. All data adopted are projected on WGS 1984 geographic coordinate system and coincide in spatial position, effectively guaranteeing the accuracy of the research process in data trimming, data space linking, and EEH calculation.

3.2. Research Methods

3.2.1. Estimation of Ecosystem Service Value (ESV). The estimation of ecosystem service value (ESV) represents an objective cognition of the services provided by the ecosystem to the human society and the value transmitted to economic society [35]. As the ecosystem is a complex giant system due to its structure, process, and functions, it is difficult to unify the evaluation method and parameter standard for each ESV, bringing about different results of the benchmark unit price of ESV calculated by different calculation methods. Therefore, the estimated ESV is a relative index. At present, the main estimation methods include the function value method and the equivalent factor method. As kilometer grids were taken as the basic units in this research, which, however, are difficult to measure the price of unit service function, the equivalent factor method was adopted to calculate the benchmark unit price of ESV based on the value equivalent per unit area.

Based on the widely recognized research results [36, 37] of scholars Coastanza and Xie Gaodi, the benchmark unit price of ESV corresponding to the acquired land cover data (as shown in Table 1) was mainly determined with reference to the equivalent factor method improved by Xie Gaodi et al., to calculate the ESV changes, supplemented by the adjustment of Li Kuiming et al. to the equivalent factor for Beijing-Tianjin-Hebei region [38]. The formula for estimating the ecosystem service value (ESV) is as follows:

$$\mathrm{ESV} = \sum_{i=1}^{m}\sum_{j=1}^{n} A_j E_{ij} \, (i = 1, 2, 3, \ldots, m;\ j = 1, 2, 3, \ldots, n). \tag{1}$$

Note: ESV refers to ecosystem service value; A_j refers to the area of j-type land; E_{ij} refers to the benchmark unit price of total ecosystem service value of j-type land per unit area within unit time/(yuan/hm^2 a). For the benchmark unit price of the ESV, the year is selected as the unit time and hectare as the unit area.*Note.* The data provided by GlobeLand30 are divided into 10 types, but the data types of

Table 1: Ecological service value per unit area of Land (Yuan/hm^{2}a).

Ecosystem function		Land types							
		Farmland	Forest land	Grassland	Shrub land	Waters	Artificial surface	Bare land	Wetland
Supply	Food production	745.17	231.00	74.52	163.94	596.14	0.00	0	380.04
	Raw materials production	290.62	529.07	104.32	245.91	171.39	0.00	0	372.59
Regulation	Gas regulation	536.52	1751.15	380.04	849.49	573.78	0.00	14.9	1415.82
	Climate regulation	722.81	5238.55	998.53	2250.41	1706.44	0.00	0	2682.61
	Hydrological regulation	573.78	2615.55	730.27	1646.83	76186.18	−5596.23	22.36	18055.47
	Waste disposal	1035.79	1482.89	327.87	745.17	4135.69	−1833.12	74.5	2682.61
Support	Soil conservation	1095.40	2131.19	462.01	1035.76	693.01	126.68	14.9	1721.34
	Maintaining biodiversity	760.07	1937.44	417.30	946.37	1900.18	298.07	14.9	5864.49
Culture	Providing aesthetic landscape	126.68	849.49	186.29	417.30	1408.37	178.84	7.45	3524.65
	Total	5886.84	16766.33	3681.15	8301.18	87371.18	-6825.76	149.01	36699.62

tundra, glacier, and permanent snow cover are not involved in the research scope, so the benchmark unit price of their ESV is not determined.

Based on the benchmark unit price of ESV and land cover data types, ArcGIS 10.2 software was employed to calculate the grid data of ESV with a spatial resolution of 30 m ∗ 30 m. Using fishing net tools, spatial links, and other tools, the grid data with a spatial resolution of 30 m ∗ 30 m were processed into kilometer grid data by the calculation formula of ecosystem service value (ESV), then the kilometer grid data of ESV with a precision of 1 km ∗ 1 km in Beijing and the second green isolation area in 2000, 2010, and 2020 were obtained.

When constructing the fishing net with a precision of 1 km ∗ 1 km, the GDP kilometer grid scope was taken as the spatial reference, and topological verification was carried out after generation of the fishing net with a precision of 1 km ∗ 1 km, ensuring the spatial overlapping of the ESV kilometer grids with the GDP kilometer grids, and effectively guaranteeing the subsequent calculation accuracy of the EEH.

3.2.2. Estimation and Zoning of EEH. Based on the literature review, the EEH estimation method has been disputed. The EEH obtained from data calculation based on the value of ecological and economic system is a relative index. At present, the widely used method for estimating the EEH (EEH) takes the ratio of ESVpr to GDPpr as the relative index—by calculating and referencing the ratio of ESVpr of the basic unit to GDPpr of the basic unit during corresponding research periods [39]. This ratio can effectively quantify the harmonious relationship between economic development and ecological change and better dynamically compare the degree of mutual influence between ecological environment change and economic development within the research period [39].

As mentioned above, ArcGIS 10.2 was used to complete the estimation of ESV and then convert it into grid vector data. Next, the ESV kilometer grid data and GDP kilometer grid data were linked and placed in the same layer. The EEH in 2000–2010 and 2010–2020 was estimated using the formula of EEH. The relevant formula for estimating EEH is as follows:

$$\mathrm{EEH} = \frac{\mathrm{ESV}_{\mathrm{pr}}}{\mathrm{GDP}_{\mathrm{pr}}}, \tag{2}$$

$$\mathrm{ESV}_{\mathrm{pr}} = \frac{\mathrm{ESV}_{\mathrm{pj}} - \mathrm{ESV}_{\mathrm{pi}}}{\mathrm{ESV}_{\mathrm{pi}}}, \tag{3}$$

$$\mathrm{GDP}_{\mathrm{pr}} = \frac{\mathrm{GDP}_{\mathrm{pj}} - \mathrm{GDP}_{\mathrm{pi}}}{\mathrm{GDP}_{\mathrm{pi}}}. \tag{4}$$

Note: EEH refers to the index of EEH; ESVpi refers to the ecosystem service value (ESV) of each research unit in the starting year within the research period/100 million yuan; ESVpj refers to the ecosystem service value (ESV) of each research unit in the last year within the research period (/ten thousand yuan); GDPpi refers to the GDP of each research unit in the starting year within the research period (/ten thousand yuan); GDPpj refers to the GDP of each research unit in the last year within the research period (/ten thousand yuan).

Based on the operation results of formulas (3) and (4), formula (2) may have the following five results: Result 1—if formula (3), i.e., ESVpr has an operation result bigger than or equal to 0, and formula (4), i.e., GDPpr has an operation result bigger than 0, the result of formula (2) will be bigger than or equal to 0; Result 2—if ESVpr has an operation result bigger than 0, and GDPpr has an operation result less than 0, the result of formula (2) is less than 0; Result 3—if ESVpr has an operation result less than or equal to 0, and GDPpr has an operation result bigger than 0, the result of formula (2) is less than or equal to 0; Result 4—if ESVpr has an operation result less than 0, and GDPpr has an operation result less than 0, the result of formula (2) is bigger than 0; Result 5—if the result of GDPpr is 0, formula (2) is untenable. Among the above-specified results, Result 4 and Result 5 have the greatest influence on the accuracy of the EEH calculation result of formula (2). With the second green isolation area of Beijing as the research subject, the economy of Beijing from 2000 to 2020 was on a fast track, and there were few units with negative GDP growth or no change. In this research,

there were few units with negative GDP growth in the basic unit grids, and no basic units with GDPpr result of 0. Therefore, the poor influence of results 4 and 5 on the accuracy of the overall analysis results could be ignored.

In Result 1, if ESV of the research unit ecosystem increased, the economy developed positively, and if the increase rate was greater, the ecological environment was effectively protected, and the eco-economic system achieved sustainable development. In Result 2, if ESV of the ecosystem increased, the economy experienced negative growth, the ecological system was restricted by economic development, its self-recovery and improving ability was affected, so the EEH was poor. In Result 3, when the economy of the research unit developed positively, its GDP increased continuously with a compromise of the ESV of its ecosystem. Based on existing research, the results of EEH during 2000–2010 and 2010–2020 were classified in detail, and the EEH was divided into 10 levels; the higher level indicated the higher EEH, with the results listed in Table 2.

4. Result Analysis

The second green isolation area is located at the edge of the central urban area of Beijing. In order to showcase the development of its eco-economic system more intuitively and compare it with other areas of Beijing, the whole eco-economic system of Beijing was also analyzed.

4.1. Development and Change of GDP in the Second Green Isolation Area. From 2000 to 2020, China witnessed rapid economic development, and Beijing, the capital of China, experienced roaring economic growth. Despite the main function of the second green isolation area being to relieve the immigration of the capital and ease the disorderly urban sprawl, under the background of the huge development of the times, the economy of the second green isolation area has made great progress. The gross GDP of the second green isolation area registered 39.27 billion yuan in 2000, 246.712 billion yuan in 2010, and 1,293.501 billion yuan in 2020. Thus, the economy of the second green isolation area reached a state of high-speed growth in the two decades.

According to the GDP distribution of kilometer grid units, the economic GDP of the inner areas adjacent to the central urban areas was higher than that of the periphery during the three research periods (as shown in Figure 2), and the economic, spatial evolution characteristics were relatively fixed. In 2000, economic development of the second green isolation area was relatively balanced, and there was little difference between the maximum and minimum GDP value of the kilometer grid basic units. The minimum value of the basic unit was about 2.6 million yuan and the maximum value was about 27.18 million yuan. The basic units with lower GDP value were mainly distributed in Yangfang Town, Nanzhao Town, and Baishan Town in Changping District on the northwest side of the second green isolation area, and the basic units with higher GDP value were mainly distributed in the inner west, central area, and whole eastern area. In 2010, the gap of economic development between the inner and outer ring in the second green isolation area increased; the minimum value of basic units was about 16.76 million yuan, and the maximum value was about 164.74 million yuan. The basic units with lower GDP value were mainly distributed in the peripheral northwest and east of the second green isolation area-some towns (subdistricts) of Changping District and Tongzhou District, while the basic units with higher GDP value were mainly distributed in the inner side adjacent to the central urban area of Beijing and some peripheral towns (subdistricts) of Daxing District and Shunyi District. In 2020, the economic development gap between the inner and outer sides of the second green isolation area further widened - the minimum value of basic units was about 15.31 million yuan, and the maximum value was about 2,848.99 million yuan. The basic units with lower GDP value were mainly distributed in some towns (subdistricts) of Fangshan District and Mentougou District on the east side of the periphery of the second green isolation area, while the basic units with higher GDP value were mainly distributed in some towns (subdistricts) of Haidian District and Chaoyang District near the central urban area of Beijing in the inner north. It can thus be seen that, although the economy of the second green isolation area developed rapidly in the past two decades, the imbalance of economic development deepened gradually. This phenomenon is related to the overall economic development of Beijing (as shown in Figure 3): notwithstanding several economic cores that emerged in the development process of Beijing in the past two decades, and new areas such as Shunyi District and Tongzhou District have been actively constructed, the economic cores are still concentrated in the central urban area, such that the economic aggregate of the central urban area is much higher than that of the outer suburbs, resulting in uneven economic development inside and outside of the second green isolation area.

4.2. Development and Change of Ecological Service Value in the Second Green Isolation Area. Based on the equivalent factor method, the change of ecological service value(ESV) in the second green isolation area was mainly affected by the change of land cover (as shown in Figure 4). From 2000 to 2020, the land type with the largest increment of land cover in the second green isolation area was artificial land surface—a large number of farmland converted to the artificial land surface. Besides, the grassland and forest land also increased from 2010 to 2020, as a positive impact of the construction policy of country park rings in the second green isolation area. If comparatively analyzing the land use change in the second green isolation area and Beijing's land use change (as shown in Figure 5), it can be concluded that the past two decades witnessed an incremental development of land use in Beijing. As a result, the urban artificial land surface spread outward from the central urban area, resulting in the expansion of the artificial land surface in the second green isolation area from the inner to the outer side. On the whole, the spatial evolution characteristics were relatively fixed.

Table 2: Classification criteria of ecological-economic system harmony.

S/N	Type	Scope	Description
1	Level 10	$0.8 \leq EEH \leq 1$	The eco-economic system develops harmoniously towards a sustainable state
2	Level 9	$0.6 \leq EEH < 0.8$	The eco-economic system develops positively with good harmony
3	Level 8	$0.4 \leq EEH < 0.6$	The eco-economic system is well developed in a harmonious manner
4	Level 7	$0.2 \leq EEH < 0.4$ or $EEH > 1$	The balanced development of eco-economic system promotes harmonious development
5	Level 6	$0 \leq EEH < 0.2$	Both the ecosystem and economic system develop positively, but the economy develops rapidly and the ecosystem is relatively stable
6	Level 5	$-0.2 \leq EEH < 0$	The service value of ecosystem declines, while the economy keeps growing at a relatively high speed, and the eco-economic system is still relatively stable, but attention shall be paid to ecological conservation to prevent further degradation of ecological environment quality
7	Level 4	$-0.4 \leq EEH < -0.2$	The ecosystem is poorly developed, and the harmony between economic development and ecosystem construction is reduced
8	Level 3	$-0.6 \leq EEH < -0.4$	The development of the eco-economic system is relatively unharmonious and ESV declines to some extent
9	Level 2	$-0.8 \leq EEH < -0.6$	The development of the eco-economic system is unharmonious, and the ecosystem is adversely affected by compromise of the service value
10	Level 1	$EEH < -0.8$	The development of ecological and economic systems is not matched and harmonious

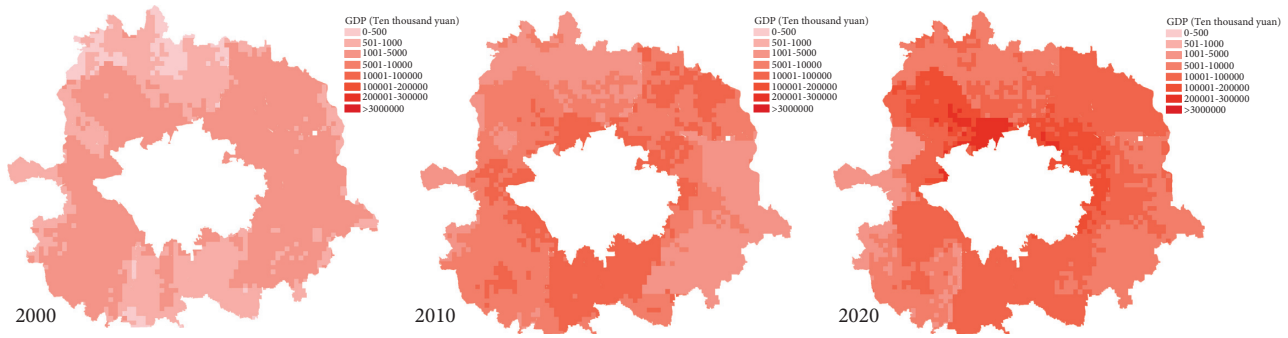

Figure 2: GDP development and change of the second green isolation area (2000–2020).

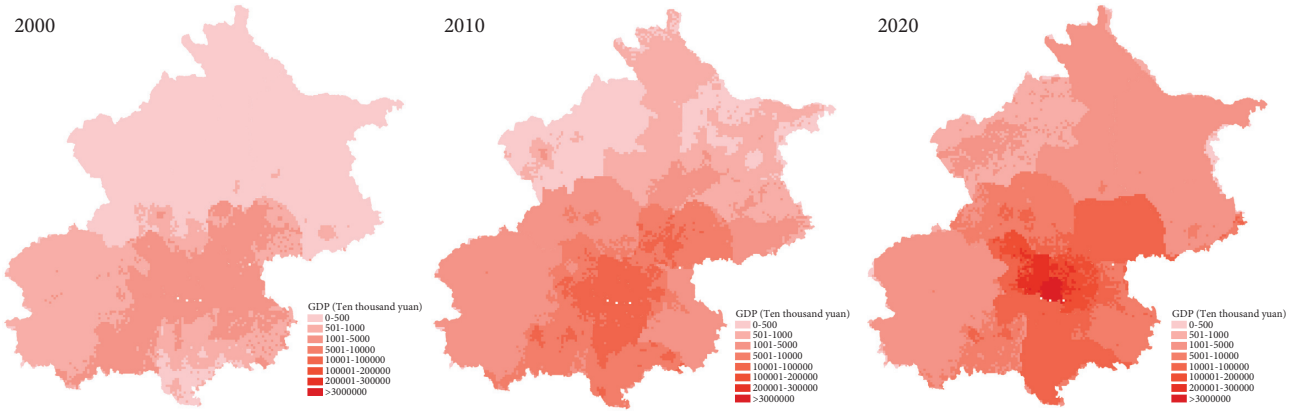

Figure 3: GDP development and change of Beijing (2000–2020).

In terms of ecological service value (ESV), judging from the distribution of ESV in kilometer grid units, the high ESV values in the second green isolation area during the three study periods are mainly distributed in the mountainous region of Mentougou District on the west side and the urban water system, whilst the low ESV values are mainly distributed in the artificial expansion area (as shown in Figure 6). It is worth noting that with the continuous construction of the second green isolation area—increasing green space, implementing decremental development, and constructing a country park ring, high ESV units increased in terms of urban built-up areas except for the western

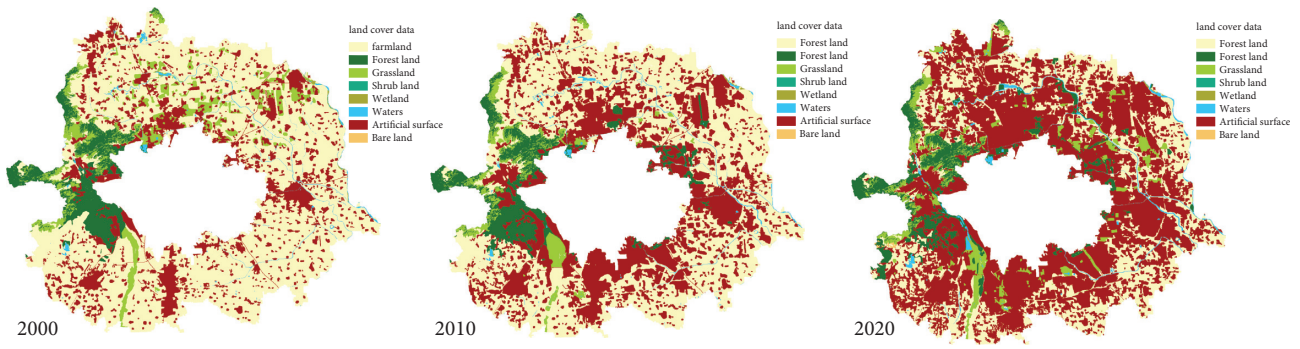

Figure 4: Land cover change of the second green isolation area (2000–2020).

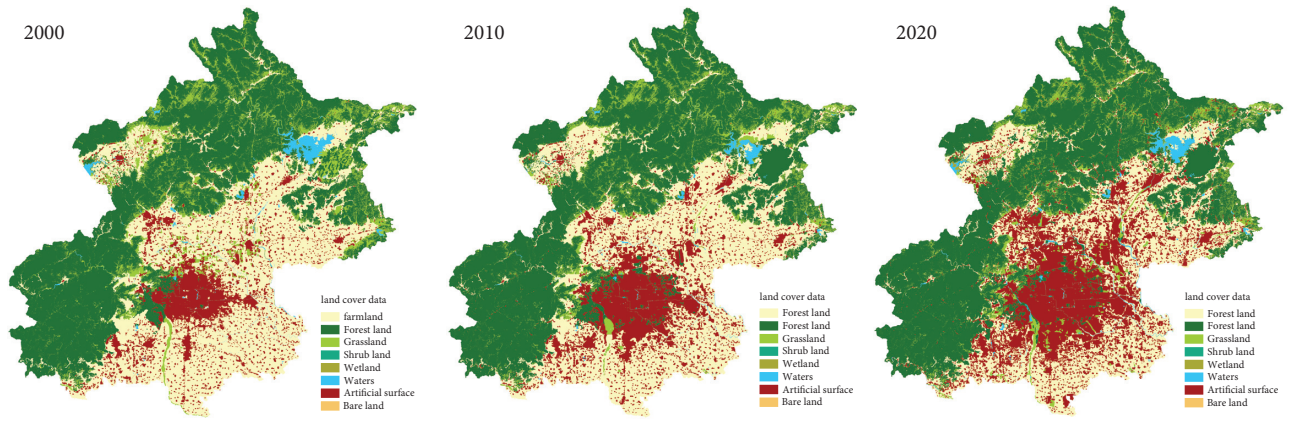

Figure 5: Land cover change of Beijing (2000–2020).

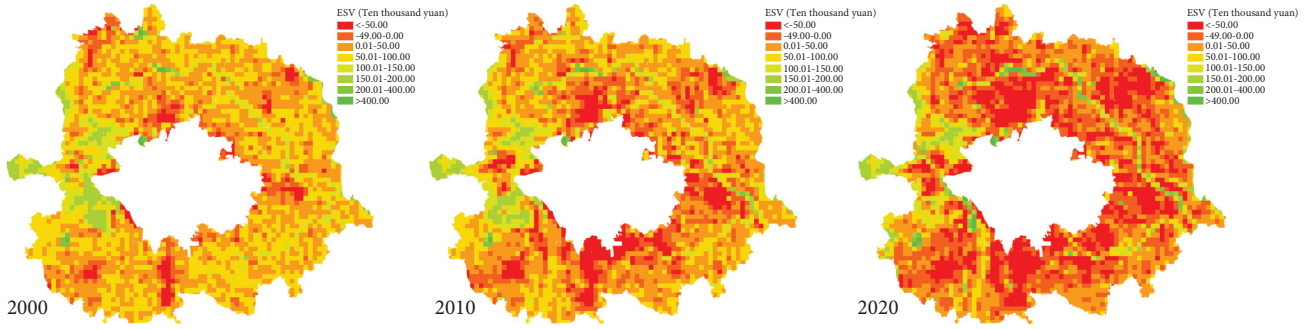

Figure 6: ESV change of the second green isolation area (2000–2020).

mountainous areas. On the whole, however, the ecological service value of the second green isolation area has been decreasing from 2000 to 2020, in tune with the total ecological service value in Beijing (as shown in Figure 7), which was 17.1 billion yuan, 15.7 billion yuan, and 14.9 billion yuan in 2000, 2010 and 2020, respectively. This is because, in the context of urban increment, the ecological environment made concessions for economic development, so a large amount of farmland was converted into an artificial land surface, resulting in a negative increase of ESV.

4.3. Development and Change of EEH in the Second Green Isolation Area. Based on GDP kilometer grids and ESV kilometer grids during the research periods, the statistical calculation results of the EEH in the second green isolation area (as shown in Table 3) show that there were most basic units in Level 5 and Level 6 from 2000 to 2020, of which those in Level 5 and Level 6 from 2000 to 2010 accounted for 77.7% and those in Level 5 and Level 6 from 2010 to 2020 accounted for 41.6%. In terms of time sequence changes during the research period of 2010–2020, the number of units with lower levels such as Level 1, Level 2, Level 3, and Level 4 increased significantly. Correspondingly, the number of units with higher levels such as Level 7, Level 8, Level 9, and Level 10 also increased. On a comparative basis, the EEH in the second green isolation area during 2010–2020 had a trend of polarization (as shown in Figure 8). From the perspective of spatial changes for either the basic unit of the kilometer grids or the township units (as shown in Figure 9),

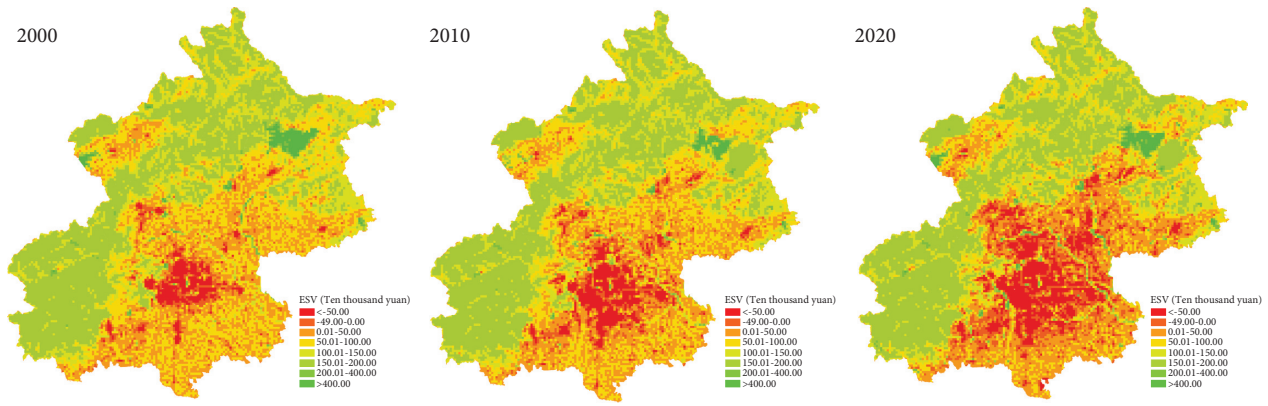

Figure 7: ESV change of Beijing (2000–2020).

Table 3: Category conversion and unit quantity of EEH in the second green isolation area.

Status type	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10	Total
2000–2010	0	1	29	181	1109	1730	73	33	4	4	3,164
2010–2020	245	140	270	371	755	1088	247	26	10	12	3,164

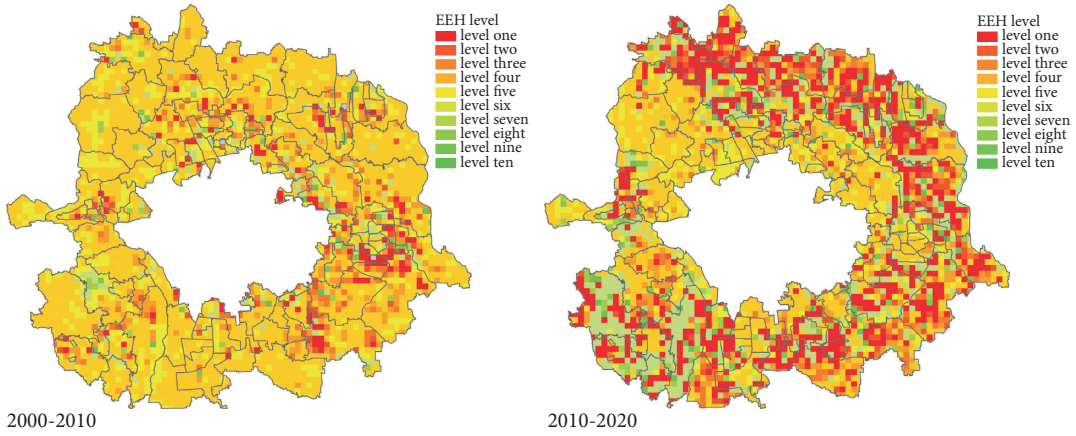

Figure 8: EEH change of grid units in the second green isolation area (2000–2020).

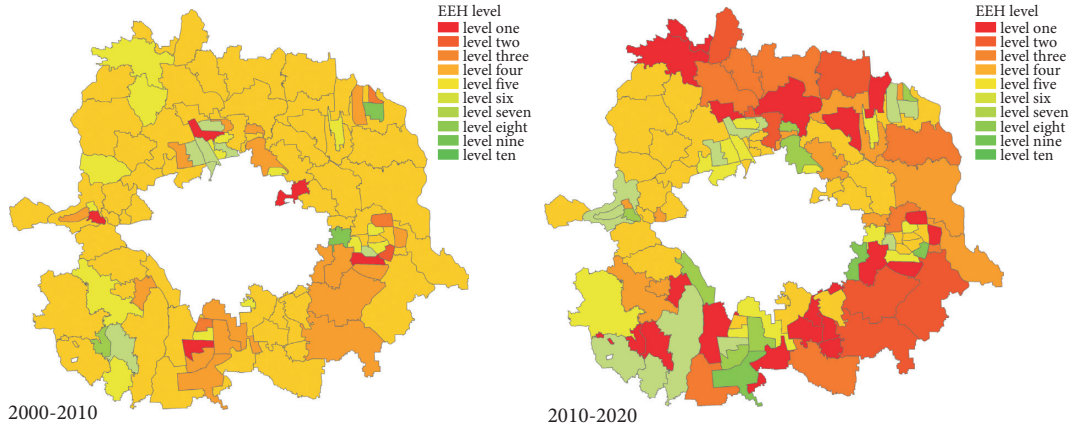

Figure 9: EEH change of township units in the second green isolation area (2000–2020). Note: the administrative boundary vector data are the transformation results of the research team based on the *Basic Geographical Map of Beijing Administrative Boundaries (2020 Edition)*.

the areas with a significant decrease of EEH during the research periods were concentrated on the periphery of the second green isolation area.

The polarization of EEH in the second green isolation area is related to the development of Beijing. According to the EEH of Beijing during the research periods (as shown in Figure 10), there were most basic units with overall EEH in Level 6 from 2000 to 2010 and a majority of basic units in Level 5 from 2010 to 2020. The areas with a significant decrease of EEH were concentrated in the newly-added artificial land surfaces. Beijing, as the capital of our country, is one of the regions with the fastest economic development in China. With the rapid development of the urban economy, the urban incremental development inevitably resulted in the transformation of some ecosystem land into construction land in Beijing. That is to say, a large number of land types such as forest land, grassland, and wetland shown in the land cover data were transformed into artificial land, which reduced the overall ESV of the city inevitably. However, the development of Beijing has recently reached a new stage from incremental development to stock development, and its economic development has transformed from high-speed to high-quality development. So, overall construction volume in Beijing was under control, and measures were taken to reduce the urban capacity, increase green spaces and improve quality. The second green isolation area, as an important area for reducing urban population and controlling urban sprawl in Beijing, accommodated the construction land both for the sprawl of the central urban area and for the spread of urban towns in Huairou District, Miyun District, Shunyi District, and Tongzhou District. Yet, due to the rapid development of an early entry into the stock development of the central urban area, the new construction land in the second green isolation area increased more in the outer area, resulting in the decrease of the EEH outside the second green isolation area. At the same time, as an important green space in Beijing, the second green isolation area was proposed to construct a country park ring in the latest general planning of Beijing, which brought about continuous construction of large parks in the second green isolation area in recent years. A large amount of green space construction increased the number of units with higher EEH in the second green isolation area, finally forming the state of polarization of the EEH changes.

5. Discussion

5.1. Summary. Based on the basic units of kilometer grids, the EEH in the second green isolation area of Beijing was calculated using the ratio of ESVpr to GDPpr, then compared with the EEH of Beijing, and finally the development of the EEH in the second green isolation area was analyzed in detail.

The study found that the total ecological service value of the ecosystem in the second green isolation area continued to decrease from 2000 to 2020, but the total economic volume continued to increase. At the same time, during the research period, the EEH in the second green isolation area was polarized. Affected by the incremental urban development, the EEH of the outside area with growing artificial surface land decreased significantly. At the same time, as Beijing entered the stage of incremental development, the EEH with growing green spaces increased partly, along with the growing number of units with higher EEH levels.

In summary, the construction of the second green isolation area has indeed increased the green space coverage and the EEH in certain areas, but the sprawl of construction land in the second green isolation area of Beijing has not been effectively controlled, and large-scale construction has been carried out to shape a series of development cores, which generated negative impact on the overall EEH of the second green isolation area. This indicates that under the background of sound economic development, due attention shall be paid to protect the natural environment and prevent the further decrease of the total ESV and worsening of EEH in the second green isolation area.

To implement smoothly the policy of reducing urban capacity, to improve quality and increasing green spaces, and to enhance the harmonious development of the eco-economic system in the second green isolation area, the following suggestions are put forward based on the research results: In general, the units with lower GDP growth rate or negative growth rate can be listed as optional units for green space's site selection, and for the units with extremely high GDP growth rate, it is necessary to increase the green space properly for the purpose of improving the development quality while maintaining the area of green space. For Fangshan District, Mentougou District, and other basic units where the ecological environment is good, the economic growth rate is far lower than that in the central urban area, and the economy is still in the stage of incremental development; it is necessary to improve the quality of economic development on the basis of protecting the ecological environment to avoid the impact of economic development on the environment; for the well-developed basic units such as Haidian District, Fengtai District, and Chaoyang District, it is necessary to increase the green spaces appropriately while improving the quality of economic development; for the basic units with construction margin such as Miyun District, Huairou District, Shunyi District, and Changping District, it is necessary to increase the green space based on the control of the construction quantity.

5.2. Prospect. As there is no unified standard for the calculation method of the ecosystem service price, the benchmark unit price of ecosystem services adopted herein needs to be further analyzed. In particular, it requires for in-depth study on whether the dynamic change of ecosystem service benchmark unit price of the artificial land surface shall be combined with its greening rate. The research hereto focused on discussion of the harmony of the change rate of the ecosystem and economic system in the second green isolation area of Beijing, with its aim of estimating the degree of economic system in the second green isolation area of Beijing, and providing some scientific suggestions on reducing urban capacity and increasing green spaces in the

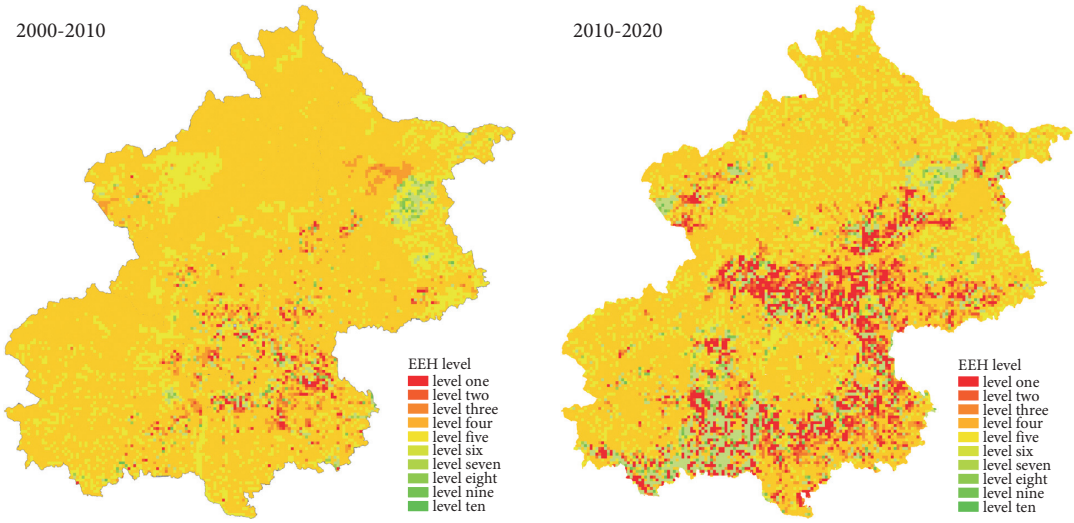

Figure 10: EEH change of township units in the second green isolation area (2000–2020).

second green isolation area. However, the factors affecting the development of the second green isolation area also include social population change, land use degree, etc., which need to be further studied by each research team. In addition, the construction of country park ring in the second green isolation area is still not completed, and under the background of reducing urban capacity and improving quality in Beijing, how the policy of reducing urban capacity, increasing green spaces, and improving quality affects the EEH in the second green isolation area needs continuous concern of each research team.

Data Availability

The data hereto contain administrative boundary vector data, GDP data, and land cover data in the corresponding research period. Among them, the administrative boundary vector data are the transformation results of the research team based on the Basic Geographical Map of Beijing Administrative Boundaries (2020 Edition), and the basic data are derived from "Tianditu • Beijing" (https://beijing.tianditu.gov.cn/). GDP data within the research scope are mainly sourced from the National Science and Technology Basic Condition Platform, the National Earth System Science Data Center (http://www.geodata.cn), and the vector data of the national GDP kilometer grids are prepared by WGS 1984 geographic coordinate system. The land cover data are mainly sourced from the global land cover data product service website of the National Geomatics Center of China (DOI: 10.11769).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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