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Spatiotemporal Evolution Analysis of Habitat Quality under High-Speed Urbanization: A Case Study of Urban Core Area of China Lin-Gang Free Trade Zone (2002–2019)

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Abstract: This paper, examining the Pilot Free Trade Zone Lin-Gang Special Area in China (Shanghai), identifies the relationship between urban expansion and habitat change and analyzes the influence mechanism of habitat quality (HQ) on spatiotemporal distribution. The results show the following: (1) From 2002 to 2019, the HQ in the study area decreased significantly, and the spatial differences gradually expanded over time. The HQ was low in the southwest and high in the northeast, and low-level habitats gradually moved to the southwest. This spatiotemporal evolutionary law was consistent with the local government's 2003–2020 plans, which are composed of the joint development of a logistics park in the north, the Lin-Gang industrial zone in the west, and Shanghai port in the south. (2) Due to the interspersed distribution of high and low habitats caused by urban development and expansion, Moran's index in spatial autocorrelation decreased over time, which means the spatial agglomeration of HQ decreased and that homogeneity increased. (3) The spatial distribution of HQ was quantified by landscape analysis. The results showed that the fragmentation degree in high-level habitat areas increased with time, while the middle-level habitat areas first increased and then decreased, and the low-level habitat areas displayed the opposite change in trend to that of the middle habitat.

Keywords: urbanization; habitat quality; spatiotemporal evolution; landscape pattern; Lin-Gang free trade zone

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1. Introduction

Urbanization is an inevitable global process [1]. China is in an era of rapid development. Studies have shown that in the past 18 years, China's new urban area accounted for 47.5% of the world's total new urban area, and the rate of urban expansion is more than three times that of developed countries [2]. Although urban development is regarded as a symbol of regional economic prosperity, the use and transformation of land and increasing human activities have led to a series of environmental problems, such as soil erosion, environmental pollution, habitat degradation, biodiversity reduction, and ecosystem imbalance [3–8]. The main reason is that the material flow and energy flow of the ecosystem that covers the surface are disturbed and destroyed by humans, which in turn changes the distribution pattern and function of the ecological environment [9,10]. Moreover, under the interference of human activities, land use changes in a certain space–time range change the spatial structure of the landscape, restrict various landscape ecological processes, affect the distribution of habitats, and thereby affect human survival and social development.

Habitat quality (HQ) refers to the ability of an ecosystem to provide appropriate conditions for the persistence of individuals and populations [11,12]. As an indicator of regional biodiversity and ecosystem service levels [13], the evaluation of HQ began in the mid-1960s. With the development of information technology, the research on HQ evaluation in the 1990s progressed in theory and technology. It has gradually attracted the attention of scholars in the research field, especially the study of HQ based on changes in land-use landscape patterns, which has become a research hotspot in recent years. It can be divided into two categories in terms of research methods and scales. One is the evaluation of HQ based on field surveys [14]. Hamer assessed how accessible habitat and local habitat variables determine species richness and community composition [15]. It was found that there was a strong relationship between local habitat variables and species richness and community composition, highlighting the importance of both availability and quality of habitat for amphibian conservation near major roads. Balasooriya et al. collected plant samples through field investigation, determined plant parameters of different land use types, and evaluated urban HQ [16]. Partyka and Peterson took a river belt as their research area, and constructed evaluation indicators to evaluate the habitat conditions of animals and epiphytes [17]. The above scholars have conducted HQ research on the basis of field surveys. This method is mostly used in large-scale areas such as rivers, roads, and small cities. Sampling methods are used to conduct animal and plant surveys. Based on the obtained habitat-related parameters, an evaluation system is constructed for evaluation. However, this type of method is time consuming and labor intensive. Moreover, it is difficult to obtain data of long series, which limits the analysis of time dynamics. The second is the establishment of an ecological evaluation model for evaluation research [18]. Based on the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) model, Leh et al. and Mushet et al. conducted studies on the biodiversity and HQ of amphibian habitats in Ghana and Côte d'Ivoire in western Africa and in four ecological regions in the United States [19,20]. Sherrouse et al. and Perez-Vega et al., respectively, chose the Social Values for Ecosystem Services (SolVES) model, and the Dinamica Environment for Geoprocessing Objects (EGO) for ecological assessment research [21,22]. Boumans et al. combined global applications, watershed models, and marine application case studies to develop a Multi-scale Integrated Models of Ecosystem Services (MIMES) analysis framework that aims to assess the dynamics related to ecosystem service functions and human activities [23]. This type of quantitative research method using ecological models is usually used to express the distribution of habitats at a macro level. However, there are relatively few studies on the quantification of the characteristics of the spatial distribution of HQ under different disturbance factors and the evolutionary law in time [24,25].

In the process of urbanization, large areas of natural habitat are transformed into impervious surfaces, causing habitat loss [26–28]. Moreover, the development of roads, railways, and other impervious surfaces has led to the fragmentation of such habitats. The change in different land types leads to a change in HQ. The spatial distribution of HQ is one of the key factors allowing for the exploration of the relationship between urban development and HQ. Therefore, in the process of urban expansion, how the spatiotemporal evolution of HQ can be quantified is very important [29–32]. Landscape fragmentation analysis is a very useful quantitative ecological tool. It can measure the organization of landscape elements in both space and time. Fragmentation is usually described as a process in which different land use types are decomposed into smaller plots at the landscape scale, resulting in different ecological consequences. At present, many related indicators have been developed to quantitatively measure landscape changes [33–37]. Likewise, many software packages, such as Fragstats and PatchAnalyst, have been developed to enable people to better understand the species richness, ecosystem services, human activities, and landscape structure in a certain area [38,39].

As the first state-level new area in China, Pudong New Area is a "symbol" of China's reform and opening up. As a new national development strategy with the same status as Pudong New Area, China (Shanghai) Pilot Free Trade Zone Lin-Gang Special Area has undergone nearly 20 years of development and construction, and has formed a substantial scale of urban built-up areas. The rapid socioeconomic development and urbanization process not only brought about the expansion of built-up areas but also caused the destruction of many natural habitats [40]. Therefore, exploring the relationship between the process of urban expansion and the evolution of habitat quality in the Lin-Gang Special Area not only has great value in regard to habitat restoration in future development, but it also has great instructive value for other similar urban planning and construction [41].This study takes the core area of the Lin-Gang Special Area as the research object to explore the spatiotemporal evolution of HQ and its influencing factors under the background of high-speed urbanization. Specifically, the purpose of this research is as follows: (1) to use the InVEST model to evaluate and visualize the HQ of the study area in different periods; (2) to conduct spatial autocorrelation analysis of HQ in different periods based on the GeoDa model, and to examine the spatial distribution characteristics and mutual influence degree of different levels of habitat; (3) using the Fragstats-moving window model, to quantify the spatial patterns of different levels of habitat with the landscape pattern index and to analyze their spatiotemporal evolution rules; and (4), finally, to analyze the impact of the urbanization process on the spatiotemporal pattern evolution of HQ.

2. Study Area

The Pilot Free Trade Zone Lin-Gang Special Area in China (Shanghai) is located in the southeast of Shanghai, south of Pudong International Airport and north of Yangshan international hub port (Figure 1). The special area is a rare area that integrates five modes of transportation: sea, land, air, rail, and river. It is an important area involved in the two national strategies of the Yangtze River Economic Belt and the Maritime Silk Road Economic Belt. The special area is divided into 11 parts. The main urban area is composed of four parts, one of the most important is the Lin-Gang core area, which aims to build the area into an economy with a new height of openness and a new strategic space for Shanghai as a global city. In 2002, the Shanghai Municipal Government began to compile the overall development plan for Lin-Gang, and then carried out the construction according to the planning content. By 2019, the total area of the core area was 104.23 km^2, of which 54 km^2 of land was filled by the reclamation project, which started in 2002. This area mainly included the central activity area, the university district, and the logistics park. Among them, the construction land rapidly expanded from 2.3 km^2 in 2002 to 24.8 km^2 in 2019, an increase of nearly 11 times. At same time, traffic land increased from 0.7 to 10.9 km^2 over the period of 18 years, while the proportion of farmland decreased from 13.5% to 11.1%. All of the above indicate that the core area has undergone rapid urbanization.

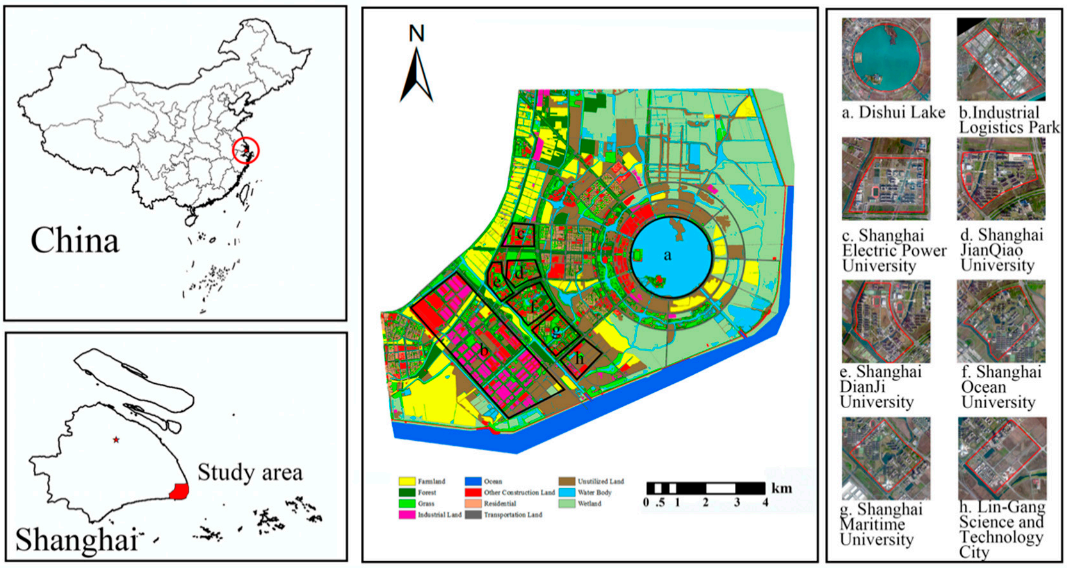


Figure 1. Location of the Lin-Gang core area.

3. Research Methods

3.1. Subsection Remote Sensing Image Classification

The remote sensing images of the Lin-Gang core area were from Google Earth with a resolution of 5 m (2002, 2006, 2010, 2015, and 2019). According to the Classification of Land Use Status (GB/T 21010-2017), the 11 types of land use and land cover (LULC) for this study, obtained through visual interpretation based on ArcGIS 10.2, were grassland, forest land, farmland, residential land, industrial land, other construction land, unutilized land (mainly including wild grassland, saline–alkali land, and bare land), transportation land, water bodies, wetland, and ocean, respectively. Classification accuracy was determined using field survey information collected from some government departments in 2002, 2006, 2010, and 2015. Through the field selection of 200 real sample areas and the classification results of 2019 for comparative analysis, the overall classification accuracy of the five-year LULC was determined to be above 90%, which met the research needs.

3.2. Habitat Quality Assessment

InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) is a model system developed by the U.S. Natural Capital Project Group to assess the amount of ecosystem services and their economic value, and to support ecosystem management and decision making [42]. We used the InVEST Habitat Quality model, which combines information on LULC and threats to biodiversity to produce HQ maps. HQ refers to the ability of the environment to provide suitable production conditions for the survival of individuals or populations. The value range is 0–1, the higher the score, the better the HQ. The HQ value of each grid is determined by two factors: (1) Habitat suitability. Generally speaking, natural land is more sensitive to ecological threat factors, and artificial land has a relatively strong anti-interference ability to ecological threat factors, meaning that its sensitivity is relatively weak. A higher value of sensitivity indicates a higher sensitivity of the land use type to threat factors which range from 0 to 1. (2) The degree of habitat degradation, that is, the degree of degradation of the habitat caused by the threat source. The formula of HQ is as follows:

$$Q_{xj} = H_j\left(1 - \left(\frac{D_{xj}^z}{D_{xj}^z + k^z}\right)\right) \tag{1}$$

where Q_{xj} is the HQ of grid element x in LULC j; H_j is the habitat suitability of j; D_{xj} is the degree of habitat degradation; z is the normalized constant, usually taking the value 2.5; k is the half-saturation constant, which is half of the maximum degree of degradation.

3.3. Spatial Autocorrelation Analysis

Spatial autocorrelation indicates the degree of correlation of a certain attribute of geographic objects at different spatial locations [43]. The statistical content includes the relationship between spatial objects and their neighboring objects and their attribute characteristics. It is mainly divided into global autocorrelation and local autocorrelation analysis. Moran's index is used to characterize the global index of spatial autocorrelation and measure the similarity of evaluation values of spatial neighboring units [44]. The index range is −1–1, $I > 0$ means positive correlation, $I = 0$ means no correlation, and $I < 0$ means negative correlation. The global Moran's I index can be calculated by the following formula:

$$I = \frac{n}{S_0}\frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j}z_i z_j}{\sum_{i=1}^{n} z_i^2} \tag{2}$$

$$S_0 = \sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j} \tag{3}$$

where z_j is the deviation of element I from its average value, $w_{i,j}$ is the weight of elements i and j; n is the number of elements; S_0 is the aggregation of all spatial weights.

In this paper, based on the global spatial autocorrelation model, the local indicators of spatial association (LISA) cluster map was used for local spatial autocorrelation analysis.

The spatial distribution relationship is divided into four clustering types [45]: high and high clusters (H–H), high and low clusters (H–L), low and high clusters (L–H), and low and low clusters (L–L) to explore the spatial correlation characteristics of HQ. The calculations were performed using GeoDa 1.14.0 software.

3.4. Landscape Pattern Analysis

To uncover and understand the interrelations between urban land use changes and HQ, spatial features and temporal processes had to be jointly analyzed [46]. The land use transfer matrix was produced using ArcGIS software to analyze the dynamic changes of land use types between adjacent years. Then, Fragstats 4.2 software was used to analyze the characteristics of landscape pattern changes. With reference to the relevant research [47,48], based on the actual situation of the study area, the following were selected to calculate the landscape pattern index of the three types of HQ each year: NP (The number of patches index reflects the number of patches of the corresponding landscape type), PD (Patch density means that the number of patches per unit area reflects the density of patches), LPI (The largest patch index is the proportion of the largest patches in a landscape type in relation to the whole landscape area; it reflects the dominant species in the landscape), DIVISION (The landscape division index reflects the degree of separation of the landscape; the closer the value is to 1, the higher the degree of division of the landscape type), SHDI (Shannon's diversity index shows the changes in the number and proportion of landscape types. In a landscape system, the richer the land use, the higher the degree of fragmentation, the greater the uncertainty of the information content, and the higher the SHDI value), SHEI (Shannon's evenness index reflects the notion that the richer the landscape type, the higher the degree of fragmentation. Generally, with the uniform distribution of constituent patches, the closer the value is to 1, the more evenly distributed the patch types and the greater the diversity).

The moving window method is an important functional analysis module in the Fragstats software. It can more clearly reflect the whole process of realization of the dynamic change in landscape pattern, and, at the same time, it can analyze the spatial distribution characteristics of the landscape pattern in more depth [49] and visualize the spatial data of the landscape index to realize the quantification of the landscape index on the area scale [38]. Regarding the landscape metrics, DIVISION and SHDI index were selected to obtain the annual landscape fragmentation and landscape diversity maps through the moving window method.

4. Results Analysis

The land reclamation project in the core area of Lin-Gang started in June 2002. It can be seen from the land use transfer matrix (Table 1) that up to 2006, a total of 32.8 km^2 of the ocean converted to land, of which 23.8 km^2 was converted into wetlands, accounting for the vast majority of the area transferred from the ocean. At the same time, part of the original wetland (5.2 km^2) was turned into unutilized land. In addition, due to reclamation and other factors, the salt drying plant near the coast closed, and 5.5 km^2 of the water body was also converted into unutilized land. As a result, the area of unutilized land increased substantially in 2006. On the other hand, the development of the city is inseparable from the close connection of transportation. In 2006, the area of transportation land increased by 649%, which greatly promoted the development convenience of the core area. From 2006 to 2010, the area of unutilized land displayed the largest transformation, decreasing from 16.9 to 6.8 km^2, of which 4.3 km^2 was converted to grassland, 2.5 km^2 to transportation land, and 1.4 km2 to forest land. Secondly, the area of wetland decreased significantly, with 3.1 km^2 being converted to farmland and 3.6 km^2 to water bodies. From 2010 to 2015, the area of wetland further decreased and mainly transformed into farmland, unutilized land, and water bodies. The area of residential land, industrial land, and other artificial buildings increase by 75%. Compared with 2015, the area of farmland decreased significantly in 2019, with 2.5 km^2 converted to unutilized land and 4.1 km^2 to wetland.

Table 1. Land use transfer matrix in the Lin-Gang core area. (km^2).

Time Period	LULC	Farmland	Forest Land	Grassland	Industrial Land	Ocean	Other Construction Land	Residential Land	Transportation Land	Unutilized Land	Water Body	Wetland
2002–2006	Farmland	4.591	0.870	0.394	0.003	1.415	0.001	0.071	0.015	0.259	1.961	3.877
	Forest Land	1.324	3.730	0.246	0.009	0.032	0.006	0.149	0.077	0.079	0.310	0.149
	Grassland	0.195	0.611	0.647	0.010	0.442	0.007	0.067	0.021	0.088	1.721	1.462
	Industrial Land	0.104	0.074	0.028	0.016	0.003	0.003	0.007	0.001	0.018	0.089	0.071
	Ocean	0.000	0.000	0.000	0.000	10.335	0.000	0.000	0.000	0.000	0.001	0.000
	Other Construction Land	0.020	0.300	0.114	0.020	0.363	0.002	0.038	0.020	0.012	0.233	0.215
	Residential Land	0.035	0.258	0.035	0.026	0.000	0.001	0.383	0.019	0.033	0.016	0.004
	Transportation Land	0.441	0.652	0.418	0.020	0.689	0.004	0.121	0.362	0.129	1.023	1.289
	Unutilized Land	1.336	1.404	1.360	0.072	1.326	0.010	0.217	0.126	0.374	5.491	5.162
	Water Body	0.204	0.211	0.150	0.002	4.757	0.002	0.018	0.012	0.030	2.254	2.219
	Wetland	0.002	0.000	0.145	0.001	23.787	0.000	0.003	0.033	0.011	1.664	8.970
2006–2010	Farmland	8.223	1.394	0.281	0.033	0.000	0.015	0.119	0.115	1.104	0.160	3.133
	Forest Land	1.063	1.777	0.518	0.009	0.017	0.042	0.078	0.594	1.424	0.175	0.217
	Grassland	1.197	1.303	1.676	0.037	0.002	0.098	0.154	0.570	4.314	0.538	1.853
	Industrial Land	0.069	0.071	0.102	0.187	0.000	0.004	0.013	0.015	0.640	0.010	0.015
	Ocean	0.000	0.001	0.000	0.000	9.389	0.014	0.000	0.001	0.002	0.005	0.003
	Other Construction Land	0.227	0.237	0.380	0.075	0.061	0.839	0.092	0.364	1.431	0.070	0.172
	Residential Land	0.077	0.093	0.135	0.014	0.000	0.012	0.175	0.051	0.218	0.017	0.129
	Transportation Land	0.843	0.817	0.722	0.037	0.010	0.221	0.131	2.993	2.486	0.291	0.590
	Unutilized Land	1.224	0.100	0.781	0.014	0.002	0.042	0.018	0.147	3.146	0.340	0.940
	Water Body	0.349	0.291	0.271	0.003	0.000	0.008	0.028	0.089	0.932	7.187	3.569
	Wetland	0.185	0.027	0.402	0.006	0.855	0.041	0.001	0.211	1.180	1.065	23.994
2010–2015	Farmland Land	8.106	0.388	1.083	0.001	0.000	0.051	0.032	0.508	1.132	0.484	4.707
	Forest Land	1.062	2.737	1.719	0.017	0.000	0.234	0.068	1.225	0.333	0.164	0.308
	Grassland	0.787	0.944	3.576	0.029	0.004	0.289	0.058	0.925	0.998	0.366	0.812
	Industrial Land	0.096	0.066	0.379	0.836	0.000	0.267	0.019	0.104	0.187	0.044	0.188
	Ocean	0.000	0.001	0.001	0.000	9.359	0.004	0.000	0.000	0.001	0.000	0.117
	Other Construction Land	0.750	0.348	1.000	0.099	0.014	2.098	0.032	0.653	1.048	0.152	0.412
	Residential Land	0.113	0.056	0.361	0.010	0.000	0.106	0.609	0.152	0.239	0.048	0.001
	Transportation Land	0.610	0.826	1.358	0.047	0.000	0.630	0.084	4.641	0.668	0.218	1.317
	Unutilized Land	1.707	0.271	1.220	0.087	0.000	0.077	0.013	0.385	1.189	0.362	3.222
	Water Body	0.308	0.127	0.330	0.001	0.023	0.015	0.002	0.117	0.193	7.964	2.085
	Wetland	1.038	0.149	0.716	0.000	0.016	0.175	0.005	0.429	0.765	2.927	14.798
2015–2019	Farmland Land	8.403	0.272	0.176	0.001	0.000	0.013	0.012	0.055	0.950	0.043	0.816
	Forest Land	0.142	5.364	1.158	0.013	0.000	0.196	0.110	0.754	0.141	0.054	0.121
	Grassland	0.564	0.609	4.087	0.018	0.000	0.262	0.069	0.405	0.592	0.085	0.742

Table 1. *Cont.*

Time Period	LULC	Farmland	Forest Land	Grassland	Industrial Land	Ocean	Other Construction Land	Residential Land	Transportation Land	Unutilized Land	Water Body	Wetland
	Industrial Land	0.003	0.016	0.023	1.890	0.000	0.174	0.005	0.045	0.033	0.000	0.150
	Ocean	0.000	0.000	0.000	0.000	7.743	0.011	0.000	0.001	0.000	0.024	0.065
	Other Construction Land	0.044	0.105	0.164	0.115	0.002	4.719	0.057	0.409	0.322	0.009	0.123
	Residential Land	0.006	0.061	0.038	0.001	0.000	0.188	1.303	0.070	0.027	0.003	0.001
	Transportation Land	0.060	0.823	0.501	0.102	0.015	0.607	0.117	8.105	0.317	0.026	0.205
	Unutilized Land	2.528	0.364	2.064	0.030	0.000	0.399	0.021	0.404	4.905	0.353	3.628
	Water Body	0.629	0.106	0.244	0.005	0.000	0.013	0.002	0.035	0.239	9.691	1.046
	Wetland	4.113	0.147	0.333	0.011	1.724	0.024	0.000	0.116	1.008	0.876	14.121

On the whole, the Lin-gang core area, as a new city rising from the ground, has developed rapidly after just 20 years. The area of green space (forest land and grassland) increased from 11.6 to 15.5 km^2; the area of artificial construction land (residential land, industrial land, other construction land, and transportation land) increased from 3.9 to 21.0 km^2; the area of unutilized land increased from 1.0 to 14.7 km^2. At present, a comparatively livable and pleasant urbanization pattern has formed. According to the latest plan issued in 2019 for the core area, it is expected that by 2035, the area of artificial construction land will continue to grow, approximately doubling the existing basis. Modern urban construction will be vigorously carried out around Dishui Lake, especially in the undeveloped areas in the northwest [50].

4.1. InVEST-HQ Model Parameter Selection

After 18 years of urbanization in the study area, the disturbance of human activities has had a huge impact on the change in LULC. The construction land, including residential land and industrial land, most intensively reflects the threats of human activities to natural habitats. Moreover, farmland, as a partly artificial and partly natural land type with frequent human disturbance, is also suggested to be threat source, which is the same as artificial transportation land [51]. Therefore, in this paper, farmland, transportation land, residential land, other construction land, industrial land, and unutilized land are set as threat factors. In addition, in the process of urban construction, in order to increase the livability of a city, local governments also plan and layout the land use types with better ecological benefits. In this research, these types mainly include the forest land, grassland, wetland, water bodies, and ocean. Finally, according to the InVEST model User's Guide [42] and the research results of relevant scholars [18,52,53], we set the parameters of ecological threat factors and the sensitivity of habitat types to various threat factors (shown in Tables 2 and 3).

Table 2. Threat factors and their maximum distance of influence, weight, and type of decay over space.

Threat Factors	Maximum Distance of Influence	Weight	Type of Decay over Space
Farmland	4	0.7	Linear
Transportation Land	3	1	Exponential
Residential Land	5	0.7	Exponential
Other Construction Land	8	0.6	Exponential
Industrial Land	8	1	Exponential
Unutilized Land	6	0.5	Exponential

Table 3. The sensitivity of land use type to habitat threat factors.

LULC	Habitat Suitability	Farmland	Transportation Land	Residential Land	Other Construction Land	Industrial Land	Unutilized Land
Forest Land	1	0.5	0.7	0.7	0.9	0.9	0.6
Grassland	1	0.7	0.8	0.8	0.1	0.1	0.5
Ocean	0.9	0.5	0.2	0.2	0.8	0.8	0.5
Transportation Land	0	0	0	0	0.2	0.2	0
Residential Land	0	0	0.7	0	0.4	0.4	0.5
Farmland	0.4	0	0.5	0.4	0.7	0.8	0.4
Water Body	0.7	0.7	0.3	0	0.5	0.5	0.3
Other Construction Land	0	0	0	0.5	0	0	0
Unutilized Land	0.2	0.5	0.7	0.7	0.8	0.8	0
Industrial Land	0	0	0.3	0	0.3	0	0
Wetland	1	0.7	0.6	0.7	0.8	0.8	0.8

According to the above parameters, the HQ maps of the study area were obtained from the InVEST-HQ model. We analyzed the scores, and the results are shown in Table 4. From 2002 to 2019, the average HQ of the study area dropped from 0.842 to 0.582, indicating that the overall decline in HQ was significant. In addition, the standard deviation index rose from 0.214 to 0.406, indicating that the unevenness of the spatial distribution of the urban habitat over time further expanded. In order to analyze the impact of the urbanization process on the habitat in detail, we divide the HQ into three parts: low (0–0.33), middle (0.34–0.66), and high (0.67–1). From 2002 to 2019, the proportion of low-level habitats increased significantly, increasing by nearly 12 times. In particular, large areas of unutilized land were reclaimed in 2002, as well as a lot of transportation land required for development and construction, resulting in a sharp increase in the area of low-level habitats by eight times in 2006. At the same time, the area of high-level habitats decreased by one-third from 2002 to 2006. In general, the proportion of high-level habitats showed a decline, dropping by nearly 40%. The reason for this is that after the completion of the land reclamation project in 2004, a large area of the ocean was transformed into unutilized land. The middle-level habitat was mainly manifested in the change in farmland. The area of farmland in 2019 was different from the previous year-on-year increase, and there was a sharp decline, with a total decrease of 5.8 km^2.

Table 4. Habitat quality index of the Lin-Gang core area (2002–2019).

Year	Average Value	Standard Deviation	Area (km^2)/Proportion (%)					
			High-Level		Middle-Level		Low-Level	
2002	0.842	0.214	92.86	89.09	8.24	7.91	3.01	2.88
2006	0.681	0.363	66.11	63.42	13.45	12.91	24.55	23.56
2010	0.673	0.377	67.68	64.94	14.58	13.99	21.85	20.96
2015	0.598	0.398	58.21	55.85	16.49	15.82	29.40	28.20
2019	0.582	0.406	57.74	55.39	10.74	10.30	35.64	34.19

Research found that the HQ not only changes significantly in time, but also has specific spatial distribution. As show in Figure 2, the overall quality of habitat was high in 2002. Because the overall planning of the Lin-Gang core area began in 2002, when the entire area was in the undeveloped stage, the land use types were mainly farmland, residential land, wetland, and the eastern sea. In terms of habitat distribution, the middle-level habitat was mainly composed of a small range of farmland, among which the interspersed residential land was low-level habitats. The spatial distribution of HQ in 2006 was very different from that in 2002. High-level habitats were still mainly distributed in the east and south, while the middle-level habitat expanded to the north and southwest. Due to land reclamation in 2002, a total of 32.8 km^2 of land area increased in the Lin-Gang core area, with about 1.4 km^2 becoming farmland, which became the main growth factor in the middle-level habitat area. In addition, the low-level habitat area mainly grew in the west, which was mostly composed of residential land, industrial land, and other construction land. According to the development plan of the Lin-Gang core area [54], as a major landscape factor, the Dishui Lake would play an important role in living and tourism. As a result, more artificial buildings have been constructed, which has led to the deterioration of the regional HQ. On the other hand, the construction of the Yangshan Deepwater Port began in 2002. Based on its geographical location, logistics land was added to the southwest of the core area to support the construction of Yangshan Port, which also caused degradation of the HQ. From 2006 to 2019, the low-level habitat area showed an overall trend of westward expansion in terms of space, and the main increases were seen for industrial land and residential land. The middle-level habitat is mainly reflected in the expansion to the southeast; the main reason for this is that part of the unutilized land reclaimed from the sea was converted into farmland. In the new plan released in 2017 [55], in order to further optimize the overall spatial layout of the region, the Lin-Gang core area was developed with the intention of building a modern open area with a service industry focus on finance, so as to enhance

Shanghai's ability of global resource allocation. Consequently, farmland in the north of Dishui Lake was expropriated. The spatial distribution of overall HQ over the past five years was high in the northeast and low in the southwest.

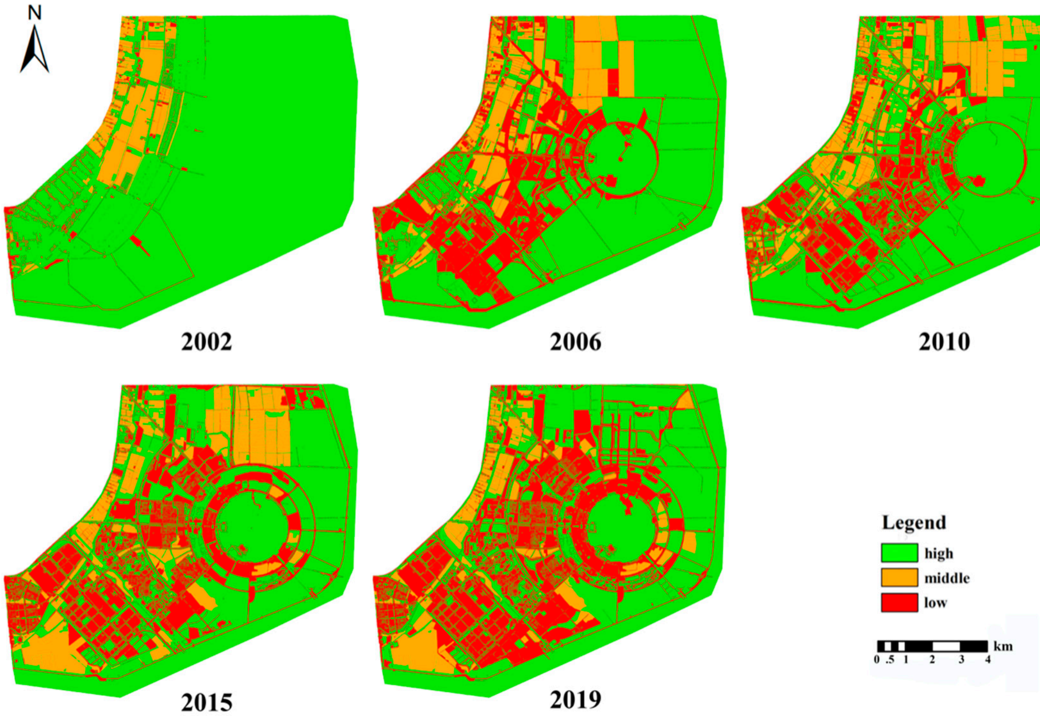


Figure 2. The spatial distribution pattern of high-, middle- and low-level habitat quality.

4.2. Spatial Distribution of Habitat Quality

According to Geoda software, the global Moran's index of the HQ map from 2002 to 2019 is 0.633, 0.690, 0.551, 0.541, 0.560, the index values are all greater than 0, indicating that the HQ of the study area is positively correlated in spatial distribution. The fluctuation of the index indicates that the spatial agglomeration of HQ in the study area is gradually reduced in land development and construction, that is, the spatial positive correlation between H–H and L–L is reduced, and the spatial negative correlation between H–L and L–H is enhanced, which shows that spatial heterogeneity is strengthened.

The LISA cluster map can further illustrate the correlation between the attribute values of the studied regional units and the attributes of neighboring regional units, and it can be determined whether it belongs to spatial clustering or spatial isolation [56]. From the LISA cluster maps (Figure 3), it can be seen that in 2002, H–H was mainly distributed in the eastern coastal area and the southwest. As land development and utilization moved to the southwest, while the land expansion moved eastward, H–H in the south gradually decreased. By 2019, H–H was mainly distributed in the northeast. L–L shifted from the northwest to the southwest in 2002, mainly distributed in the industrial logistics park, residential land areas, and school areas in the southwest. In addition, due to the increase in high-level habitat patches around the low-level habitats such as roadside trees, residential land green belts and other facilities gradually improved; the high-level habitat areas surrounded by low-level habitats, that is, negatively correlated H–L, show an upward trend, leading to the gradual fragmentation of L–L. L–H is the area in which there are low-level habitats surrounded by high-level habitats. Since this occupies a small area, its changing trend is not obvious. The distribution change trend of the LISA spatial cluster map is consistent with the spatial distribution of HQ, as mentioned at Section 4.1.

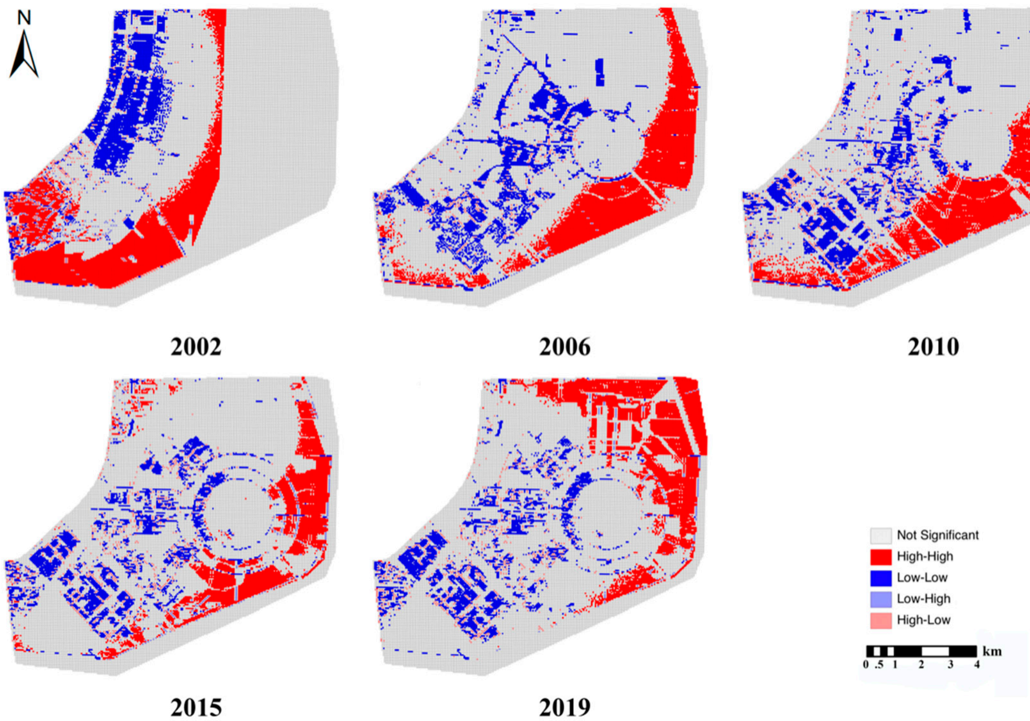


Figure 3. Local indicators of spatial association (LISA) cluster maps of habitat quality.

4.3. Landscape Pattern Analysis

From Figure 4a, it can be seen that the number of high-level habitat patches in the study area increased during the 2002–2015 14-year period from 1307 to 17,508. The PD increased from 14.076 to 300.751/km^2. When the unit area is unchanged, the larger the number of patches, the higher the fragmentation of the landscape pattern [57]. Therefore, from 2002 to 2015, high-level habitat fragmentation was significant. In 2019, both NP and PD dropped slightly, while the DIVISION index grew slowly, indicating that the increasing trend of landscape fragmentation slowed down. In high-level habitats, the largest patches in five years were all ocean land types. The sharp decline in the index from 2002 to 2006 was attributed to land reclamation project. After that, the proportion of ocean area in the entire landscape stabilized. The DIVISION index moved increasingly closer to 1, indicating that the high-level habitats in the study area have been in a relatively high fragmentation state since 2006, and the landscape structure has become more fragmented over time. The SHDI and SHEI increase year by year. The higher the value, the more diversified and uniform the landscape type. Because these two indexes continue to increase as time goes by, but there was no increase in new land use types, the distribution of landscape types in the study area tend to be homogenized, and the complexity of landscape structure composition is enhanced. According to the above, from 2002 to 2006, the overall fragmentation of the high-level habitats increased sharply. The reason for this is that the reclamation project led to the development and utilization of large areas of the ocean into other types of construction land, and, at the same time, the dominant index, the LPI, decreased significantly. From 2006 to 2015, with the rapid development of the city, land use intensified, resulting in further fragmentation of high-level habitats. In 2017, the government proposed higher quality, more efficient, and more sustainable land development and protection policies [55], which slowed down the fragmentation of high-level habitats from 2015 to 2019.

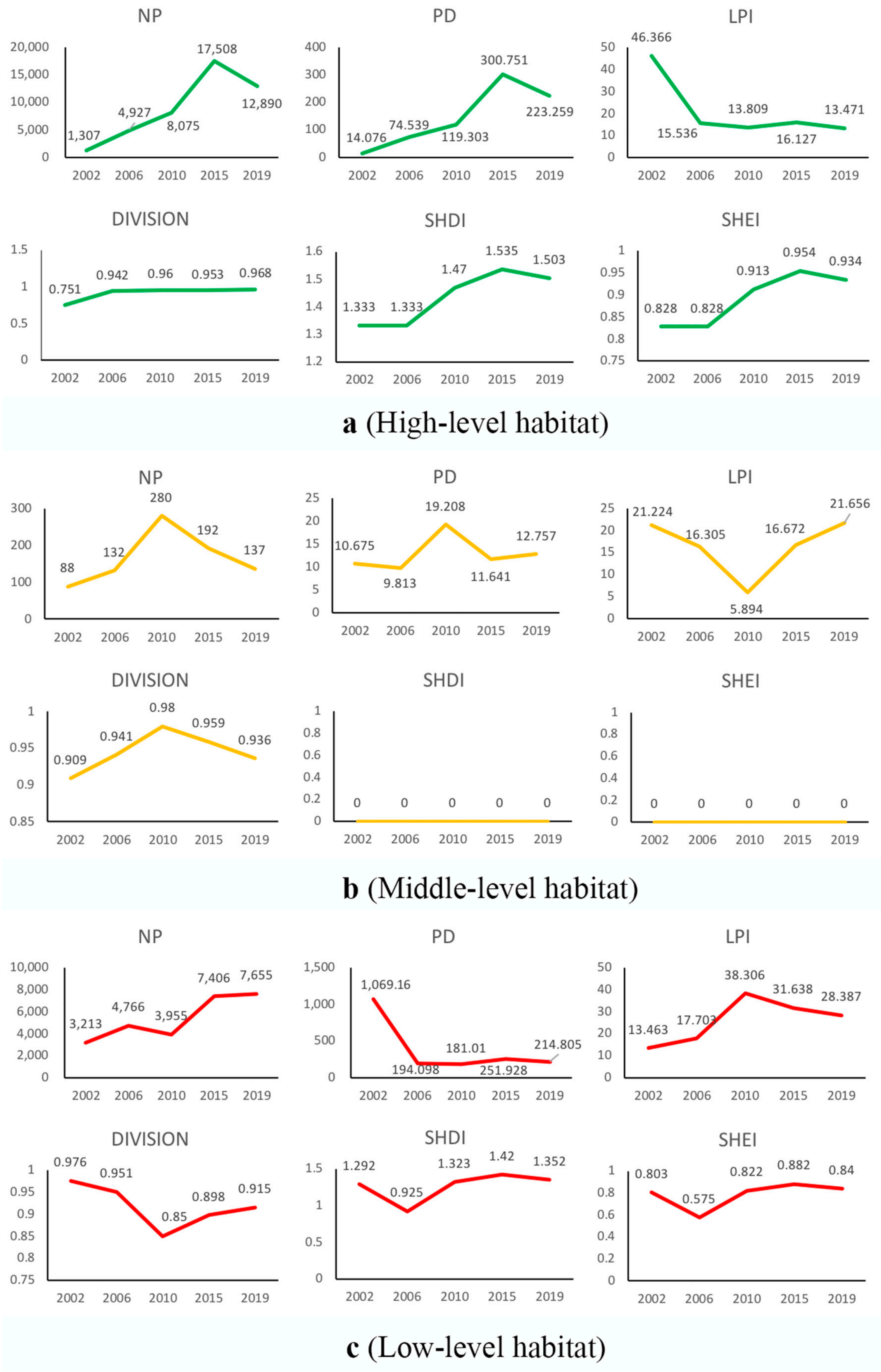


Figure 4. Landscape indexes of the Lin-Gang core area (2002–2019).

In the middle-level habitat (Figure 4b), a change in the landscape pattern of farmland was observed. As there was only one land use type, both the SHDI and the SHEI were 0. The NP, PD, and DIVISION indexes fluctuate greatly on the whole. They increased first from 2002 to 2010, and decreased from 2010 to 2019. In contrast, the LPI decreased first and then increased, indicating that the landscape dominance reached its lowest level in 2010 when the degree of fragmentation was the highest. From 2010 to 2019, the NP of farmland declined. The reason for this is that Shanghai's policy of intensive land use has turned small patches of farmland into large ones, which led to a decrease in PD with an increase in farmland area from 2010 to 2015. In contrast, the PD increased from 2015 to 2019 due to the significant reduction of farmland area. Similarly, this was also the result of LPI decreasing first and then increasing.

It can be seen from Figure 4c that the NP showed an increasing trend as a whole, except for a decrease in 2010, which indicates that the fragmentation of the landscape in low-level habitats increased significantly during this period. The PD decreased sharply from 2002 to 2006 and then remained stable. The PD was 1069.156/km^2 in 2002. The reason for the excessively large patch density is because the areas of low-level habitats in 2002 were much smaller than in the other four years, while the NP showed minor changes. The LPI of low-level habitats was the opposite of that of high- and middle-level habitats, showing a trend of first increasing and then decreasing, and reaching its maximum value in 2010. Combining the three indices of NP, PD, and DIVISION, it can be observed that landscape fragmentation and landscape dominance are negatively correlated. The greater the landscape fragmentation, the smaller the dominance. The reclamation project started in 2002 and ended in 2004. During this period, the SHDI decreased from 1.292 to 0.925. After reclamation, part of the ocean was converted into low-level habitats, and the index increased to 1.323 by 2010. This shows that the development of the reclamation project has a negative impact on the diversity of regional habitats. The SHDI and SHEI showed an upward trend from 2006 to 2019, which means the landscape heterogeneity of the low-level habitats in the study area increased, and the relative difference in the proportion of various land use types decreased. This reflects the changing trend of the average landscape patch area being continuously reduced.

4.4. Analysis of Habitat Landscape Pattern Based on the Moving Window Model

In order to explore the relationship between the urbanization process and the spatiotemporal evolution of HQ, we used the moving window model to quantify the spatial distribution of the HQ in the study area. On the landscape index selection of the moving window analysis tool, the DIVISION and SHDI indices can reflect the fragmentation and diversity of the landscape, respectively. Therefore, these two indices were used as quantitative indicators of HQ spatial layout in this study.

Figure 5 shows the moving window of the low-level habitat landscape fragmentation index and diversity index, which indicate that the development degree of the study area is relatively low. The residential land in rural areas were scattered and distributed in dots. The rural trails were mostly distributed in strips. Most of the low-level habitats were in a fragmented state. In 2006, the low-level habitats were highly fragmented in the logistics park, the residential areas of the southwest corner, and around the main traffic arteries, as well as Dishui Lake. At the same time, the high fragmentation habitats were clustered around low fragmentation habitats. In 2010, with the increase in the NP, fragmentation intensified significantly. As of 2010, Shanghai Maritime University and Shanghai Ocean University have been implemented. The fragmentation of the education park on the southwest side of Dishui lake has gradually become prominent. Moreover, the government planned to build new residential areas on the west and southwest sides of Dishui Lake as supporting houses for faculty and staff, which would have significantly increased the degree of fragmentation. In the southwest part of the education park is the logistics park; with the development and construction of Yangshan Port, the planning background and scope of the original logistics park have undergone major changes. In addition to the expansion of the land area, Luchaogang Railway Station was put into operation at the end of 2005. The introduction of the railway branch line into the development plot of the logistics park satisfies the multimodal transport and speeds up the process of land utilization and development. By 2010, the habitat of the logistics park was further fragmented. In 2015, with the increase in the area of low-level habitats, the speed of land use and development further accelerated, and the residential areas on the west and northwest sides of Dishui Lake continued to expand outward. Shanghai DianJi University, Shanghai JianQiao University, and Shanghai Electric Power University were successively completed in 2015, leading to the expansion of the education park area and increasing fragmentation. The Lin-Gang Science and Technology City in the southeast of the education park was established in 2015 and covers an area of about 7 km^2. Because the construction has just started, it has not shown obvious fragmentation. The fragmented habitats are mainly distributed in the northwest and southwest regions of the Science and Technology City. The fragmented area of residential areas (where the original residents live) in the southwest corner also increased. In 2019, the area of low-level habitats surrounding Dishui Lake increased significantly, because Dishui Lake has extremely high commercial tourism value. Due to the small area of available land around it and the various types of land for commercial and entertainment purposes, the patch density increased, which led to fragmentation of the area.

Figure 5b shows the landscape diversity map. It can be seen that the landscape diversity and landscape fragmentation of low-level habitats show a similar trend in space–time evolution. We suggest that the reason for this is that in a landscape system, the richer the land use type, the higher the degree of fragmentation, the greater the uncertainty of information content, and the higher the calculated SHDI.

It can be seen from Figure 6 that the overall fragmentation and diversity of the middle-level habitat was relatively low. In our research, the middle-level habitat area was mainly farmland. From 2002 to 2019, although the total area changed greatly, due to the special attributes of farmland, it mainly presents agglomeration distribution in space. In contrast, few other non-farmland land use types that distributed around farmland led to landscape fragmentation and diversity.

High-level habitats mainly include grassland, forest land, wetland, water bodies, and ocean. They are divided into two parts in space: one is in the undeveloped area in the east of the study area, and the other is scattered in the built-up area of west. As show in Figure 7a, in 2002, the traffic arteries of the salt drying field in the western built-up area were scattered in the high-level habitats, resulting in a high degree of fragmentation and diversity. After four years of urban expansion, the area of high-level habitats decreased, and high fragmentation and high diversity areas become more scattered. During the land development process, due to the particularity of the construction of various projects and the construction period, some of the original wetland in the corner of the south was temporarily idle and abandoned, resulting in fragmentation. The year of 2010 is the final year of the 11th Five-Year Plan for Shanghai Lin-Gang New City. While the urban ecological environment, infrastructure, and functional project layout construction have been enhanced, urban parks, road greening, and other environmental constructions have also achieved positive initial results. The highly fragmented habitats in the western part of the study area are mostly street trees, community greening, and park corridors. From 2010 to 2019, there was no significant change in fragmentation and diversity of high-level habitat areas. The subtle differences are mainly caused by the increase or decrease in scattered green space in the process of urban construction.

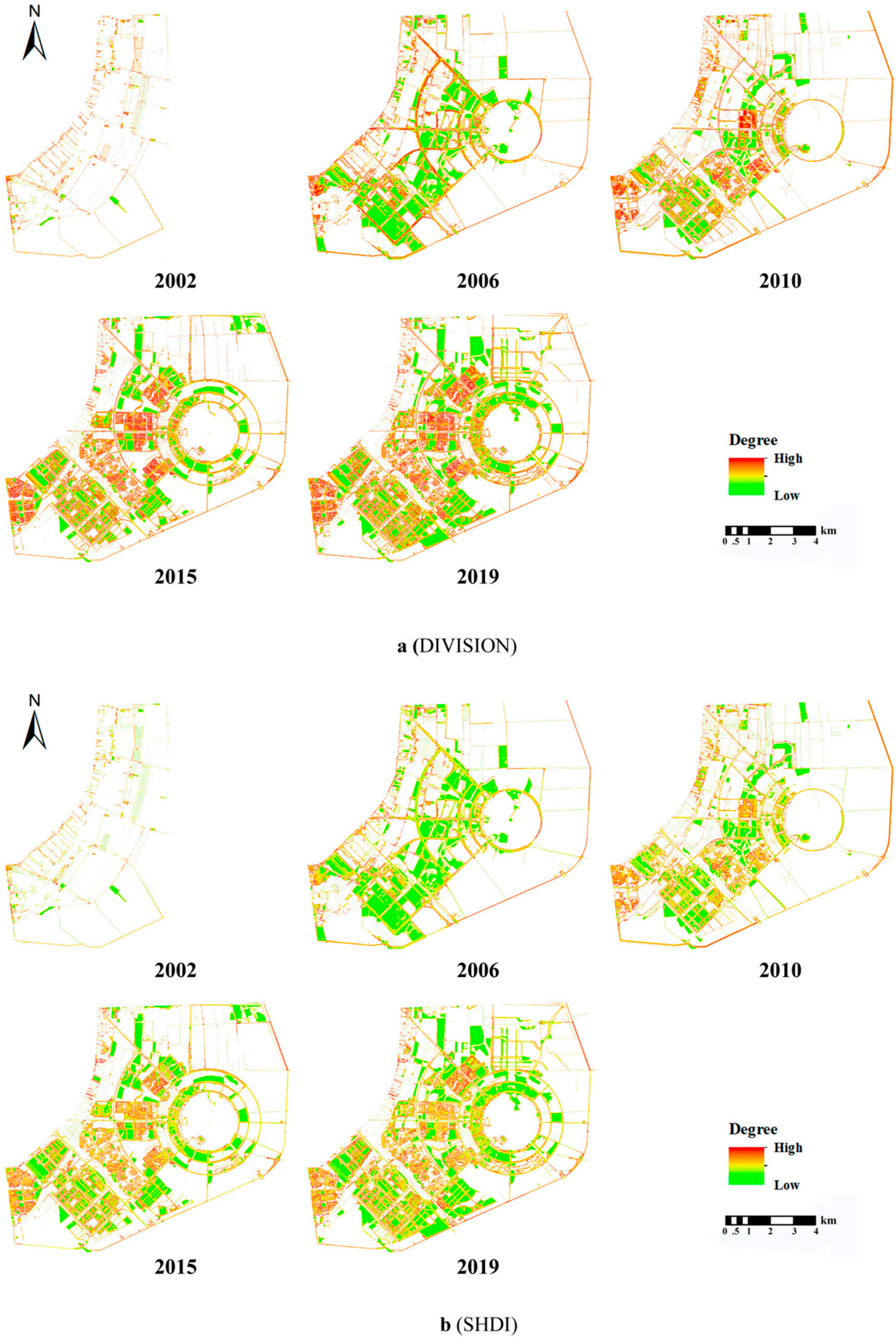
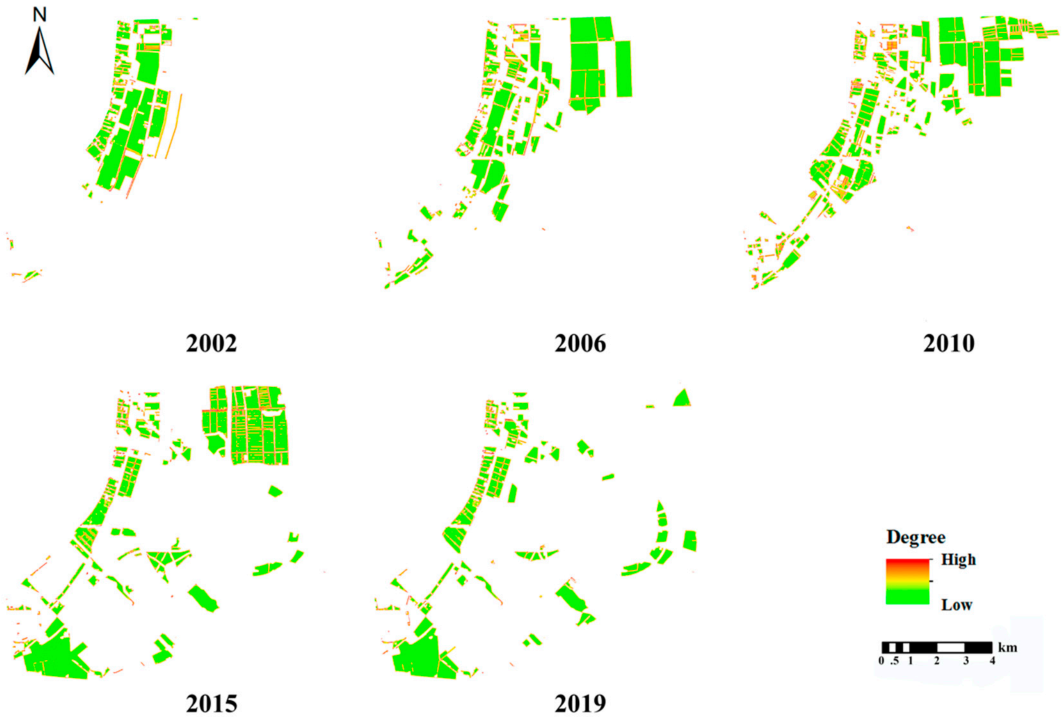
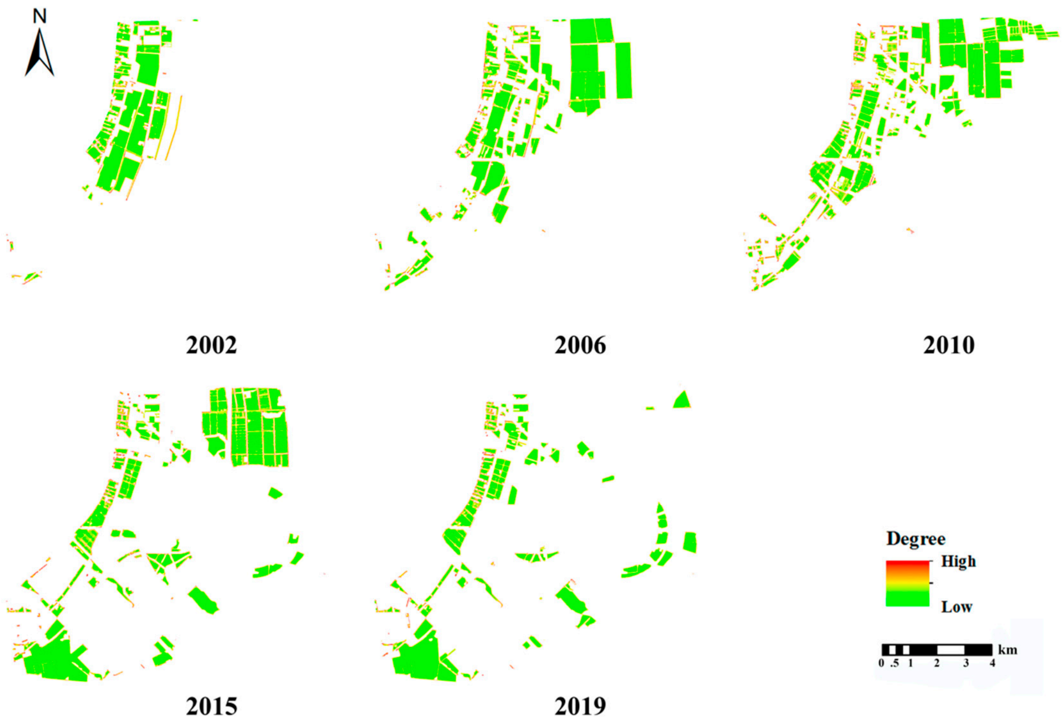


Figure 5. Spatial distribution of landscape fragmentation (**a**) (DIVISION) and diversity (**b**) (SHDI) of low-level habitats.

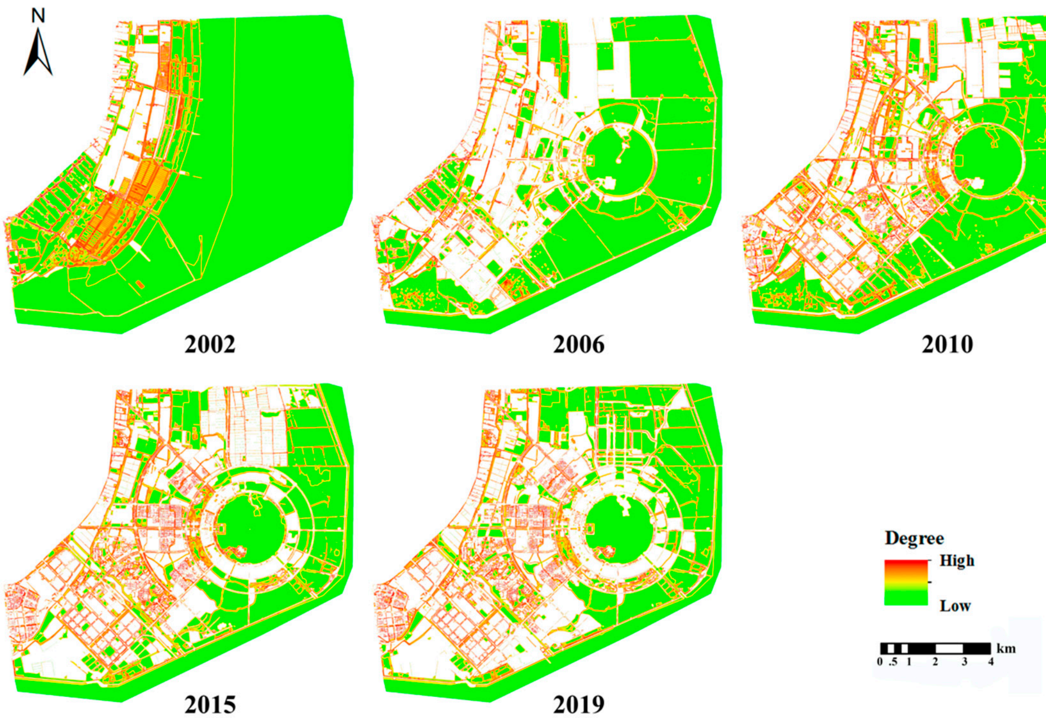


a (DIVISION)



b (SHDI)

Figure 6. Spatial distribution of landscape fragmentation (**a**) (DIVISION) and diversity (**b**) (SHDI) of middle-level habitats.



a (DIVISION)

b (SHDI)

Figure 7. Spatial distribution of landscape fragmentation (**a**) (DIVISION) and diversity (**b**) (SHDI) of high-level habitats.

5. Conclusions

This research, examining the core area of the Pilot Free Trade Zone Lin-Gang Special Area in China (Shanghai), analyzes the impact of rapid urbanization on habitat quality. From 2002 to 2019, buildings in the core area increased by 17.1 km^2, accounting for about 53.4% of the target year 2035. At the same time as rapid urbanization, the regional habitat also changed accordingly. The results show that the overall habitat quality declines with the increase in buildings. In addition, different levels of habitat quality are closely related to the spatial layout of the urban area. The denser the buildings are, the lower the habitat quality is. Among them, the low habitats in industrial areas are relatively concentrated, while those in tourism and commercial areas are relatively fragmented. The spatial layout of these industries mainly depends on government policies. In the process of planning, the government first considers economic benefits. When cities develop to a certain scale, habitat problems are exposed and show certain spatial distribution rules, and it is necessary to targeted solve the problem of poor habitat quality during the later development. Therefore, in the development process from 2020 to 2035, we recommend the following: (1) For the industrial logistics area in the southwest of the high-risk habitat area, the area of landscape types with good habitat quality, such as forest land, grassland, and water bodies, should be properly increased. (2) In regard to the high-habitat areas in the northeast, attention should be paid to both economic benefits and ecological environmental protection in the future development process. Priority should also be given to the development of unutilized land, and wetland, green land, and other land types with good ecological benefits should be protected. (3) In the commercial residential area around Dishui Lake with more new artificial buildings, it is necessary to consider reducing the habitat area of small patches and strengthening the intensive use of land-intensive land management to reduce the negative effects of habitat fragmentation caused by human activities.

In addition, in order to reduce the impact of urban construction on natural habitats, it is necessary to consider the industrial layout at the beginning of urban planning. The Chinese government requires the Lin-Gang Special Area to achieve a special economic function zone with strong international influence and competitiveness by 2035 (of which the GDP will reach CNY 1 trillion, accounting for about 1% of China's current GDP). As the most important and influential national urban development strategy in China, its support is unprecedented. In the construction process, with maximum support from all sides, other constraints can also be weakened to achieve the construction of a new city in a short time. Common large-scale urban construction is a long-term process, and the impact of urban expansion on habitats requires a long observation period. Taking the Lin-Gang core area as an example, it can reflect the habitat problems brought by rapid urban construction in a short period. Therefore, the relationship between urban expansion and habitat quality in the Lin-Gang core area has important reference value for the construction of other cities in China.

Common habitat quality analysis usually discusses the overall change in the habitat in the research area while ignoring the internal spatial distribution characteristics of different levels of habitats, which are very important for studying the layout of buildings and the impact of the habitat. This research combines landscape analysis and habitat quality analysis, quantifies the spatial distribution characteristics of habitats through landscape index, and then effectively links the relationship between building layout and habitat quality, which has great value for the construction of ecocities under the restriction of limited land.

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References

1. Lyu, R.; Zhang, J.; Xu, M.; Li, J. Impacts of urbanization on ecosystem services and their temporal relations: A case study in Northern Ningxia, China. *Land Use Policy* **2018**, *77*, 163–173. [CrossRef]
2. Sun, L.; Chen, J.; Li, Q.; Huang, D. Dramatic uneven urbanization of large cities throughout the world in recent decades. *Nat. Commun.* **2020**, *11*. [CrossRef]
3. Cui, E.; Ren, L.; Sun, H. Evaluation of variations and affecting factors of eco-environmental quality during urbanization. *Environ. Sci. Pollut. Res.* **2015**, *22*, 3958–3968. [CrossRef]
4. Yao, L.; Liu, J.; Wang, R.; Yin, K.; Han, B. A qualitative network model for understanding regional metabolism in the context of Social-Economic-Natural Complex Ecosystem theory. *Ecol. Inform.* **2015**, *26*, 29–34. [CrossRef]
5. Han, B.; Liu, H.; Wang, R. Urban ecological security assessment for cities in the Beijing-Tianjin-Hebei metropolitan region based on fuzzy and entropy methods. *Ecol. Model.* **2015**, *318*, 217–225. [CrossRef]
6. Pullanikkatil, D.; Palamuleni, L.G.; Ruhiiga, T.M. Land use/land cover change and implications for ecosystems services in the Likangala River Catchment, Malawi. *Phys. Chem. Earth Parts A/B/C* **2016**, *93*, 96–103. [CrossRef]
7. Zhu, E.; Deng, J.; Zhou, M.; Gan, M.; Jiang, R.; Wang, K.; Shahtahmassebi, A.R. Carbon emissions induced by land-use and land-cover change from 1970 to 2010 in Zhejiang, China. *Sci. Total Environ.* **2019**, *646*, 930–939. [CrossRef]
8. Zhu, E.; Deng, J.; Wang, H.; Wang, K.; Huang, L.; Zhu, G.; Belete, M.; Shahtahmassebi, A.R. Identify the optimization strategy of nitrogen fertilization level based on trade-off analysis between rice production and greenhouse gas emission. *J. Clean. Prod.* **2019**, *239*, 118060. [CrossRef]
9. Paruelo, J.M.; Burke, I.C.; Lauenroth, W.K. Land-use impact on ecosystem functioning in eastern Colorado, USA. *Glob. Chang. Biol.* **2001**, *7*, 631–639. [CrossRef]
10. Dresser, C.; Inc, M. Evaluation of Integrated Suface Water and Groundwater Modeling Tools. *Water Resour. Res.* **2001**, *35*.
11. Goldstein, J.H.; Caldarone, G.; Duarte, T.K.; Ennaanay, D.; Hannahs, N.; Mendoza, G.; Polasky, S.; Wolny, S.; Daily, G.C. Integrating ecosystem-service tradeoffs into land-use decisions. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, 7565–7570. [CrossRef] [PubMed]
12. Terrado, M.; Sabater, S.; Chaplin-Kramer, B.; Mandle, L.; Ziv, G.; Acuña, V. Model development for the assessment of terrestrial and aquatic habitat quality in conservation planning. *Sci. Total Environ.* **2016**, *540*, 63–70. [CrossRef]
13. Zhu, C.; Zhang, X.; Zhou, M.; He, S.; Gan, M.; Yang, L.; Wang, K. Impacts of urbanization and landscape pattern on habitat quality using OLS and GWR models in Hangzhou, China. *Ecol. Indic.* **2020**, *117*, 106654. [CrossRef]
14. De Mendonça, M.J.C.; Sachsida, A.; Loureiro, P.R.A. A study on the valuing of biodiversity: The case of three endangered species in Brazil. *Ecol. Econ.* **2003**, *46*, 9–18. [CrossRef]
15. Hamer, A.J. Accessible habitat delineated by a highway predicts landscape-scale effects of habitat loss in an amphibian community. *Landsc. Ecol.* **2016**, *31*, 2259–2274. [CrossRef]
16. Balasooriya, B.L.W.K.; Samson, R.; Mbikwa, F.; Vitharana, U.W.A.; Boeckx, P.; Van Meirvenne, M. Biomonitoring of urban habitat quality by anatomical and chemical leaf characteristics. *Environ. Exp. Bot.* **2009**, *65*, 386–394. [CrossRef]
17. Partyka, M.L.; Peterson, M.S. Habitat quality and salt-marsh species assemblages along an anthropogenic estuarine landscape. *J. Coast. Res.* **2008**, *24*, 1570–1581. [CrossRef]
18. Wu, Y.; Tao, Y.; Yang, G.; Ou, W.; Pueppke, S.; Sun, X.; Chen, G.; Tao, Q. Impact of land use change on multiple ecosystem services in the rapidly urbanizing Kunshan City of China: Past trajectories and future projections. *Land Use Policy* **2019**, *85*, 419–427. [CrossRef]
19. Leh, M.D.K.; Matlock, M.D.; Cummings, E.C.; Nalley, L.L. Quantifying and mapping multiple ecosystem services change in West Africa. *Agric. Ecosyst. Environ.* **2013**, *165*, 6–18. [CrossRef]
20. Mushet, D.M.; Neau, J.L.; Euliss, N.H. Modeling effects of conservation grassland losses on amphibian habitat. *Biol. Conserv.* **2014**, *174*, 93–100. [CrossRef]
21. Sherrouse, B.C.; Semmens, D.J.; Clement, J.M. An application of Social Values for Ecosystem Services (SolVES) to three national forests in Colorado and Wyoming. *Ecol. Indic.* **2014**, *36*, 68–79. [CrossRef]
22. Pérez-Vega, A.; Mas, J.F.; Ligmann-Zielinska, A. Comparing two approaches to land use/cover change modeling and their implications for the assessment of biodiversity loss in a deciduous tropical forest. *Environ. Model. Softw.* **2012**, *29*, 11–23. [CrossRef]
23. Boumans, R.; Roman, J.; Altman, I.; Kaufman, L. The multiscale integrated model of ecosystem services (MIMES): Simulating the interactions of coupled human and natural systems. *Ecosyst. Serv.* **2015**, *12*, 30–41. [CrossRef]

24. Benocci, R.; Brambilla, G.; Bisceglie, A.; Zambon, G. Eco-acoustic indices to evaluate soundscape degradation due to human intrusion. *Sustainability* **2020**, *12*, 455. [CrossRef]
25. Winkler, D.; Bidló, A.; Bolodár-Varga, B.; Erdő, Á.; Horváth, A. Long-term ecological effects of the red mud disaster in Hungary: Regeneration of red mud flooded areas in a contaminated industrial region. *Sci. Total Environ.* **2018**, *644*, 1292–1303. [CrossRef]
26. Mcdonald, R.I.; Kareiva, P.; Forman, R.T.T. The implications of current and future urbanization for global protected areas and biodiversity conservation. *Biol. Conserv.* **2008**, *141*, 1695–1703. [CrossRef]
27. Seto, K.C.; Güneralp, B.; Hutyra, L.R. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, 16083–16088. [CrossRef]
28. Güneralp, B.; Seto, K.C. Futures of global urban expansion: Uncertainties and implications for biodiversity conservation. *Environ. Res. Lett.* **2013**, *8*. [CrossRef]
29. Swenson, J.J.; Franklin, J. The effects of future urban development on habitat fragmentation in the Santa Monica Mountains. *Landsc. Ecol.* **2000**, *15*, 713–730. [CrossRef]
30. Li, T.; Shilling, F.; Thorne, J.; Li, F.; Schott, H.; Boynton, R.; Berry, A.M. Fragmentation of China's landscape by roads and urban areas. *Landsc. Ecol.* **2010**, *25*, 839–853. [CrossRef]
31. Krauss, J.; Bommarco, R.; Guardiola, M.; Heikkinen, R.K.; Helm, A.; Kuussaari, M.; Lindborg, R.; Öckinger, E.; Pärtel, M.; Pino, J.; et al. Habitat fragmentation causes immediate and time-delayed biodiversity loss at different trophic levels. *Ecol. Lett.* **2010**, *13*, 597–605. [CrossRef]
32. Scolozzi, R.; Geneletti, D. A multi-scale qualitative approach to assess the impact of urbanization on natural habitats and their connectivity. *Environ. Impact Assess. Rev.* **2012**, *36*, 9–22. [CrossRef]
33. Botequilha Leitão, A.; Ahern, J. Applying landscape ecological concepts and metrics in sustainable landscape planning. *Landsc. Urban Plan.* **2002**, *59*, 65–93. [CrossRef]
34. Moser, D.; Zechmeister, H.G.; Plutzar, C.; Sauberer, N.; Wrbka, T.; Grabherr, G. Landscape patch shape complexity as an effective measure for plant species richness in rural landscapes. *Landsc. Ecol.* **2002**, *17*, 657–669. [CrossRef]
35. Li, H.; Wu, J. Use and misuse of landscape indices. *Landsc. Ecol.* **2004**, *19*, 389–399. [CrossRef]
36. Uuemaa, E.; Antrop, M.; Roosaare, J.; Marja, R.; Mander, Ü. Landscape metrics and indices: An overview of their use in landscape research. *Living Rev. Landsc. Res.* **2009**, *3*, 1–28. [CrossRef]
37. Béliveau, M.; Germain, D.; Ianăş, A.N. Fifty-year spatiotemporal analysis of landscape changes in the Mont Saint-Hilaire UNESCO Biosphere Reserve (Quebec, Canada). *Environ. Monit. Assess.* **2017**, 189. [CrossRef] [PubMed]
38. Mcgarigal, K.; Cushman, S.; Neel, M. *FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps*; University of Massachusetts: Amherst, MA, USA, 2002; ISBN 0278-4807.
39. Pătru-Stupariu, I.; Stupariu, M.S.; Tudor, C.A.; Grădinaru, S.R.; Gavrilidis, A.; Kienast, F.; Hersperger, A.M. Landscape fragmentation in Romania's Southern Carpathians: Testing a European assessment with local data. *Landsc. Urban Plan.* **2015**, *143*, 1–8. [CrossRef]
40. Du, X.; Huang, Z. Ecological and environmental effects of land use change in rapid urbanization: The case of hangzhou, China. *Ecol. Indic.* **2017**, *81*, 243–251. [CrossRef]
41. Miller, J.R.; Hobbs, R.J. Habitat Restoration—Do we know what were doing? *Restor. Ecol.* **2007**, *15*, 382–390. [CrossRef]
42. Sharp, R.; Tallis, H.T.; Ricketts, T.; Guerry, A.D.; Wood, S.A.; Chaplin-Kramer, R.; Nelson, E.; Enaanay, D.; Wolny, S.; Olwero, N.; et al. InVEST User Guide. *Natl. Cap. Proj.* **2018**, 21.
43. Wang, Q.; Yang, S.; Zheng, M.; Han, F.; Ma, Y. Effects of vegetable fields on the spatial distribution patterns of metal(Loid)s in soils based on GIS and Moran's I. *Int. J. Environ. Res. Public Health* **2019**, *16*, 4095. [CrossRef] [PubMed]
44. Ma, F.; Liu, F.; Sun, Q.; Wang, W.; Li, X. Measuring and spatio-temporal evolution for the late-development advantage in China's provinces. *Sustainability* **2018**, *10*, 2773. [CrossRef]
45. Jia, Y.; Tang, X.; Liu, W. Spatial-temporal evolution and correlation analysis of ecosystem service value and landscape ecological risk in wuhu city. *Sustainability* **2020**, *12*, 2803. [CrossRef]
46. Wang, H.; Tang, L.; Qiu, Q.; Chen, H. Assessing the impacts of urban expansion on habitat quality by combining the concepts of land use, landscape, and habitat in two Urban agglomerations in China. *Sustainability* **2020**, *12*, 4346. [CrossRef]
47. Yirigui, Y.; Lee, S.W.; Nejadhashemi, A.P.; Herman, M.R.; Lee, J.W. Relationships between riparian forest fragmentation and biological indicators of streams. *Sustainability* **2019**, *11*, 2870. [CrossRef]
48. Kowe, P.; Mutanga, O.; Odindi, J.; Dube, T. A quantitative framework for analysing long term spatial clustering and vegetation fragmentation in an urban landscape using multi-temporal landsat data. *Int. J. Appl. Earth Obs. Geoinf.* **2020**, *88*, 102057. [CrossRef]
49. Kong, F.; Nakagoshi, N. Spatial-temporal gradient analysis of urban green spaces in Jinan, China. *Landsc. Urban Plan.* **2006**, *78*, 147–164. [CrossRef]
50. Announcement of the General Planning of the Land and Space of the Lingang New Area of the China (Shanghai) Pilot Free Trade Zone. 2020. Available online: http://ghzyj.sh.gov.cn/ghgs/20200622/c1d9cde4f2ee4b60a345c2dc2598335e.html (accessed on 30 October 2020).
51. Bai, L.; Xiu, C.; Feng, X.; Liu, D. Influence of urbanization on regional habitat quality:a case study of Changchun City. *Habitat Int.* **2019**, *93*. [CrossRef]

52. Sun, X.; Jiang, Z.; Liu, F.; Zhang, D. Monitoring spatio-temporal dynamics of habitat quality in Nansihu Lake basin, eastern China, from 1980 to 2015. *Ecol. Indic.* **2019**, *102*, 716–723. [CrossRef]
53. Aneseyee, A.B.; Noszczyk, T.; Soromessa, T.; Elias, E. The InVEST habitat quality model associated with land use/cover changes: A qualitative case study of the Winike Watershed in the Omo-Gibe Basin, Southwest Ethiopia. *Remote Sens.* **2020**, *12*, 1103. [CrossRef]
54. Shanghai Lingang New City Management Measures. 2004. Available online: http://www.moj.gov.cn/Department/content/2004-03/10/595_210181.html (accessed on 30 October 2020).
55. Land and Space Master Plan of Pudong New Area. 2017. Available online: http://hd.ghzyj.sh.gov.cn/xxgk/ghjh/202003/t20200303_960552.html (accessed on 30 October 2020).
56. Shi, Q.; Gao, J.; Wang, X.; Ren, H.; Cai, W.; Wei, H. Temporal and spatial variability of carbon emission intensity of urban residential buildings: Testing the effect of economics and geographic location in China. *Sustainability* **2020**, *12*, 2695. [CrossRef]
57. Wang, C.; Wang, G.; Dai, L.; Liu, H.; Li, Y.; Zhou, Y.; Chen, H.; Dong, B.; Lv, S.; Zhao, Y. Diverse usage of waterbird habitats and spatial management in Yancheng coastal wetlands. *Ecol. Indic.* **2020**, *117*, 106583. [CrossRef]