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AN ECOSYSTEM-SERVICE EVALUATION METHOD OF A RIVER BASIN WITH RAPID CHANGES IN LAND USE WITHIN A SHORT TERM

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Abstract: In 2015, Zhangjiakou City was selected as the co-host city for the 2022 Winter Olympics. In order to improve ecosystem service functions, land use types in the region were changed greatly within the short term. Therefore, existing evaluation methods of the ecosystem service value (ESV) are not applicable to such an underdeveloped region. With the year of 2015 as the key time node, a dynamic process evaluation method of ESV was established for Zhangjiakou City based on classic equivalent factors in this study. The five economic coefficients of net primary productivity (NPP) coefficient, precipitation adjustment coefficient, soil conservation adjustment coefficient, habitat adjustment coefficient and accessibility adjustment coefficient were introduced into the classic method to correct the commonly Chinese equivalent factors to obtain the actual ESV. Firstly, the results obtained from the dynamic process evaluation method could clearly distinguish the changing trend of ecosystem service value (ESV) after the change of land use type. Secondly, the ESV increment calculated with the dynamic process evaluation method was more sensitive to land use change. The change in the forest area proportion was the most significant and reached 6.8%, and corresponding ESV increment was 14.89%. Thirdly, from the perspectives of 11 sub-categories of ecosystem services, the ESV of hydrological regulation was the largest and reached 30%. The ESVs of food production, raw material production, maintenance of nutrient cycle, water supply and aesthetic value supply were relatively small. From the sub-categories of enhancing ecosystem services, the ESV of each sub-category increased after changing land use type. Fourthly, after the introduction of five economic adjustment coefficients, the ESVs of the other four categories of ecosystem services, except the ESV of biodiversity, increased significantly after the change in the land use types. The results indicated that the dynamic evaluation method could better identify the sensitive factors affecting the value of regional ecosystem services.
Keywords: Dynamic process evaluation; Rapid change in land use types; Ecosystem service value; Zhangjiakou City

1 INTRODUCTION

Ecosystem service refers to the products and services that ecosystem provides for human beings through ecological structures, functions and processes [1]. In recent years, due to rapid urban expansion and rapid economic development, human beings have utilized ecosystem services excessively, thus leading to ecosystem degradation [2]. The evaluation of ecosystem service value (ESV) is the foundation of ecosystem protection and management [3]. However, a widely accepted evaluation system of ESV has not yet been developed at home and abroad. The differences in evaluation methods also lead to the significant differences in evaluation results, thus limiting the objective knowledge of ecosystem service functions and their values.

Two types of ESV evaluation methods are currently available, namely, the functional value evaluation method and the equivalent factor evaluation method. In the functional value evaluation method, some economic methods are used to convert the mass of different materials into a unified monetary value [4,5]. This method can accurately measure the size of certain service functions in a region. However, the evaluation of different service functions often requires different ecological equations and parameters and the calculation process is more complicated [6]. Therefore, the method is mostly applied in the regions with developed economy and comprehensive basic data. In addition, when this evaluation method is used, it is necessary to choose the service function to be evaluated and set corresponding parameters, thus leading to the great uncertainty in evaluation results and increasing the difficulty in the comparison among the evaluation results of various ecosystems [7]. The equivalent factor evaluation method was first proposed by Costanza et al. [4]. According to the proposed method, different ecosystem service functions are divided into different categories and the equivalent values are obtained based on the meta-analysis results. Then the regional ESV is obtained with the area of each ecosystem. Compared with the functional value evaluation method, the equivalent factor evaluation method can evaluate the ESV in a large area more effectively and is widely used. Mendoza-González et al. introduced the economic coefficient to evaluate the ESV along the Gulf Coast [8]. Kreuter et al. investigated the impact of urban expansion on ESV in Bexar County from 1976 to 1991 by combining land exchange analysis with the ecosystem service value factor provided by Costanza et al. [9]. Yi et al. evaluated the ecosystem services of the San Antonio River Basin (SARB) in the United States based on land use change by modifying the global equivalent factors. Richardson et al. believed that only the immediate ESV value transfer factor could provide meaningful value information to be transformed [10,11]. Yi et al. pointed out that before the adoption of Costanza's value factor, the economic coefficient should be corrected [10]. The evaluation results of the equivalent factor method were not reliable if the equivalent factor could not accurately reflect the ecological background of study areas [12]. After Costanza et al. first expressed ecosystem services in monetary units, Silvestri et al. [13] evaluated ESVs at different scales, such as global scale [4], regional scale [5], watershed [14], coastal zones [15], and individual ecosystems, such as wetlands [16], forestland and highway [17]. However, when the unit value for the global ecosystem proposed by Costanza et al. was applied in other regions, individual differences were ignored, thus resulting in large errors. In order to solve the current situation of ESV evaluation in China, Xie et al. conducted a questionnaire survey on more than 700 ecologists based on the evaluation model proposed by Costanza and others and obtained the “China Ecosystem Service Value Equivalent Factor Table” [5]. The values of mutual contributions between ecosystem service functions and the economic values of farmland food production services are considered in the table and it is more comprehensive and more targeted than previous evaluation methods. The method developed by Xie et al. solved the conversion problem of global equivalents per unit area in China and had been applied in ESV evaluation of various cases from a regional scale to a national scale [18,19]. However, although the equivalent factor method of Xie et al. solved the regional difference between the world and China, the method evaluated the ESV of the static ecological environment and belonged a static evaluation method. This method could not achieve an accurate evaluation of the ESV of the changing ecological environment. In order to accurately reflect the temporal and spatial changes of the ESV, most scholars currently only provided corrections for the values of food production per unit farmland area. The simple correction was obviously too monotonous and not consistent with the reality. Based on the equivalent factors proposed by Xie et al., five economic indicators were introduced to identify the key factors affecting each service function, and then a spatial heterogeneity evaluation model was established which could reflect the differences in service functions. The model provides a more comprehensive and objective evaluation methodology for rapidly changed land utilization patterns.

This study is based on the ecological status of Zhangjiakou City, which is located in the northwest of Beijing. Zhangjiakou City was originally an economically underdeveloped region. The opportunity of 2022 Winter Olympics promoted its rapid economic development and rapid expansion and the ecosystem services and functions were severely challenged. In order to enhance the ecological services for the 2022 Winter Olympics, local land utilization pattern was rapidly transformed within the short term. Therefore, it is necessary to establish a process ESV evaluation method considering land use change. It can calculate the value of ecosystem service value after land use change, analyze the important factors affecting ESV increment, and guide the conversion of land use type toward ESV increment direction. It provides a new idea for the restoration of environmental ecological systems and the sustainable green development in the region.

2 STUDY AREA AND DATA SOURCES

2.1 Study Area

Zhangjiakou City is located at the junction of Beijing, Hebei, Shanxi, and Inner Mongolia and in the northwestern part of Hebei Province. It is the meeting point of the Beijing-Tianjin-Hebei Economic Circle. Zhangjiakou City has 6 districts (Qiaodong District, Qiaoxi District, Xuanhua District, Xiahua District, Wanquan District, and Chongli District) and 10 counties (Zhangbei County, Kangbao County, Wuyuan County, Shangyi County, Yu County, Yangyuan County, Huai'an County, Huailai County, Zhuolu County, and Chicheng County). Its total area is about 36800 km2 (113°50′~116°30′ E, 39°30′~42°10′ N). In 2015, Zhangjiakou City was officially confirmed as one of the venues of the 24th Winter Olympic Games. Then, regional land use types and their spatial structures have also undergone significant changes, which in turn affected the ESV in the region.

2.2 Data Sources

The land use distribution data from 2013 to 2017 were provided by the Land and Resources Bureau of Zhangjiakou City. The land types in the study area included cultivated land, forest land, grassland, lakes/rivers and unused land. Due to the small area of wetlands in Zhangjiakou City, wetlands were not considered in the study. The data of the types and prices of foods were provided by the Zhangjiakou Municipal Development and Reform Commission and the meteorological data were from the China Meteorological Data Network. Other data were from China Statistical Yearbook and Zhangjiakou City Economic Statistics Yearbook from 2013 to 2017.

3 METHODS

In this study, the ESV change caused by the land use change in Zhangjiakou City was calculated with the unit area value equivalent factor method based on dynamic correction. Firstly, we used the Millennium Ecosystem Evaluation (MA) method as a baseline for the classification of ecosystem services and divided ecosystem services into 11 ESVs. Then, based on previous studies [20-22], five eco-economic indicators were selected to spatially correct the 11 ESVs and the annual ESV changes in the two stages were compared in order to explore the impact of venue announcement of the Winter Olympic Games and the applicability of the process evaluation method in Zhangjiakou City. The plant net primary productivity index (NPP) is generally positively correlated with food production, raw material production, gas regulation, climate regulation, the maintenance of circulating nutrients and environment purification [6]. The precipitation adjustment coefficient could measure the actual level of water supply and hydrological regulation in the study area. The soil conservation spatial-temporal adjustment coefficient was used to regulate the soil conservation function in the study area. The habitat regulation coefficient could modify the biodiversity value according to the resistance encountered by the organism during migration. The accessibility adjustment coefficient could correct the cultural aesthetic service value according to the recreation opportunity spectrum theory. Finally, with the dynamically corrected equivalent factors, the spatial distribution of the ESV of Zhangjiakou City was calculated from the perspectives of land use and 11 ESV subcategories.

3.1 Division of Study Stages

In 2015, Zhangjiakou City was determined as one of the venues for the 2022 Winter Olympics. The land use type change in Zhangjiakou City is shown in Fig. 1. The land use situation was significantly changed from 2015 to 2017. Therefore, we divided the study period from 2013 to 2017 into two stages (one stage from 2013 to 2015 and the other stage from 2015 to 2017), compared the annual ESV changes in the two stages, and further explored the impact of the preparation for the Winter Olympic and the applicability of the process evaluation method in Zhangjiakou City.

3.2 Adjustment Coefficient

The correction of the equivalent factor in this study is based on the equivalent factor table proposed by Xie et al. in 2015. In this study, based on the previous study [12], five key ecological economic indicators were selected to spatially correct 11 ecological service functions as follows:

$$F_{ij} = F_j \times E_{ij} \quad \text{(j=1,2…5)} \tag{1}$$

where Fij refers to the equivalent factor of the j-th type of service function of a certain ecosystem in the i-th region; Fj refers to the national average equivalent factor of the ecosystem (where the first category of service functions include food production, raw material production, gas regulation, climate regulation, maintenance of nutrient cycling and environment purification; Category 2 includes water supply and hydrological regulation; Category 3 refers to biodiversity; Category 4 refers to soil conservation; Category 5 refers to aesthetic landscape); Eij refers to the spatial regulation factor of the ecosystem in the i-th region for the j-th service function (Ei1 to Ei5 correspond to five types of service functions, respectively referred to as NPP regulatory factors, rainfall adjustment factors, habitat quality adjustment factors, soil erosion degree adjustment factors and accessibility adjustment factor).

3.2.1 NPP adjustment coefficient

Supply service refers to products obtained from ecosystems, such as foods, fuels, fibers, freshwater, and genetic resources. These service functions are generally positively correlated with biomass. The net primary productivity index (NPP) reflects the efficiency of carbon fixation and light energy conversion. NPP directly reflects the production capacity of vegetation community in natural environment and is the main factor regulating the terrestrial ecological process. The NPP regulation factor is calculated as follows:

$$E_{\mathrm{i1}} = N_{\mathrm{iv}} / \overline{N} \tag{2}$$

where Niv refers to the NPP (t•hm-2) of the v-th month in the i-th region of this ecosystem; $\overline{N}$ represents the national annual average NPP (t•hm-2) of this ecosystem.

3.2.2 Precipitation adjustment coefficient

The water supply and hydrological regulation are related to the change in precipitation. The precipitation regulation factors are as follows:

$$E_{i2} = H_{iv} / \overline{H} \tag{3}$$

where Hiv is the average unit area precipitation (mm•hm-2) in the v-th month of the i-th region; $\overline{H}$ is the average unit area precipitation (mm•hm-2) in the whole country. According to the precipitation data of each meteorological station in Zhangjiakou from 2013 to 2017, the monthly average precipitation of each region is calculated by Kriging interpolation in ArcGIS10.2 and the precipitation regulating factor is obtained with Eq. (3).

3.2.3 Soil conservation adjustment coefficient

Based on the most widely used soil loss equation for estimating soil erosion, the adjustment factors of spatio-temporal variations of soil conservation equivalent factors in different regions are calculated as follows:

$$E_{i3} = E_{iv} / \overline{E} \tag{4}$$

where Eiv is the simulation amount of soil conservation in the v-th month of the i-th region; $\overline{E}$ is the average simulation quantity of soil conservation per unit area in China. In this study, based on the simulation quantity of soil conservation calculated with the general soil loss equation, the spatiotemporal adjustment factors of soil conservation were obtained.

3.2.4 Habit quality adjustment coefficient

Creatures encounter different resistances when they migrate between different land types. The greater the resistance is, the greater the migration difficulty is. The resistance leads to poor habitat quality and affects regional biodiversity levels [23]. Forest land is the most suitable habitat for terrestrial organisms. Therefore, in this study, forest lands were extracted from land use data as the ecological source, whereas other land types were set as cost grids. Cost parameters were set according to the report by Li. et al [24]. The habitat quality adjustment factor is calculated as follows:

$$E_{i4} = 1/\left(\frac{R_i}{\overline{R_i}}\right) \tag{5}$$

where R_i is the average resistance of the i-th region and $\overline{R}_i$ is the national average resistance.

3.2.5 Accessibility adjustment coefficient

According to the theory of Recreation Opportunity Spectrum (ROS) [21], cultural service function is determined by two key factors, namely, entertainment potential index (RPI) and recreation accessibility index. The equivalent factors of cultural services reflect the RPI of different land ecosystems and the accessibility determines the actual supply level of cultural services in these ecosystems. The accessibility adjustment factor is calculated as follows:

$$E_{i5} = RD_i / \overline{RD_i} \tag{6}$$

where RD_i is the average road density (km/hm2) of the i-th region; $\overline{RD_i}$ is the national average road density.

3.3 ESV Per Unit Area in Zhangjiakou

In the ESV equivalent factor table revised by Xie et al. in 2015 [6], the economic value of annual natural grain output of the farmland with an area of 1 hm2 is defined as 1 and the ESV equivalent factors of other ecosystems are the contribution of corresponding ecosystems to the food production and services of the farmland. The weighted average of the net profit of corn, naked oats, potatoes and other food crops was treated as the standard equivalent factor value. Due to the fluctuation of planting area and grain price caused by natural and market factors, the average value of net grain profit from 2013 to 2017 was taken as the economic value of standard equivalent factor in this study. The equivalent factors in Zhangjiakou City are shown in Table 1. The economic value of the standard equivalent factor in this study is calculated as follows:

$$\mathrm{E_a} = 1/7 \sum_{\mathrm{i}=1}^{\mathrm{n}} \frac{\mathrm{m_j p_j q_j}}{\mathrm{M}} \quad (\mathrm{i}=1,2,3\ldots,\mathrm{n}) \tag{7}$$

$$P_{ij} = F_{ij} \times E_a \tag{8}$$

where Ea indicates food production value per unit area of farmland (RMB/hm2); i is the crop type, pi is the average price of the i–th crop (RMB / t); qi is the unit yield of the i–th crop (t/hm2); mi is the area of the i–th crop (hm2); m is the total area of n crops (hm2); Pij is the unit area value (RMB/(hm2·a)) of the j-th ecosystem services in the i-th region; F_{ij} is the unit area value equivalent of the j-th ecosystem in the i-th region.

3.4 Dynamic Evaluation Model of Zhangjiakou's ESV

ESV is calculated as follows:

$$ESV = \sum S_j \times P_j \tag{9}$$

where ESV is the total value of regional ecosystem services (RMB); S_j is the area of the j-th ecosystem (hm2).

4 RESULTS

4.1 ESVs of Different Land-Use Types

According to the dynamic evaluation method, the ESVs of various land use types in Zhangjiakou City from 2013 to 2017 were evaluated with Eq. (9). The ESV of Zhangjiakou City firstly decreased from 2013 to 2015 and then increased from 2015 to 2017 (Table 2). In 2017, the total ESV of Zhangjiakou City reached ¥ 242.22 billion, which was ¥ 5.06 billion higher than that of 2015, indicating that the process evaluation method could detect the total ESV change in this area. Fig. 2 shows the ESVs of various land use types. The ESV differences among different types of lands are significant (Fig. 2). In the study period, forests, lakes and grasslands contributed the majority to the entire ESV, about 90%. Compared to forests, lakes and grasslands, the other two types of land use (farmland and unused land) provided relatively small ESVs. Among them, the ESV ratio of cultivated land decreased firstly and then increased, and the ESV of unused land decreased year by year. At the same time, the process evaluation method could identify the sub-category changes of ESV in the region. The area increments of cultivated lands, forest, lake/river and grasslands in the second stage were increased compared with those in the first stage (Fig. 3). The area increment of forest land was 6.26% and corresponding ESV increment was 14.89%. The area increment of cultivated land was 5.60% and corresponding ESV increment was 14.51%. The area of unused land was decreased by 0.7% and corresponding ESV increment was -8.37%. The above results indicated that the ESV calculated with the process evaluation method was sensitive to the change in land use type.

4.2 ESVs of Different Sub-Categories

The ESVs of different sub-categories of ecosystem services are shown in Table 3. ESV proportions of hydrological regulation and climate regulation were the largest and respectively reached 30% and 20%. The ESV proportions of gas regulation, waste treatment, biodiversity maintenance, soil conservation were more than 5% and the ESV proportions for the other five sub-categories of food production, the production of raw materials, maintenance of nutrient cycling, water supply and providing aesthetic values were all less than 5%. The hydrological regulation service, which was mainly provided by forestland and lakes/rivers, accounted for the largest proportion of 32.55% in 2017 (Fig. 4). The services of climate regulation, gas regulation, waste treatment, biodiversity maintenance and soil conservation, which were mainly ascribed to forestland, accounted for 55% of the total value. However, the ESVs of the services of food production, raw material production, maintenance of nutrient cycling, water supply and providing aesthetic values shared the smaller proportion. The results of the sub-category of the process growth of ecosystem services are shown in Fig. 5. The ESV growth rate of each sub-category in the period from 2015 to 2017 was higher than that in the period from 2013 to 2015 (Fig. 5), especially the two ecological functions (food production; soil conservation). The ESV growth rates of these two functions from 2013 to 2015 were only - 0.14% and - 0.42%, whereas the ESV growth rates of the two functions from 2015 to 2017 were respectively 4.51% and 5.27%. The above results showed that various ecological transformation policies for the Winter Olympics increased the total ESV and the growth rate of multiple sub-categories. The process evaluation method could accurately identify the changes.

4.3 Influences of Economic Adjustment Coefficients on Different Types of ESVs

The functions of food production, raw material production, waste treatment, climate regulation, gas regulation and nutrient cycling were changed significantly after the correction (Fig. 6) because the introduction of NPP significantly improved the equivalent factors of the service value of the first category of ecosystems. The values of ecosystem services, such as water supply and hydrological regulation, were respectively increased by ¥ 1.1×107 RMB and ¥ 3.6×108 after the correction, indicating that the values of ecosystem services in the second category was significantly affected by precipitation. Due to the serious soil erosion in Zhangjiakou, before the ecological policy of returning farmland to forest was adopted, the habitat was damaged seriously and the migration process of animals was damaged. No significant change was observed in the study period and the value of biodiversity was reduced by ¥ 1.7×108. The growth rate of soil conservation value was 5.23% after the correction (Fig. 6) because the change of soil conservation value in Zhangjiakou City could be accurately identified after adjusting the service value of such ecosystem with soil erosion factors. The providing aesthetic value was significantly changed after the correction because the actual supply level of landscape aesthetics in Zhangjiakou City was significantly improved after the introduction of accessibility factors. In conclusion, the five economic adjustment coefficients used in this paper could identify the sensitive factors that affect ESV in this area. The method could provide the more targeted results.

5 DISCUSSION

The ecosystem service value of Zhangjiakou City was obtained with the process evaluation method before and after Zhangjiakou City was determined as the venue of the 2022 Winter Olympic Games. According to the detailed composition of ecosystem service functions, the advantages and influencing factors of the process evaluation method are summarized below.

Firstly, in the process evaluation method, NPP was selected to correct the equivalent factor of the first category of service functions because the net primary productivity of vegetation could measure the impact of the regional land use change process on vegetation with a unified scale. Ecosystem services such as climate regulation, gas regulation and nutrient cycling were closely related to forest covering. The ecosystem service functions such as climate regulation, gas regulation and nutrient cycling were increased significantly in this area, indicating that the process evaluation method could accurately identify the spatio-temporal regulation factors, and quantitatively reflect the ESV changes of the above ecosystem service functions during the land use transformation period.

Secondly, the functions of water supply and hydrological regulation were strongly affected by precipitation. In the study, precipitation regulation factors were used to modify the service value of the second category of ecosystems. The precipitation of Zhangjiakou City from 2013 to 2017 was slightly higher than that of the whole country, and the ESV increment of water supply and hydrological regulation were respectively 1.68% and 0.95%, indicating that the process evaluation method could identify the influencing factors of ecosystem service functions more accurately than the uncorrected equivalent factor evaluation method.

Thirdly, soil conservation was affected by natural soil erosion, precipitation, vegetation coverage and other factors. Soil erosion coefficient was affected by the above factors and could be used to measure soil conservation capacity. The process dynamic evaluation method modified by soil erosion factors indicated that the soil conservation value of Zhangjiakou City was obviously affected by land use change. Soil conservation value accounted for about 10% of the total ESV and increased year by year, indicating that the soil conservation value in Zhangjiakou City could be dynamically identified by the equivalent factor modified with soil erosion factor. In addition, the soil conservation value was increased by 5.23% compared with the evaluation result obtained with the national equivalent factor, indicating that the process evaluation method could accurately identify the influencing factors of soil conservation function.

Fourthly, the values of ecosystem services, such as food production, raw material production and environment purification, were closely related to the economic level and the technological development level. The proportion of the primary industry in Zhangjiakou was higher and the proportions of secondary industry and tertiary industry were lower. The ecological preparation for the Winter Olympic Games greatly promoted the optimization of economic structure and rapid economic development. The values of food production and raw material production also increased significantly with the growth of economic level (Fig. 4). Zhangjiakou City, due to the 2022 Olympic Games, promoted the establishment of diversified clean energy supply systems such as wind power, solar photovoltaic, clean coal power, biomass energy and geothermal energy, accelerated the establishment of a clean and efficient Olympic energy supply system, and significantly improved the environment purification ability.
Fifthly, aesthetic value reflects the actual potential of landscape aesthetics and the accessibility factor reflects the supply level of landscape aesthetics by measuring the convenience of a certain location to a designated location. The more convenient the transportation is, the stronger the supply functions of culture and entertainments are. The aesthetic value of Zhangjiakou was significantly affected by accessibility factors. The aesthetic value provided by the region was increased by 1.21% from 2015 to 2017 (Fig. 3) and the increment was ¥ 1100×104, indicating that the process evaluation method could adjust the aesthetic value of the region with accessibility factors.

6 CONCLUSION

In underdeveloped areas experiencing dramatic changes of land use types within a short period, a suitable evaluation method of ecological values is not available. In the study, based on the consideration of NPP adjustment coefficient, rainfall adjustment coefficient, soil conservation adjustment coefficient, habitat adjustment coefficient and accessibility regulatory factor adjustment coefficient, a dynamic evaluation method of ecosystem service functions is proposed. Taking Zhangjiakou City as an example, the dynamic process evaluation method was used to calculate and evaluate the changes of ESV. During the entire study period, the ESV of Zhangjiakou City declined in the first phase (2013-2015) and then increased rapidly in the second phase (2015-2017). This change between the two phases clearly indicated that the supporting policy played an active role in protecting ecological zones. The ESV increment of soil conservation was 5.23% after the correction. The ESV increment of cultural aesthetic value was 3.42% and the ESV increments of water supply and hydrological adjustment were respectively 1.68% and 0.95%. The above results showed that the process evaluation method adopted in this study provided more details than the uncorrected evaluation method. From the perspective of the impact of land use on the ESV, the ESV increment was significantly sensitive to land use change. The change proportion of the forest area was the highest and reached 6.8% and corresponding ESV increment was 14.89%. The change proportion of cultivated land area was 5.60% and corresponding ESV increment was 14.51%. In addition, the five economic factor adjustment coefficients selected by the process evaluation method were suitable for analyzing the economically underdeveloped regions with rapid changes in land use types within a short period. The ESV assessment method is applicable to the regions with rapid changes in the land use pattern within a short period. In summary, the evaluation results were consistent with the rapid development of Zhangjiakou City in recent years, indicating that the evaluation results were reasonable and in line with the actual situation. The study provides an effective method for calculating the short-term rapid change of land use in the future. Therefore, Zhangjiakou City should seize the opportunity of the 2022 Winter Olympics to avoid post-Olympic effects and actively promote the reform of ecosystem management and regional green sustainable development. The dynamic process evaluation method also helps to understand or deeply study the dynamic influencing factors of ecosystems, and supports regional planning for the sustainable development of ecosystems.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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