Spatiotemporal variation characteristics of green space ecosystem service value at urban fringes: a case study on Ganjingzi District in Dalian, China

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Abstract: In this study, a green space classification system for urban fringes was established based on multisource land use data from Ganjingzi District, China (2000–2015). The purpose of this study was to explore the spatiotemporal variation of green space landscapes and ecosystem service values (ESV). During 2006–2015, as urbanization advanced rapidly, the green space area decreased significantly (359.57 to 213.46 km^2), the ESV decreased from 397.42 to 124.93 million yuan, and the dynamic degrees of ESV variation were always <0. The green space large plaque index and class area both declined and the number of plaques and plaque density increased, indicating green space landscape fragmentation. The dynamic degrees of ESV variation in western and northern regions (with relatively intensive green space distributions) were higher than in the east. The ESV for closed forestland and sparse woodland had the highest functional values of ecological regulation and support, whereas dry land and irrigated cropland provided the highest functional values of production supply. The findings of this study are expected to provide support for better construction practices in Dalian and for the improvement of the ecological environment.

Keywords: urban green space; ESV; sensitivity; landscape index; urban fringe; Ganjingzi District

Introduction

Urban ecosystems are increasingly under threat from urban population growth, urban land use expansion(Fu et al., 2017; Jonathan et al., 2015; Leverkus and Castro, 2017; Wu et al., 2015), and socioeconomic activities(Koopman et al., 2018; Mensah et al., 2017; Scott et al., 2013; Song and Deng, 2017), which consequently reduce the ecosystem service value (ESV) and affect the sustainable development of human society(Costanza et al., 1997; Duveneck and Scheller, 2015; Koopman et al., 2018; Liu et al., 2017; Zhou et al., 2014). Accurate assessment of the ESV is crucial for both reasonable urban construction planning and urban ecosystem improvement and restoration(Cui et al., 2017); thus, it is receiving increasing attention from the research community(Costanza et al., 2014; Cumming et al., 2014; Leverkus and Castro, 2017; Ossola and Hopton, 2018; Tolessa et al., 2017; Wang et al., 2017).

As an important component of urban ecosystems, urban green space provides important ecosystem services(Hoekstra et al., 2017; Netto et al., 2017). ESV is an important indicator used to measure the service function of a green space ecosystem(Netto et al., 2017). The urban green space system has a variety of ecosystem service functions, such as soil purification(Costanza et al., 1987; Kim et al., 2016), carbon–oxygen balance maintenance, environmental improvement functions(Costanza et al., 2014), climate regulation(Thomas Knoke et al., 2016), urban "heat island" effect reduction(Costanza et al., 2014; Dobbs et al., 2017; Maes et al., 2015; Zardo et al., 2017), biodiversity maintenance(Roces-Díaz et al., 2018; Schneiderman et al., 2015), landscape diversity conservation, urban landscape beautification(Kong et al., 2016), daily leisure and recreation (Andersson et al., 2014; Dickinson and Hobbs, 2017), and production functions(Cerretelli et al., 2018). Assigning a quantitative value to urban green space ecosystem services(Thomas Knoke et al., 2016), it is possible to understand the functions of urban green space vegetation in depth. This can help planners select and cultivate appropriate plants for the promotion of urban green space system planning and provide a scientific reference for urban ecosystem construction (Hoekstra et al., 2017; Kaczorowska et al., 2016; Mensah et al., 2017). Domestic and international researchers have comprehensively summarized relevant studies of urban green space ESV assessment(Tolessa et al., 2017) from the perspectives of urban green space system composition structure(Zhou et al., 2011), and classification(Foudi et al., 2017); green space services and functions(Musacchio, 2013; Pelorosso et al., 2017); landscape pattern and landscape pattern changes(Scott et al., 2013; Zhou et al., 2017); ecological efficiency(Maes et al., 2015); and green space ecosystem service valuation methods(Costanza et al., 1997; Hunter and Luck, 2015). The significance of urban green space ESV assessment for urban ecosystem construction(Zhou et al., 2018) and residential environment improvement has also been demonstrated(Qiao et al., 2013).

Variation in urban green space ESV is related closely to structural changes in urban land use, increases in construction land(Li et al., 2016a; Li et al., 2016b), and green space reduction. In most cases, the valuation of urban green space ecosystem services with respect to urban land use change and green space landscape factor variation(Zhang et al., 2015) has been calculated using land use variation models(Artmann, 2014; Cazalis et al., 2018; Kain et al., 2016; Wu et al., 2015), landscape model indices(Hansen and Pauleit, 2014; Maes et al., 2015; Wu et al., 2015) and integrated valuation, and trade-off models (e.g., InVEST). Based on satellite imagery and measured data, the effects of urban green space landscape structural variation on urban green space ESV have been investigated using ERDAS, ArcGIS, and FRAGSTATS software(Pelorosso et al., 2017; Posner et al., 2016; Qin et al., 2015; Wang et al., 2018; Yan et al., 2017; Zhang et al., 2018). Furthermore, urban green space ecosystem services and functions have been defined and evaluated, and urban green space ESV has been graded (Costanza et al., 2014; Zhou et al., 2014), providing theoretical support for urban infrastructure construction and future planning(Dobbs et al., 2017; Liu et al., 2018; Qiao et al., 2013).

As urban construction develops and the urban population increases, urban spaces will gradually expand toward the urban fringe. Urban–rural fringes, as the interfaces between “town” and “county,” are the districts that experience the most significant and rapid variation during the urbanization process(Baró et al., 2017; Vejre et al., 2010; Wagle et al., 2016). Analysis of the importance of the urban fringe green space landscape for ESV assessment can provide a theoretical reference for spatial planning and construction of urban fringe(Gunawardena et al., 2017; Manes et al., 2012; Ossola and Hopton, 2018; Qiao et al., 2017; Scott et al., 2013; Veach and Bernot, 2011; Zhou et al., 2018).

Few studies associated with urban green space ecosystem services have focused on the long-term variation of urban green space ESV with urban fringes as the research target. Therefore, the objective of this study was to establish a green space classification system for urban fringes in terms of land use based on multisource data (2000–2015) from Dalian in Ganjingzi District (China). Evaluate and calculate the ecological service value of different types of green space through the method of ecological value coefficient. Analyze the spatial characteristics of ecological service value changes of various types of green space in Ganjingzi District during 2000-2015. This provides a new research perspective for the scientific and rational application of urban green space systems and the maximization of the value of green space ecosystem services, especially in the urban areas. This provides a new research perspective for the scientific and rational application of urban green space systems and the maximization of the value of green space ecosystem services, especially in the urban areas.

Research data and methodology

Study area

Ganjingzi District (38°47′–39°07′N, 121°16′–121°45′E) is in the center of the city of Dalian in Liaoning Province, China (Fig. 1). It is adjacent to Jinzhou District to the northeast, Shahekou District to the south, and Lyushunkou District to the southwest, covering a total area of 502 km^2. Administering 14 sub-districts, or 165 communities, Ganjingzi District is located at the urban–rural fringe and in the urban expansion area of Dalian. This geographic position makes Ganjingzi District a representative region of urban green space ESV variation with practical significance for research into the urbanization process.

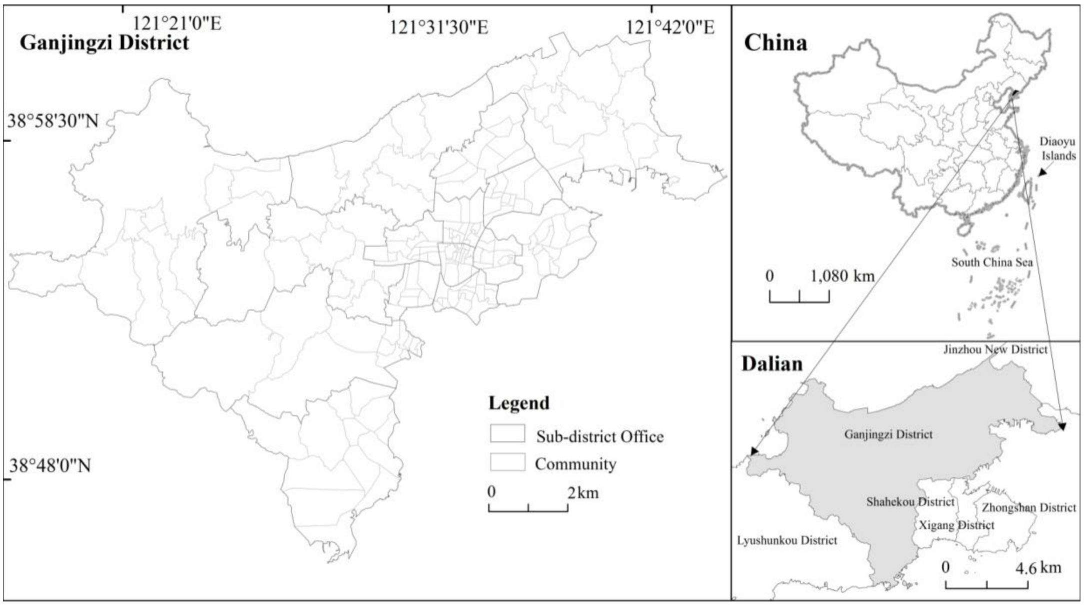

Fig. 1. Location of study area: Ganjingzi District, in the city of Dalian in Liaoning Province, China

Data and green space classification criteria

The green space in Ganjingzi District was categorized into 12 types (Table 1) by following results of the effect of green space on ESV. The categorization was based on multisource land use data from 2000–2015 (Table 2), in accordance with the Land Use Classification (GB/T2101-2007), Forestry Standard of the People's Republic of China (LY/T1812-2007), and regional characteristics of Ganjingzi District.

Table 1 Greenspace classification and content; the second-level classification was used as green space types in this study

First-level classification	Second-level classification	Content and scope
Arable land	Dry land	Cultivated land of xenobiotic plants depending on natural precipitation without irrigation facilities, including cultivated land only relying on warping irrigation.
	Irrigated cropland	Cultivated land where xenobiotic plants can be normally irrigated by guaranteed water and irrigation facilities, including non-industrialized greenhouse land for vegetable production.
Garden	Orchard	Area for fruit planting.
Forestland	Closed forestland	Forestland with a canopy density ≥ 0.2, including mangrove and bamboo forest.
	Shrub land	Forestland with an irrigation coverage ≥ 40%.
	Sparse woodland	Forestland with 10%≤canopy density < 20%.
	Young afforested land	Newly afforested land without canopy or with the potential for afforestation, with a survival rate of afforestation of no less than 41% of a reasonable afforestation number (generally referring to land afforested for no longer than 3–5 years or land sown by plane in the past 5–7 years).
	Nursery	Area for cultivating young trees or crops.
Grassland	Artificial herbage land	Land where herbage is artificially planted, with a canopy density of <0.1 and a land surface of soil; mainly used for herbaceous plants, and not used for grass or husbandry.
	Reed land	Land for reed growing, including reeds on mud flats.
	Waste grassland	Land with a canopy density of <10% and a surface of soil where weeds grow.
Other	Marshland	Land with frequent ponding or water logging, generally for helophytes.

Table 2 Land use data sources and descriptions

Data type	Data	Data source
Remote sensing image data	Land use data 2000–2015（Vector data）	Dalian Municipal Bureau of Land Resources and Housing
	2006 Dalian SPOT5 remote sensing data (resolution 2.5 m), multispectral images (resolution 10 m)	Dalian Municipal Bureau of Land Resources and Housing
	2012 Dalian resource 02C remote sensing data (resolution 2.5 m), multispectral images (resolution 10 m)	National Marine Environmental Monitoring Center
	2015 Dalian resource 02C remote sensing data (resolution 2.5 m), multispectral images (resolution 10 m)	National Marine Environmental Monitoring Center
Administrative data	Data of state, province, city, county (district), and village (town, sub-district)	Dalian Planning Bureau
Socio-economic data	Market economy data, environmental protection construction investment data, cultural tourism industry data（2000–2015）	Dalian Statistical Yearbook(2000-2015), Ganjingzi Statistical Yearbook(2000-2015)

Methods

Analysis of green space landscape composition

The green space system of Ganjingzi District was divided into the 12 second-level categories listed in Table 3 based on remote sensing interpretation, manual classification, and fieldwork investigation with the support of ENVI, ArcGIS, and FRAGSTATS 4.3 software. The structural variation of the green space landscape of Ganjingzi District during 2000–2015 was analyzed by calculating several green space landscape indices, including the number of plaques (NP), plaque density (PD), large plaque index (LPI), and class area (CA), using ENVI, ArcGIS, and FRAGSTATS 4.3 software.

Valuation of green space ecosystem services

Based on the relevant research results and the actual situation of Ganjingzi District, the ecosystem service function of green space classification were categorized: (1) regulating functions, including gas and climate regulation; (2) environmental support functions, including soil formation and conservation, waste disposal, and biodiversity and conservation; (3) production supply functions, including food production and raw material supply; (4) ecosystem service functions, such as recreation and culture (Table 5).

Ecosystem services are influenced by a variety of factors and have multiple modeling approaches to assess the value of ecosystem services. Among them(Costanza et al., 2014; Costanza et al., 1997; Costanza et al., 1987; Costanza et al., 2014), are most representative. Based on the method of value equivalent conversion, combined with the methods of market value method and pollution control cost method(Xiao et al., 2014), combined with the socio-economic data , and based on the existing landscape ecosystem service value data, the value of ecosystem services at the global scale and the national scale is used to evaluate the value of different types of ecosystem services of the green landscape, revised various types of landscape ecosystem service value coefficient(Zhang et al., 2014; Zhang et al., 2015). The ecosystem service value coefficient suitable for a small area is determined and the unit value of the greenbelt system in Ganjingzi District of Dalian City is determined (Table 3).

We used the following valuation equations of ecosystem services and functions(Wu et al., 2015):

$$\begin{aligned} ESV_k &= A_k \times VC_k \\ ESV_t &= \sum_k A_k \times VC_k \\ ESV_f &= \sum_k A_k \times VC_{kf} \end{aligned} \quad (1)$$

where ESV_k is the ESV for the k-th type of green space, ESV_f is the ESV for the f-th ecosystem function, ESV_t is the total ESV of the green space system, A_k is the area of the k-th type of green space (km^2), VC_k is the ESV coefficient of the green space system, and VC_{kf} is the ecosystem function value coefficient of the green space system.

Table 3 Green space ESV per unit area (yuan/km^2·yr) for each green space types

	Dry land	Irrigated cropland	Orchard	Closed forestland	Shrub land	Young afforested land	Sparse woodland	Nursery	Artificial herbage land	Reed land	Waste grassland	Marshland
Gas regulation	9921	6072	35414	10473	30164	19631	40736	25301	10384	10950	9471	13470
Climate regulation	9614	8173	89276	40324	20647	19673	29747	23163	47631	8633	11293	12093
Water conservation	8543	6368	97566	103123	29416	30126	32182	40134	73044	20471	18462	21362
Soil formation and conservation	23035	17094	138743	145054	58013	50496	64540	57363	83412	24510	12352	8476
Waste disposal	21046	14637	55867	23922	12014	20683	20165	35404	71432	15360	8096	9315
Biodiversity and conservation	7819	8623	102562	128461	10248	28464	40160	32080	43645	21064	16042	20163
Food production	10692	10074	18201	4353	1930	3691	2305	2216	24217	1636	1016	1326
Raw material supply	943	1021	57345	70064	8752	17465	20953	29042	5367	3013	1832	1296
Recreation and culture	313	225	14612	37260	1711	2157	10921	1031	1944	1271	1437	536

Dynamic degree of green space ESV variation

The dynamic degree of ESV variation (k) can be used to describe the ESV variation velocity of a certain type of green space over a designated period, as shown in the following equation(Wu et al., 2015):

$$k = \frac{ESV_b - ESV_a}{ESV_a} \times \frac{1}{T} \quad (2)$$

Where ESV_a is the ESV of a certain type of green space at the beginning of the study period, ESV_b is the ESV of that green space at the end of the study period, and T is the study period. If $k<0$, ESV shows a decreasing trend; if $k=0$, ESV remains constant. According to relevant research results and practical situations, the dynamic degree of green space ESV variation can be graded into seven levels (Table 4).

Table 4 Levels of the dynamic degree of ESV variation

Levels of the dynamic degree of variation	Level	Dynamic degree index
Significantly decreased	I	$-0.35 \leq k < -0.25$
Moderately decreased	II	$-0.25 \leq k < -0.15$
Slightly decreased	III	$-0.15 \leq k < 0$
No change	IV	$k = 0$
Slightly increased	V	$0 < k \leq 0.15$
Moderately increased	VI	$0.15 < k \leq 0.25$
Significantly increased	VII	$0.25 < k \leq 0.35$

Sensitivity analysis

To determine the degree of dependence of ESV on the ESV coefficient variation, an elastic coefficient was applied. This sensitivity analysis helped verify the accuracy of the ESV coefficients. The coefficient of sensitivity (CS) was calculated using the following equation(Liu et al., 2014):

$$CS = \left| \frac{(ESV_j - ESV_i)/ESV_i}{(VC_{jk} - VC_{ik})/VC_{ik}} \right| \quad (3)$$

Where *ESV*, *VC*, and *k* are the same variables as used in Eq. (3), and *i* and *j* are the parameters before and after adjustment, respectively. If CS>1, then ESV is sensitive to *VC* with a certain elasticity; the converse holds true if CS<1. A smaller value of CS demonstrates weaker dependency of ESV on *VC* and a lower impact of the green space ESV coefficients on green space ESV. An appropriate selection of the ESV coefficient for the valuation of green space ecosystem services led to a high degree of fit in this study.

Results

Analysis of green space landscape composition variation

During 2000–2015, the land use structure of Ganjingzi District experienced notable changes. With the expansion of urban construction land, the total area of urban green space declined from 359.57 to 213.46 km^2 (Fig. 2). Orchard, dry land, and irrigated cropland were distributed intensively in western, southwestern, northern, and northeastern parts of Ganjingzi District. The area of the largest and most concentrated closed forestland decreased from 212.72 to 155.78 km^2. The range of scattered shrub land and sparse woodland in the center of the district decreased rapidly during 2006–2015. The area of shrub land decreased from

32.31 to 16.46 km^2, and sparse woodland decreased from 29.72 to 13.06 km^2.

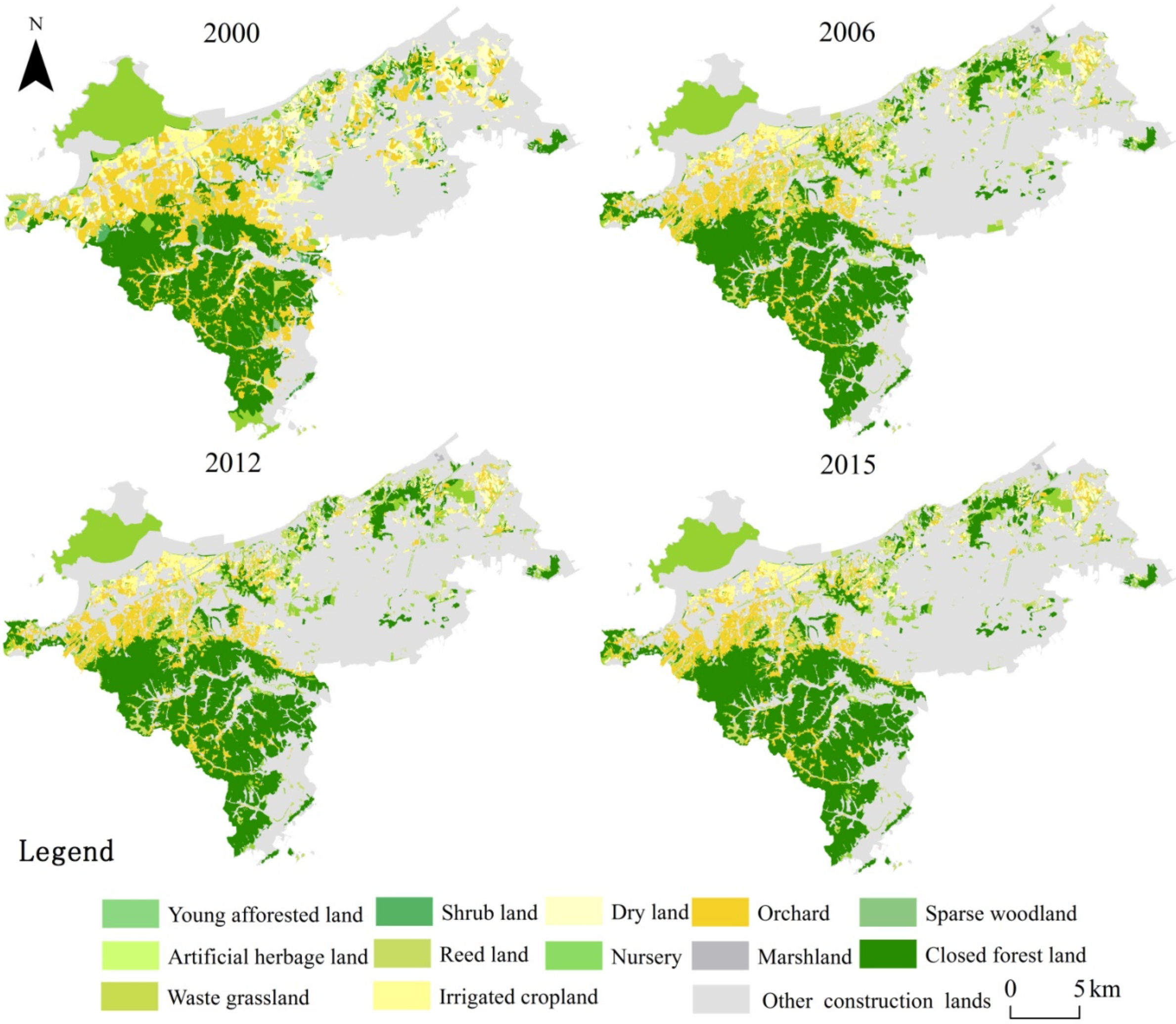

Fig. 2. Variation of green space landscape in Ganjingzi District (2000–2015)

The characteristics of the green space structural variation of Ganjingzi District (2000–2015) were obtained by analyzing the green space structure ratio and variation (Fig. 3). The values of both the number of plaques (NP) and plaque density (PD) of urban green space increased progressively, while the values of the large plaque index (LPI) and class area (CA) decreased gradually over the study period. Therefore, the green space landscape of Ganjingzi District not only experienced a reduction in area, but it also had gradual fragmentation.

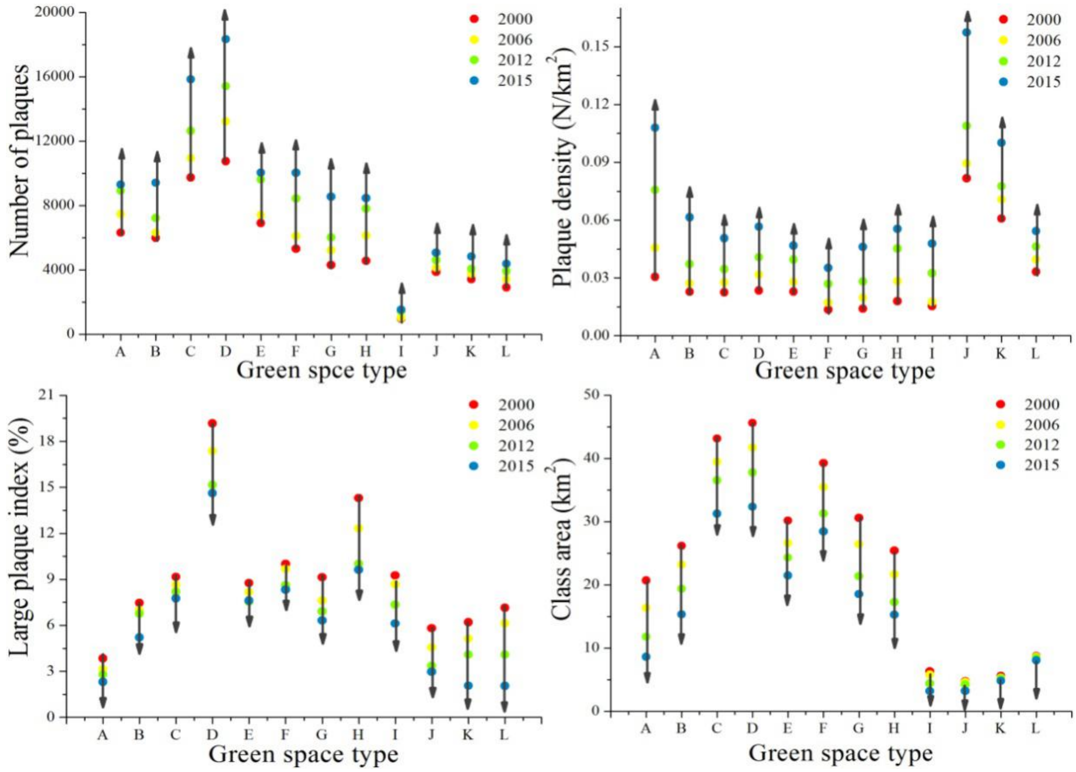

Fig. 3. Variation of green space landscape indices in Ganjingzi District (2000–2015)

A: dry land; B: irrigated cropland; C: orchard; D: closed forestland; E: shrub land; F: young afforested land; G: sparse woodland; H: nursery; I: artificial herbage land; J: reed land; K: waste grassland; L: marshland; ↑: rising trend of green space landscape index; ↓: falling trend of green space landscape index.

Analysis of spatiotemporal variation of green space landscape ESV

Analysis of green space ecosystem functional value variation

As the area of green space landscape decreased, the green space ESV also decreased gradually (Fig. 4). The total area of green space in Ganjingzi District was highest in 2000. The highest green space ESV was 477.2603 million yuan, and the ESV median was 93.6837 million yuan. The ESV then fell rapidly during 2016–2012, with the highest value increasing from 431.6593 to 98.4317 million yuan. The ESV reduced slightly during 2012–2015, with the highest value decreasing from 98.4317 to 86.3725 million yuan. Both the median ESV and the green space ESV exhibited relatively low values during 2006–2015.

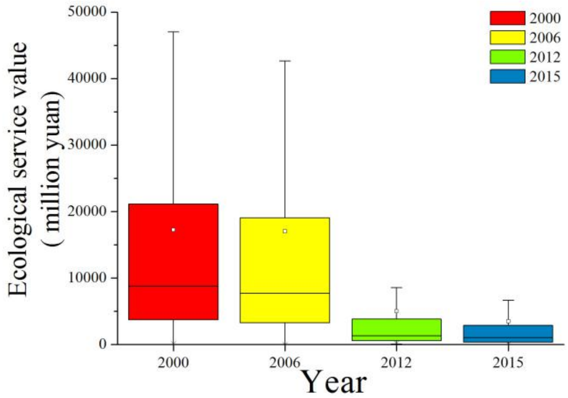

Fig. 4. Variation of green space landscape ecosystem service value in Ganjingzi District (2000–2015)

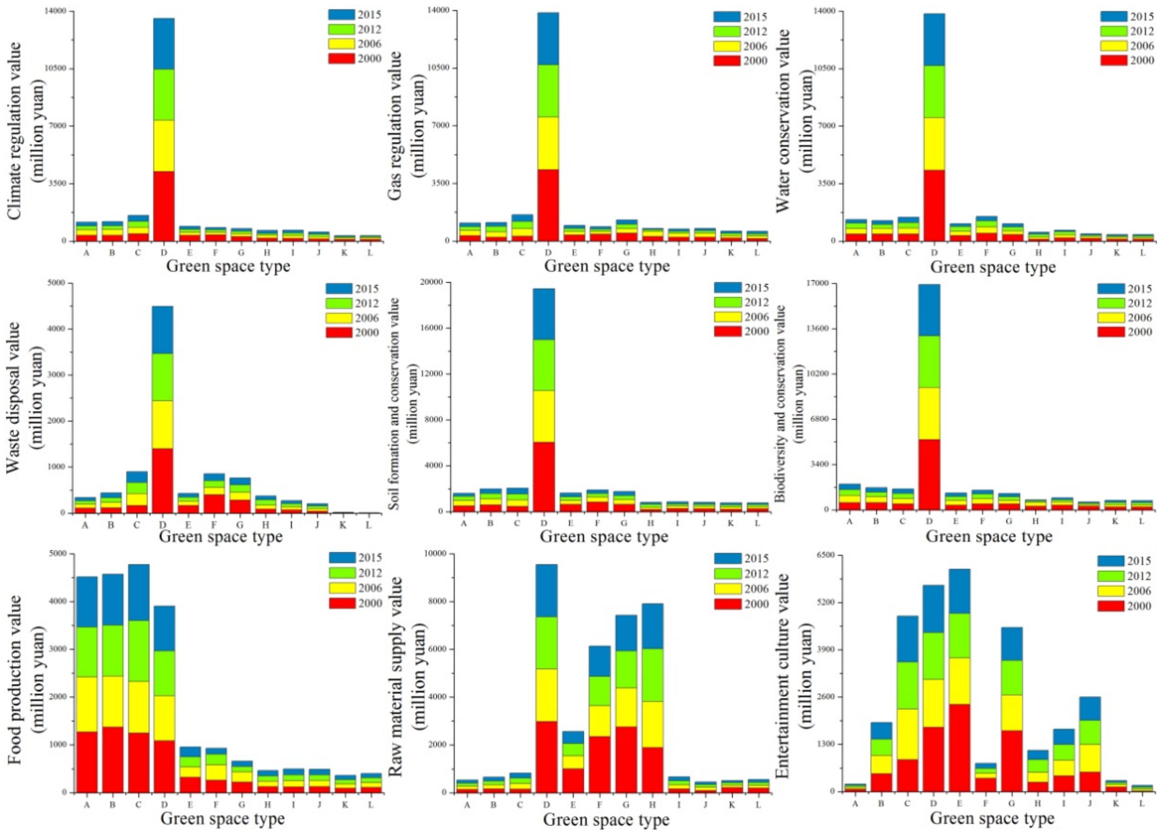

Fig. 5. Variation of green space ecosystem service and function values in Ganjingzi District (2000–2015)

A: dry land; B: irrigated cropland; C: orchard; D: closed forestland; E: shrub land; F: young afforested land; G: sparse woodland; H: nursery; I: artificial herbage land; J: reed land; K: waste grassland; L: marshland.

There were originally vast areas of closed forestland and orchard in Ganjingzi District, which had greater values of gas and climate regulation compared with other green space types (Fig. 5). During 2000–2015, the gas regulation value of orchards decreased from 0.9352 to 0.7474 million yuan, and the climate regulation value of orchards dropped substantially from 1.0514 to 0.3839 million yuan. Gas and climate regulation of closed forestland had the highest values among the various green space types with the most significant impacts. During this period, the gas regulation value of closed forestland decreased from 1.9479 to 1.3746 million yuan, and the climate regulation value of closed forestland dropped noticeably from 1.9825 to 0.6815 million yuan. Gas regulation values of the other green space types were mostly at low levels with only slight changes.

Ganjingzi District is within the urban fringe of the city of Dalian, and its agriculture accounts for a considerable proportion of the industrial structure. There were abundant areas of orchard, dry land, and irrigated cropland, which possessed greater functional values of ecological support and production supply compared with other green space types. During 2000–2015, the water conservation functional values of irrigated cropland, soil formation and conservation, and waste disposal decreased from 0.2947 to 0.2294, 0.7617 to 0.3514, and 0.7958 to 0.2879 million yuan, respectively. The values of ecosystem purification and supporting functions of other green space types, such as grassland and marshland, all remained relatively low with only slight changes. During this period, the food production value of dry land decreased progressively from 0.7421 to 0.4539 million yuan and that of irrigated cropland dropped from 0.7419 to 0.1863 million yuan. In contrast, the food production value of orchards grew from 0.4327 to 0.7563 million yuan.

Ganjingzi District has a healthy ecological environment with a number of ecological parks, including Red Flag Valley Golf Club and Jinlong Temple Forest Park, in the south and northeast of the district, respectively. Therefore, the areas of forestland and sparse woodland of Ganjingzi District have reasonably high recreational and cultural values.

Analysis of spatiotemporal variation of greenspace ESV

The green space ESV of Ganjingzi District increased slightly before significantly decreasing during 2000–2015 (Table 5 and Fig. 6). With the continuous development of urbanization, the ESVs of various green space types demonstrated different dynamic degrees of variation. From 2000 to 2006, suburban agriculture of Ganjingzi District grew rapidly. Dry land, irrigated cropland, and orchards were distributed intensively in western, northwestern, and southwestern parts of the district, and their dynamic degrees of ESV variation experienced dramatic increases, with the highest value of 0.28152. Waste grassland, artificial herbage land, and marshland were distributed in central and northeastern parts of the district, and their dynamic degrees of ESV variation declined greatly, with the lowest value of −0.36064. During 2006–2015, as the urbanization process advanced rapidly, the green space area decreased significantly and the dynamic degrees of ESV variation were always <0. In most cases, the dynamic degrees of ESV variation were reduced either moderately or significantly.

Table 5 Dynamic degrees of green space ESV variation in Ganjingzi District (2000–2015)

	Dry land	Irrigated cropland	Orchard	Closed forestland	Shrub land	Young afforested land	Sparse woodland	Nursery	Artificial herbage land	Reed land	Waste grassland	Marshland
2000–2006	0.07931	0.14621	0.21352	0.25412	0.18821	0.13094	0.14107	−0.19742	−0.18943	−0.17344	−0.35763	−0.32917
2006–2012	−0.16101	−0.25431	−0.19631	−0.01042	−0.00984	−0.18211	−0.21752	−0.23751	−0.26312	−0.24671	−0.32745	−0.32845
2012–2015	−0.18377	−0.19063	−0.14364	−0.08461	−0.12008	−0.21351	−0.22531	−0.21965	−0.26537	−0.27132	−0.32376	−0.36064

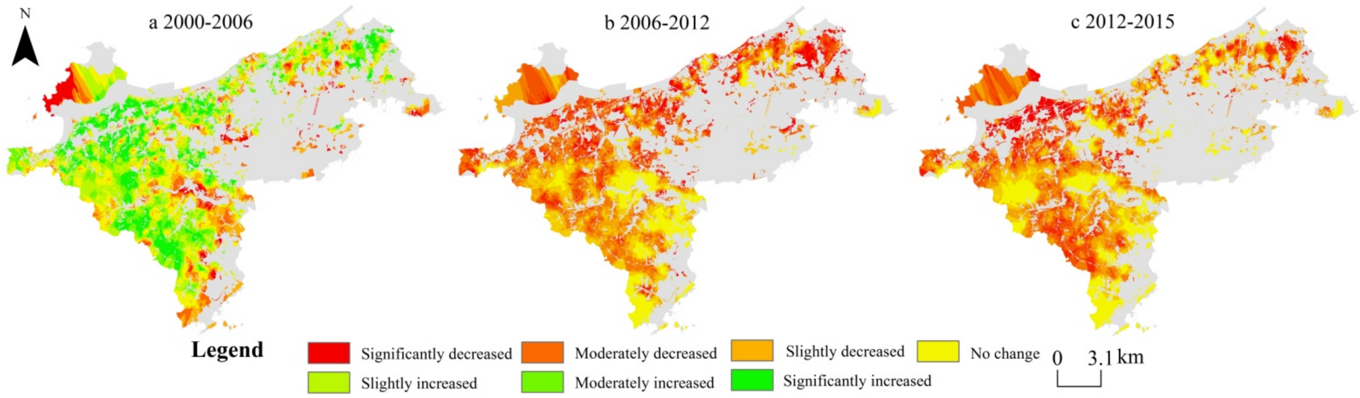

Fig. 6. Spatial distribution of dynamic degree of green space ecosystem service value variation in Ganjingzi District (2000–2015)

Sensitivity analysis of green space ESV

The distribution of sensitivity coefficients for green space ESV was obtained using sensitivity analysis (Table 6 and Fig. 7). In 2015, shrub land had the highest coefficient of sensitivity (1.075), followed by closed forestland (1.031), whereas reed land and waste grassland had the lowest values. Except for shrub land and closed forestland, the ESV sensitivity coefficients of the other green space types were <1, demonstrating the relatively weak impact on ESV and low elasticity of the estimated ESV. Therefore, the ESV coefficients determined in this study had a good degree of fit and were considered reasonable for the valuation of green space landscape ecosystem services.

Table 6 Coefficient of sensitivity of green space ESV in Ganjingzi District (2000–2015)

	Dry land	Irrigated cropland	Orchard	Closed forestland	Shrub land	Young afforested land	Sparse woodland	Nursery	Artificial herbage land	Reed land	Waste grassland	Marshland
2000	0.053	0.087	0.631	0.876	0.826	0.643	0.476	0,103	0.052	0.022	0.021	0.028
2006	0.051	0.096	0.664	1.032	0.818	0.787	0.631	0.29	0.061	0.021	0.031	0.031
2012	0.083	0.135	0.715	0.981	0.908	1.032	0.732	0.438	0.076	0.054	0.035	0.043
2015	0.124	0.297	0.821	0.931	1.075	0.965	0.801	0.521	0.083	0.063	0.036	0.047

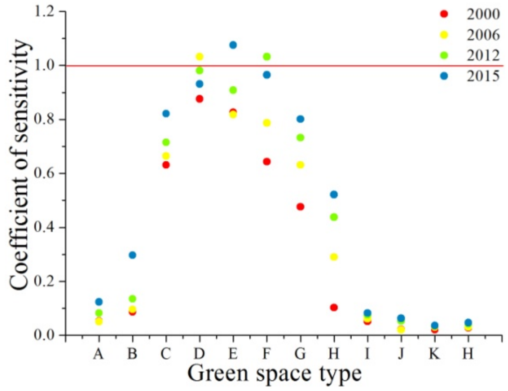

Fig.7. Distribution of coefficient of sensitivity of green space ecosystem service values in Ganjingzi District (2000–2015)

A: dry land; B: irrigated cropland; C: orchard; D: closed forestland; E: shrub land; F: young afforested land; G: sparse woodland; H: nursery; I: artificial herbage land; J: reed land; K: waste grassland; L: marshland. CS=1 is the standard value of susceptibility

Discussion and conclusions

Land provides the space upon which humans survive and perform their activities. Human economic development and urban construction will inevitably lead to changes in land use. In this study, the urban fringes of the city of Dalian were the research target. The green space system of Ganjingzi District was categorized into 12 green space types that were used to analyze the green space landscape variation and to assess the green space ESV, the coefficient of sensitivity, and ESV variation characteristics based on land use data and remote sensing data of this district during 2000–2015. The results have shown the following.

1) From the perspective of green space landscape composition, during 2000–2015, with the development of urbanization, the area of construction land increased continuously, while that of green space declined unabated from 359.57 to 213.46 km^2, leading to landscape fragmentation. The area of closed forestland suffered the greatest reduction, declining from 212.72 to 105.78 km^2. Areas of other green space types also decreased gradually.

2) From the perspective of green space ecosystem service and function values and spatiotemporal ESV variation characteristics, green space ESV decreased gradually from 397.42 to 124.93 million yuan during the study period. The ecosystem service and function values of various green space types declined gradually, whereas those of closed forestland, orchards, sparse woodland, and young afforested land were relatively high. In terms of spatial variation characteristics, the dynamic degrees of ESV variation in western and northern regions, with relatively dense green space, were higher than in the east. The ESV had a slight improvement during 2000–2006, but it gradually decreased during 2006–2015.

3) Except for shrub land and closed forestland, the ESV sensitivity coefficients of all types of green space were <1, demonstrating the relatively weak impact of the ESV coefficients on the ESV and the low elasticity of the estimated ESV. Therefore, the ESV coefficients selected in this study were considered effective for the valuation of green space landscape ecosystem services with a good degree of fit.

In summary, this study examined green space ESV variations in urban fringes during the process of urbanization in Ganjingzi District. The findings are expected to provide support for better construction practices in the city of Dalian and for the improvement of the ecological environment, Provide a new research perspective for the study of ecological services in urban fringe areas, and provide more theoretical basis for ecological construction in urban fringe. However, the relatively low precision of the green space remote sensing data in 2000 might have potentially affected the accuracy of our research. Based on the results of previous studies, based on the local socio-economic conditions, the eco-service value coefficient system that is more practically used in urban fringe areas in Dalian is revised. The lack of social and economic data affects the accuracy of evaluation. The prediction, conservation, and development of future ecological status are critical topics that require further exploration in future studies.

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