land

MDPI

Article

Land Consolidation Zoning in Coastal Tidal Areas Based on Landscape Security Pattern: A Case Study of Dafeng District, Yancheng, Jiangsu Province, China

Min Xia [1], Linyan Wang [1], Bo Wen [2], Wei Zou [1], Weixin Ou [1] and Zhongqiong Qu [1,*]

[1] College of Land Management, Nanjing Agricultural University, Nanjing 210095, China; xm@njau.edu.cn (M.X.); 20416104@njau.edu.cn (L.W.); zw@njau.edu.cn (W.Z.); owx@njau.edu.cn (W.O.)
[2] College of Landscape Architecture, Nanjing Forestry University, Nanjing 210037, China; wenbo2019@njfu.edu.cn
* Correspondence: qzq@njau.edu.cn

Abstract: It is crucial to pay close attention to the ecological security in land consolidation and utilization of coastal tidal areas and make an appropriate zoning scheme to meet the characteristics of its particular landscape. Landscape security patterns can identify the patterns that are crucial to the health and security of landscape ecological processes by analyzing and simulation them. This article applies the theory of landscape security pattern to land consolidation zoning in a coastal tidal area, Dafeng District, Yancheng, Jiangsu Province. The main landscape processes in land consolidation are explored in land consolidation in the area by literature review and field investigation, corresponding single landscape ecological security patterns are constructed using spatial analysis functions in ArcGIS 10.3, and land consolidation zones are determined according to the comprehensive landscape security pattern. The results show that: (1) The processes of water-soil conservation, water source protection, biodiversity conservation, local culture protection, and recreation are the main landscape processes. The security patterns generated by key points and resistance elements could affect land consolidation; (2) The comprehensive landscape security pattern is composed of the multi-landscape security patterns, which are classified into three levels of high, medium, and low. The areas of the levels account for 20.12%, 46.23% and 33.65% of Dafeng District, respectively; (3) The specific suggestions of ecological protection and ecological restoration in land consolidation are put forward for land consolidation zones with different levels of landscape security patterns. These results suggest that zoning based on landscape security patterns can provide guidance for land consolidation and regulation in coastal tidal areas.

Keywords: landscape security pattern; coastal tidal areas; land consolidation zones

Citation: Xia, M.; Wang, L.; Wen, B.; Zou, W.; Ou, W.; Qu, Z. Land Consolidation Zoning in Coastal Tidal Areas Based on Landscape Security Pattern: A Case Study of Dafeng District, Yancheng, Jiangsu Province, China. *Land* **2021**, *10*, 145. https://doi.org/10.3390/land10020145

Received: 2 December 2020
Accepted: 30 January 2021
Published: 2 February 2021

1. Introduction

Land consolidation is a comprehensive reallocation process in rural areas consisting of fragmented agricultural, forestry, or their part [1,2]. Through a planned adjustment and rearrangement of the fragmented land parcels and their ownership, including land rearrangement, renovation of drainage systems, the building of local roads, and so forth, land consolidation enhanced land use. As the basic and premise of land reallocation [3], land consolidation is widely practiced in many countries around the world. It not only speeds up land remediation and improves its efficiency [4] but also increases agricultural productivity [5], creates sustainable rural areas [6,7] and alleviates poverty [8].

With the emphasis on ecological remediation for alleviating the adverse impact of land consolidation on the living environment of plants and animals, the theory and research methods of landscape ecology are increasingly applied to the practice of land

consolidation planning and zoning. Based on the landscape ecological planning method advocated by Forman in 1995 [9], Kongjian Yu put forward the "landscape security pattern theory" in his doctoral thesis at Harvard University [10]. He believed there are some ecological security patterns, which are strategically important in biological conservation and landscape change [11]. After this, various landscape security patterns have been constructed and applied in spatial allocation optimization [12], ecological sources [13], scientific guidance on ecological protection and planning of urban agglomerations [14], city center planning [15], urban landscape planning [16], ecological restoration planning [17] and so on.

In coastal areas, there is a growing demand for various industrial parks and construction land because of industries and population concentration. The increasing scale and degree of coastal exploitation in coastal areas have resulted in an urgent need for coastal planning, especially in the coastal tidal area. As an important coastal wetland landscape, land-use types in the coastal tidal area are numerous and different from those in inland areas, such as a variety of rare forest land, natural reserve areas, saline-alkali land, salina, salt-pan, etc. Due to the lack of rational land ecological comprehensive consolidation planning, some tidal areas have been suffering from decreasing biodiversity and soil quality, destruction of the original ecological system, and increasingly aggravated environmental pollution in recent years [18]. It is crucial to pay close attention to the ecological security in land consolidation and utilization of coastal tidal areas and make an appropriate zoning scheme to meet the characteristics of its particular landscape. Traditional coastal planning zoning studies complied with laws and regulations, coastal policies, and zoning standards formulated by the state [19,20]. The partition of the planning zones could base on the integrated environmental, economic, and societal characteristics of the marine and terrestrial boundaries [21,22] or refer to the geomorphic and physiographic characteristics and the homogeneous environmental management units [23,24]. However, few studies have analyzed the construction of landscape ecological security patterns in coastal areas, especially in terms of applying them to land consolidation zoning and planning.

Using Dafeng District, Yancheng, Jiangsu Province as a study area, the present study aimed to explore the main landscape processes in land consolidation in the area. Single landscape ecological security patterns were constructed, and the land consolidation planning zones were conducted according to the comprehensive security pattern. The relevant countermeasures and suggestions were put forward to reference for the land consolidation decision-making in the Dafeng District.

2. Data and Method

2.1. Study Areas

China's coastal tidal areas are mainly distributed in the coastal areas of Liaoning, Shandong, Jiangsu, Zhejiang, Fujian, Taiwan, Guangdong, Guangxi, and Hainan, which are the important part of the coastal zone and also constitutes coastal economic development zone in China. Dafeng District is a municipal district of Yancheng city, Jiangsu Province, China (shown in Figure 1). It has a total population of 720,000, comprising 12 towns and Dafeng port, which is composed of three parts named Doulong, Gangqu, and Chuandong. It is located in the central coastal area of Jiangsu province (between 32°56′and 33°36′ north latitudes, 120°13′ and 120°56′ east longitudes), with a total area of 3059 square kilometers and a coastline of 112 km. The area is an alluvial plain with alternating sediments of lacustrine, fluvial, and marine facies, characterized by unique geological and geomorphic features. The terrain is wide in the south and narrows in the north, forming an irregular triangle with several rivers flowing into the sea. Dafeng District has a total area of more than 1000 square kilometers of mudflat wetlands and a total area of more than 1000 square kilometers radial sandbar—Dongsha Island, which is the largest wetland in the east of Asia. It is one of China's important reserve land resources

and space resources and has various ecological service values, which has been considered a valuable community resource.

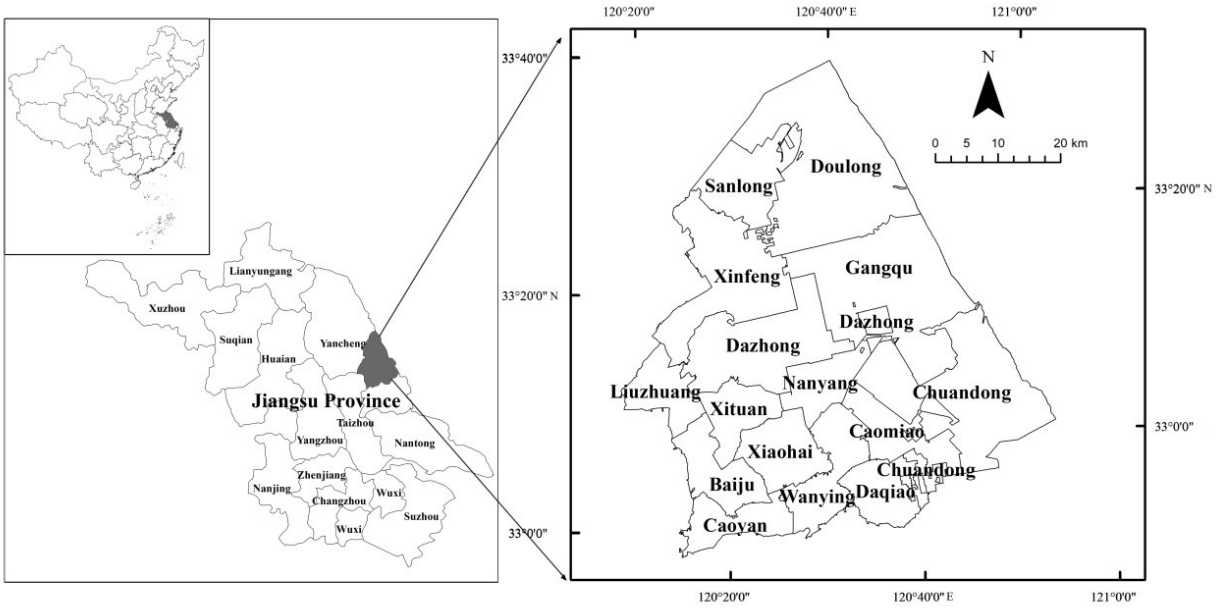

Figure 1. Location of Dafeng District.

2.2. Data Sources and Processing

The data adopted in this article mainly include four categories: 1) Land use survey data in 2016 collecting from the Municipal Bureau of Land and Resources in the Dafeng District was chosen as the base data. There are 21 land-use types in the data. According to the requirements of the study, they were reclassified into 7 types: cultivated land, garden land, forest land, grassland, construction land, watershed, and the other land (shown in Table 1). Layers of town, transportation land, industrial land, and construction land were extracted from the data and converted to raster maps with a resolution of 30 m. Data for distances from each raster to the 4 lands were calculated, respectively, using the Euclidean Distance tool in ArcGIS 10.3; 2) Vegetation coverage was calculated using the NDVI (normalized difference vegetation index) dimidiate pixel model [25], and Landsat-8 OLI_TRIS remote sensing image (30 m resolution) of 1 March 2016 (http://www.gscloud.cn) was selected as the data source. 3) Slope and slope direction were extracted from ASTER GDEM data (30 m resolution) obtained from the Geospatial Data Cloud, Chinese Academy of Sciences (http://www.gscloud.cn). 4) Distribution maps of natural scenic spots and cultural relic protection units in the Dafeng District were obtained from field investigation and vectored based on ArcGIS 10.3, then converted to raster maps with a resolution of 30 m.

Table 1. Contents of the reclassified land-use types.

Reclassified Land Use Types	Contents
Cultivated land	Paddy field, dry land
Garden land	Mulberry garden, orchard, tea garden
Forest land	Arbor forest, shrub forest
Grassland	Grassland
Construction land	town, village, transportation land, industrial land, mining land
Watershed	river, lake, pond, tidal, marshland, reservoir
Other land	bare land, unused land

3. Research Methods

The landscape security pattern is a way to identify and establish ecological infrastructure based on landscape ecology theories and methods. It holds that no matter landscape is homogeneous or heterogeneous, each point in the landscape is not equally important to some ecological environment. Some parts, points or some spatial connections among these landscapes play a key role in controlling landscape ecological processes in overcoming spatial resistance. Analysis and simulation of these processes can identify the landscape patterns that are crucial to the health and security of these processes [10].

For land consolidation zoning in coastal tidal areas based on landscape security pattern, the workflow is shown in Figure 2, and the following steps were taken:

1. The main landscape processes closely related to land consolidation in the coastal tidal area were explored by field investigation;
2. The key points (namely the source) and the resistance elements in each landscape process were found out by literature review and field investigation. Using reclassify and natural breaks method in ArcGIS 10.3, the resistance elements were classified into 9 grades according to their values;
3. In the present study, the minimum cumulative resistance model (MCR) was employed to identify the minimum cumulative value of resistance to be overcome from the source to a certain location in space. The equationfor the model is as follows [26]:

$$\mathrm{MCR} = \mathrm{fmin}\sum_{j=n}^{i=m}(D_{ij} \times R_i) \quad (1)$$

The equationis derived from the research model designed by Knaapen [26]. In theequation, MCR represents the minimum cumulative resistance. f is a function that reflects the positive correlation between the MCR and landscape ecological processes [27]. D_{ij} is the spatial distance from source unit j to landscape unit i, R_i is the resistance coefficient of landscape unit i. The R_i is determined according to the influence intensity of every element on the process, and the resistance surface is calculated based on R_i. Since the calculation is to reflect the relative trend of resistance, the resistance coefficients may only reflect the relative influence intensity rather than the absolute [10]. The resistance coefficients corresponding to the 9 resistance elements grades were assigned scores 1–9 in the present study. With the cost distance tool in ArcGIS 10.3, the minimum cumulative resistance between each pixel and the nearest unit on the cost surface was calculated by using the spatial distance and comprehensive resistance surface [27].

4. Single landscape ecological security patterns were constructed based on the MCR values, and a comprehensive landscape ecological security pattern was further constructed by overlaying the single patterns, adopting the weight-average method [11]. All of the patterns were obtained using the raster calculator and divided into low, medium, and high levels using the natural breaks method in ArcGIS 10.3;
5. Land consolidation zones were proposed in the Dafeng District according to the comprehensive landscape ecological security pattern, following its administrative division.

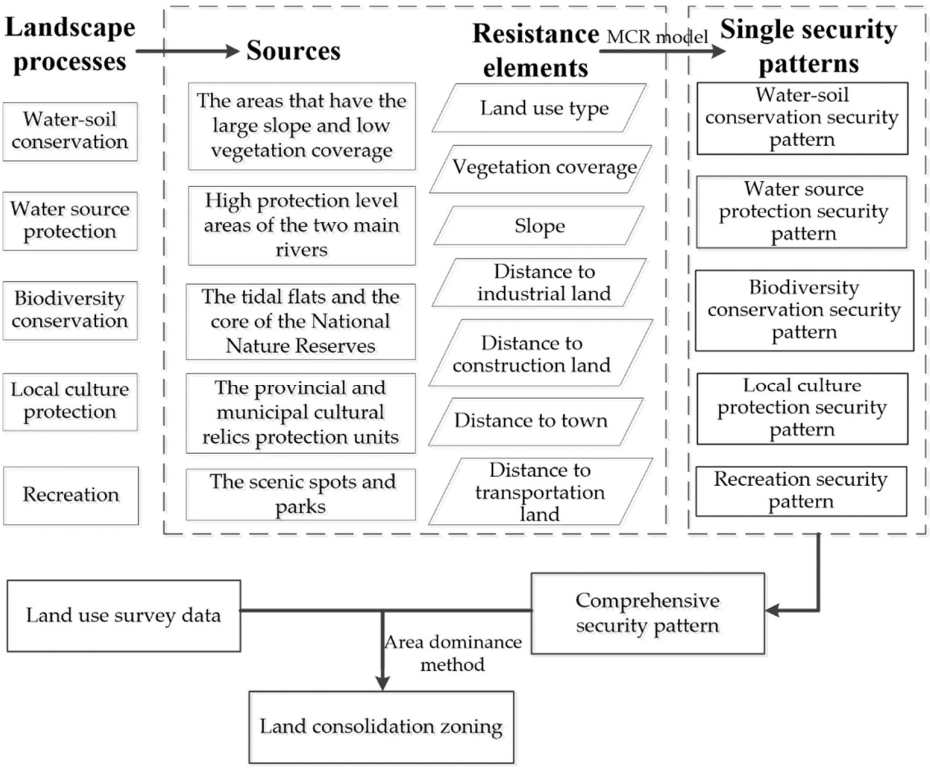

Figure 2. The workflow for land consolidation zoning in coastal tidal areas based on landscape security patterns.

4. Results

4.1. Main Landscape Processes, Their Sources and Resistance Elements in Coastal Tidal Areas

Five main landscape processes were explored in land consolidation in the Dafeng District: water-soil conservation, water source protection, biodiversity conservation, local culture protection, and recreation. A source is a starting where the landscape process takes place [28], and resistance elements are the main factors that affect the process. It is necessary to consider the influence of nature, ecology, social culture, and so on in confirming the sources and the resistance elements.

Slope, vegetation coverage, land-use type, rainfall, and soil type were the main factors causing soil erosion [11]. In the Dafeng District, there is little difference in rainfall and soil types. Consequently, the first three factors play a decisive role in the process of water-soil conservation. The areas that have slopes larger than 25° and vegetation coverage lower than 0.171 were taken as the sources of water-soil conservation, and the slope, vegetation coverage, and land-use type were taken as resistance elements.

The water reserves for drinking in the Dafeng District are relatively sufficient, but the safety of water sources has been threatened because of industrial emissions and land-use change. According to the zoning plan of centralized drinking water source protection for those areas above the county level in Jiangsu Province (source: https://wenku.baidu.com/view/0693d342a48da0116c175f0e7cd184254a351b05.html), there are two main water sources in the Dafeng District, namely Tongyu River and Xintuan River. The level 1, level 2, and quasi protection areas of the two rivers were taken as the sources of water source protection. The land-use types, vegetation coverage, and distance to industrial land were the main factors influencing water source protection.

The animals and plant resources are abundant in the Dafeng District. Some buffer zones and experimental areas of the Milu and rare bird national nature reserves are also located there. The tidal flats and the Core of the National Nature Reserves were selected

as the biodiversity conservation sources. The land-use type, distance to transportation lands, and distance to town were taken as resistance elements.

There are a large number of cultural relics in the Dafeng District, which are its precious historical and cultural heritage. The provincial and municipal cultural relics protection units such as Guqingfeng Bridge, Caoyan Ancient Village, Shi Naian's Former Residence, Zhenhai Temple were Selected as the sources of local culture protection. In space, the local culture protection is not only affected by land-use type but also by the layout of traffic road and town. Thus, land-use type, vegetation coverage, and distance to construction land were taken as resistance elements.

Various types of tourism resources provide leisure and recreation places for tourists in the Dafeng District. The scenic spots and parks such as Shinaian Memorial Hall, Doulong Manor, Meiyuan Garden in the Western Suburbs, Dafeng Zoo, and Dafeng Ocean World were selected as recreation sources. The attraction and accessibility of scenic spots and parks are the main concern of tourists. The land-use type, vegetation coverage, distance to transportation lands, and distance to town were taken as resistance elements.

The scores of the resistance coefficients and their corresponding values of resistance elements are shown in Table 2. Since the distance to transportation lands has a negative influence on biodiversity conservation and a positive influence on recreation, the effects were opposite in the two different landscape security patterns. The resistance coefficients listed in Distance to transportation lands (-) and Distance to transportation lands (+) were used to the calculation of the resistance surfaces in biodiversity conservation security pattern and recreation security pattern, respectively.

Table 2. The resistance coefficients of the resistance elements.

Resistance Coefficients	Resistance Elements							
	Land Use Type	Vegetation Coverage	Slope	Distance to Industrial Land (km)	Distance to Construction Land (km)	Distance to Town (km)	Distance to Transportation Land (-) (km)	Distance to Transportation Land (+) (km)
1	Watershed	≥0.459	≤2°	≥11.35	≥6.473	≥12.01	≥7.84	≤0.47
2	Forest land	0.422–0.459		8.94–11.35	5.05–6.47	9.77–12.01	6.22–7.84	0.47–1.04
3	Garden land	0.381–0.422	2°–6°	7.04–8.94	3.92–5.05	7.80–9.77	4.75–6.22	1.04–1.68
4	Grassland	0.339–0.381		5.47–7.04	2.93–3.92	6.02–7.80	3.45–4.75	1.68–2.45
5	Cultiated land	0.292–0.339	6°–15°	4.15–5.47	2.02–2.93	4.49–6.02	2.45–3.45	2.45–3.45
6		0.247–0.292		3.02–4.15	1.20–2.02	3.22–4.49	1.68–2.45	3.45–4.75
7	Construction land	0.208–0.247	15°–25°	2.02–3.02	0.54–1.20	2.12–3.22	1.04–1.68	4.75–6.22
8		0.171–0.208		1.06–2.02	0.16–0.54	1.03–2.12	0.47–1.04	6.22–7.84
9	Other land	≤0.171	≥25°	≤1.06	≤0.16	≤1.03	≤0.47	≥7.84

4.2. Single and Comprehensive Landscape Security Patterns in Coastal Tidal Areas

The resistance surfaces of water-soil conservation, water source protection, biodiversity conservation, local culture protection, and recreation were determined, respectively. The resistance elements in each process were equally weighted. Five corresponding single landscape ecological security patterns with high, medium and low-security levels were constructed as shown in Figure 3. The areas of the three levels are shown in Table 3:

Table 3. Areas of the 3 levels in Landscape Security Patterns.

Kinds of Security Pattern	Levels	Area/hectares	Percent/%
Water-soil conservation security pattern	Low	123,049.91	40.90
	Medium	166,575.16	55.37
	High	11,205.64	3.72
Water source protection security pattern	Low	16,342.6874	5.43
	Medium	97,737.306	32.49
	High	186,750.7077	62.08
Biodiversity conservation security	Low	150,936.87	50.17

pattern	Medium	86,065.16	28.61
	High	63,828.68	21.22
Local culture protection security pattern	Low	16,692.53	5.55
	Medium	105,428.08	35.05
	High	178,710.10	59.41
Recreation security pattern	Low	90,749.38	30.17
	Medium	187,572.07	62.35
	High	22,509.27	7.48
Comprehensive security pattern	Low	101,241.46	33.65
	Medium	139,067.08	46.23
	High	60,522.20	20.12

The areas of high-security level in the water-soil conservation security pattern are located in the small fractions of Dafeng port, with flat terrain and main land-use type of watershed. The areas of medium or low-security level spread all over the district. The medium-security level area occupies the largest space among the three types, and the residential distributed widely. The low-security level area generally has low vegetation cover and low slope. Because of less rainfall in winter and abundant in summer, it is difficult to conserve soil and water in these areas. In the water source protection security pattern, the areas of high-security level are mainly located in the east of the district. The characteristics of low relief topographic, high vegetation, and long-distances from industrial land make it better to protect the water environment and to mitigate the risk of contamination. The areas of medium-security level are on the periphery of the areas of the high-security level. The areas of low-security level are mainly concentrated in Liuzhuang town, which is characterized by low vegetation coverage and the short distance from industrial lands. Groundwater and the source water are seriously polluted by widely distributed independent industrial and mining land in the areas. In the biodiversity conservation security pattern, the areas of high-security level are located in the west and account for 21.22% of the Dafeng District. These areas are the main habitat of birds. Because of far from cities and towns and affecting by less urban construction and agricultural production, its biodiversity is stable for a long time. The areas of medium-security level are located in the middle region of the Dafeng District, and the land-use types are mainly cultivated land, construction land, and garden land. These areas carry most of the human activities and have a stable number and variety of animals and plants. The areas of low-security levels have low slopes, high vegetation cover, flat terrain, and abundant water resources. Due to its superior ecological environment, most of the wildlife inhabits. The areas of high-security level in the local cultural protection security pattern are located in the easternmost part of Dafeng District, far away from the core area of the native culture. The areas of medium-security level distribute in Xinfeng town, Dazhong town, Xituan town, and Nanyang town, where have a rich historical and cultural heritage. The areas of low-security level have high-level cultural relics such as Caoyan Ancient Village and Shi Naian's Former Residence. In the recreation security pattern, the areas of high-security level are only found in the parts of the Doulong and Chuandong. These areas are mainly mudflats and far away from scenic spots; land development and use have less influence on human recreation. The areas with medium-security level are mainly distributed in the south and north of Dafeng District. The areas of low-security level are widely distributed in the district except for Daqiao town. Natural scenic sites are concentrated in the areas.

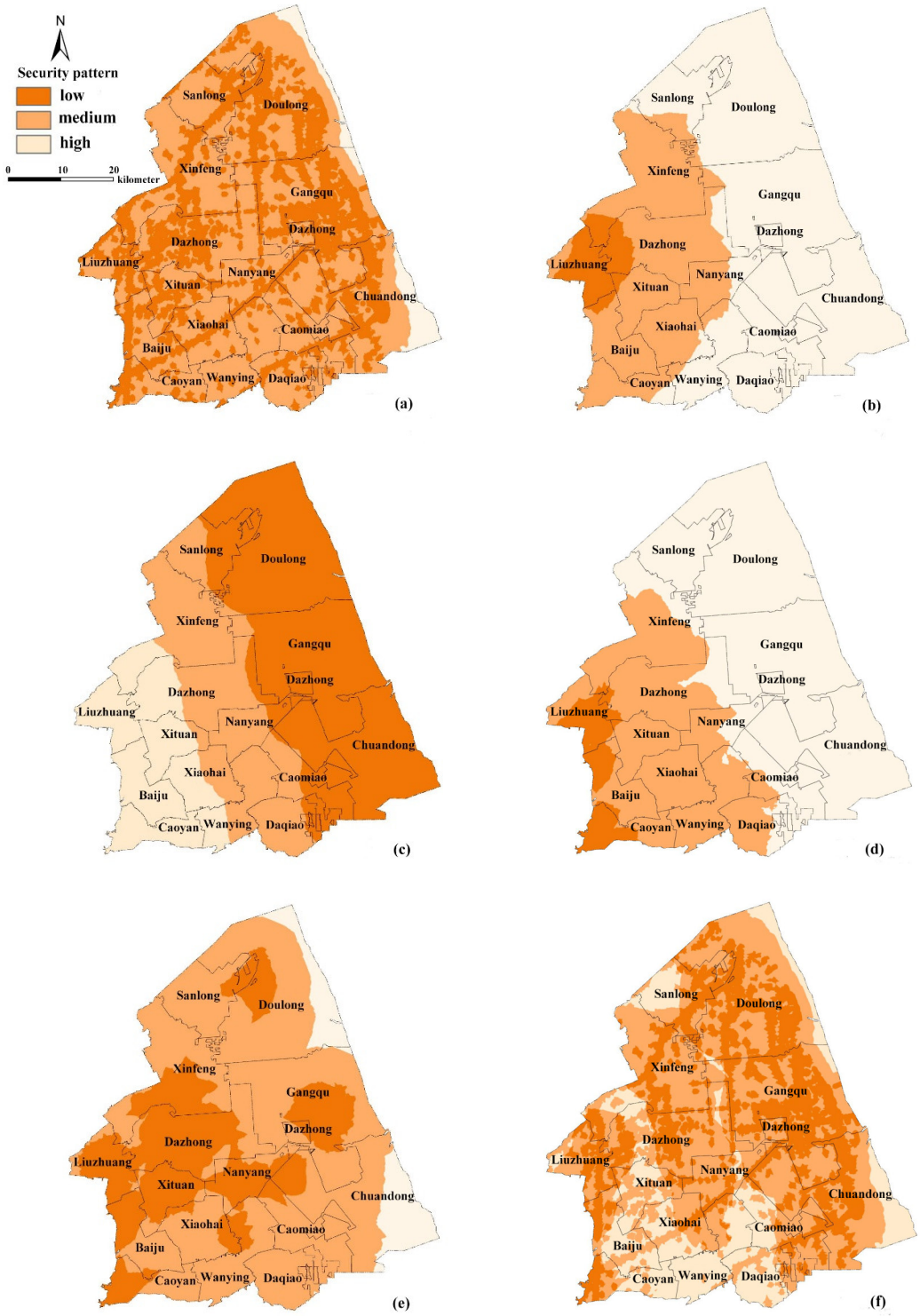

Figure 3. (**a**–**f**) Landscape security pattern. (**a**) water-soil conservation security pattern, (**b**) water source protection security pattern, (**c**) biodiversity conservation security pattern, (**d**) local culture protection security pattern, (**e**) recreation security pattern, (**f**) comprehensive security pattern.

The comprehensive landscape security pattern reflects the results and potential trends of the interactions among the five single security patterns (shown in Figure 2). Considering the relationship between landscape processes and land consolidation in the

coastal tidal areas, the weight of 0.3, 0.2, 0.3, 0.1, and 0.1 are, respectively assigned to the security patterns of water-soil conservation, water source protection, biodiversity conservation, local culture protection, and recreation. In the pattern, the areas of high and medium-security level account for 20.12% and 46.23% of Dafeng District, of which the medium-security level covers most areas of Nanyang town, Dazhong town, and Xinfeng Town. More than half of the Sanlong town, Wanying town, Daqiao town, and some small fractions are within the low-security level.

4.3. Land Consolidation Zones in Coastal Tidal Areas

Nowadays, land consolidation is generally advanced in whole villages in the Dafeng District. The reasonability of land consolidation zoning and planning can be determined by the comprehensive landscape security patterns, which reflect the joint interactions among the five main landscape processes. Based on the comprehensive landscape security pattern, the administrative villages within the study area were treated according to the area dominance method. If the administrative village had the largest low-security level area, it was identified as the land consolidation area based on ecological protection, which stressing more attention should be paid to the ecological protection in the process of land consolidation. If the administrative village had the largest medium-security level area, it was identified as the land consolidation area based on ecological protection and ecological restoration, which stressing ecological protection in some areas and ecological restoration in the other area in the process of land consolidation. If the administrative village had the largest high-security level area, it was identified as the land consolidation area based on ecological restoration, which stressing ecological restoration in the process of land consolidation. To simplify the description, the above areas are abbreviated as land consolidation zone I, II, and III, respectively, as shown in Figure 4:

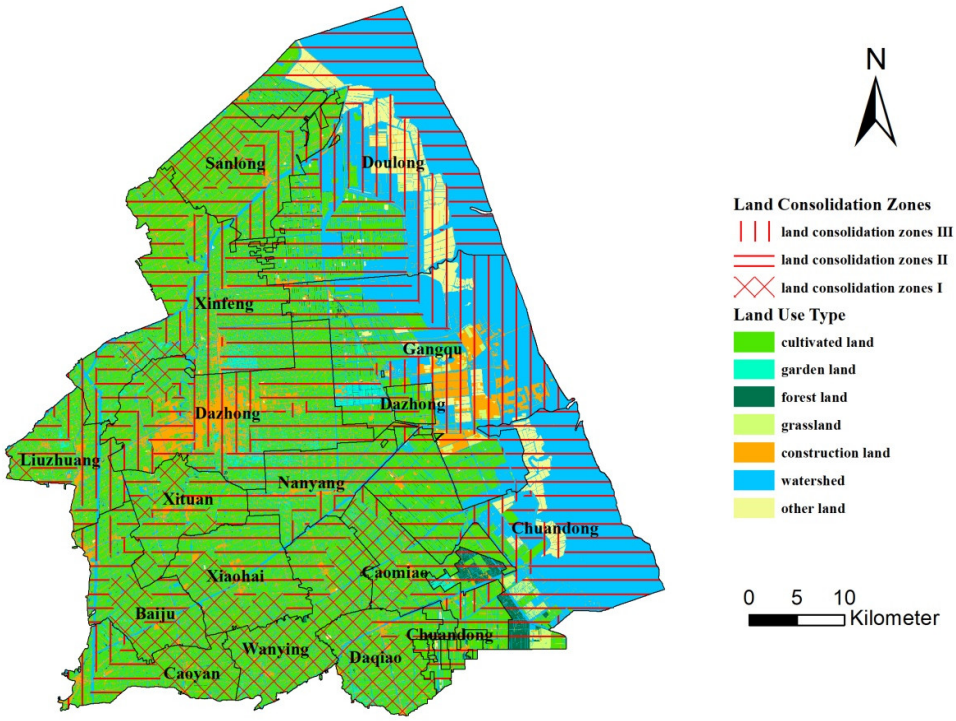

Figure 4. Land consolidation zoning map.

The area of land consolidation zones I is 49,168.03 hectares, accounting for only 16.34% of the total area, which is the smallest among the three types of zones. The zones are distributed in the west and south of the study area, mainly in the south, and the rest

scattered in the west, including 65 villages and 1 committee. Land consolidation zones II cover an area of 174,579.77 hectares, accounting for 58.04% of the total area, which is widely distributed in the study area. According to the different spatial distribution locations, land consolidation zones II can be divided into the central agglomeration, eastern banded, and other areas, including 103 villages, 7 committees, 11 farms, 5 management stations, 5 agricultural industries, 4 natural reserves, and 1 government office. Land consolidation zones III have an area of 77,062.95 hectares, accounting for 25.62% of the total area. It is mainly distributed in the west of the study area and some areas of Dafeng port. According to the spatial distribution, the restricted consolidation zones can be simply divided into the west and the east, including 42 villages, 10 committees, 3 farms, 19 management stations, 12 agricultural industries, 12 agricultural-related companies, 1 old urban area, and 1 economic port.

5. Discussion

The land use structure of the Dafeng District could be reflected by landscape indexes [29–31] that were calculated according to the land use survey data in 2016. The land-use diversity index was 0.56, which was lower than 0.63, the average level of Jiangsu Province. The dominance index of cultivated land, watershed, and construction land were 74.90, 58.26, and 7.66, respectively, which was much higher than that of forest land (0.17) and garden land (0.43). The splitting index of the watershed and cultivated land is also relatively small, only 0.64 and 0.66, respectively, indicating a relatively concentrated spatial distribution of these two land-use types. On the other hand, the splitting indexes of garden land, forest land, and construction land were relatively high, which were 7.05, 5.51 and, 4.55, respectively, indicating a scattered distribution of these land-use types. These indexes showed a low complexity of land-use types of Dafeng District in 2016. The main land-use types were cultivated land, watershed, and construction land, and the distribution of cultivated land and watershed were relatively concentrated, but the distribution of construction land was scattered. The large watershed area conforms to the feature of a coastal tidal area, while the spatial distribution characteristics of different land-use types should be paid attention to in land consolidation planning.

Land consolidation zones I have high vegetation coverage and small slope, and the land-use types are mainly cultivated land and watershed and far away from industrial land and towns. These areas have superior ecological conditions and few restrictions on land consolidation. To maintain a high ecological security pattern in these zones, ecological protection should be paid attention to in land consolidation projects. For the cultivated land with low yield and poor farming environment, the quality can be upgraded by improving the cultivation conditions and completing the irrigation and water conservancy facilities. For scattered cultivated land plots, comprehensive land consolidation of the whole region should be strengthened to promote agricultural mechanization and large-scale farming. Land consolidation zones II have the largest area and the widest range of distribution. The land-use types are mainly cultivated land, construction land, forest land, and watershed. The restrictions of land consolidation in each area are different, so land consolidation projects in these zones should be paid attention to both ecological protection and ecological restoration. The central agglomeration area is densely populated and has a large number of rural residential areas and urban construction lands with low vegetation coverage and small slope and close to industrial lands. The key measures of land consolidation in the area are to carry out redeveloping village or underused urban land to make reasonable planning and scientific layout, appropriately increasing the green area to build a perfect green ecosystem during the processes. The eastern belt area is mainly a watershed with a large number of beach resources, which is characterized by low vegetation coverage and low slope gradually decrease from west to east. The focus of land consolidation in this area is to improve and utilize the beach by developing saline soil agriculture and the fishery industry. At the same time, diversified engineering systems, mainly including topographic reconstruction,

vegetation restoration, fish and benthic restoration, and hydrological regulation, should be constructed to effectively improve the structure and function of the regional coastal ecosystem and enhance biodiversity protection. Land consolidation in the nature reserves in the zones are mainly ecological restoration, and development and utilization are prohibited. Land consolidation zones III are either rugged or close to industrial land with low vegetation coverage, and the land-use types are mainly watershed and construction land. Land consolidation in these zones should be carried out according to local conditions and improve ecological security, stressing ecological security. Land consolidation in the west is mainly agricultural land consolidation and residential land consolidation. Agricultural land consolidation focuses on land leveling, road and drainage system building, and shelterbelt system construction and improvement. At the same time, residential land consolidation focuses on a centralized layout. In the east, there are a large number of farms and enterprises relying on beach resources. The utilization rate of the beach is high, and the ecological environment is damaged to a certain extent. As a result, land consolidation in this area should pay attention to avoid further deterioration of the ecological environment. In addition to constructing a series of engineering systems like the eastern belt area of land consolidation zones II, relevant water conservancy facilities should also be completed, and the soil quality should be improved.

6. Conclusions

This article explored five main landscape processes in land consolidation in coastal tidal flats according to their characteristics, constructed a comprehensive landscape security pattern, and zoned the study area according to the security levels. The conclusions were drawn as follows:

1. Water-soil conservation process, water source protection process, biodiversity conservation process, local culture protection process, and recreation process were the main landscape processes in land consolidation in the Dafeng District. The areas that have the large slope and low vegetation coverage, high protection level areas of the two main rivers, the tidal flats and the core of the National Nature Reserves, the provincial and municipal cultural relics protection units, the scenic spots and parks were the sources of the processes, respectively. The resistance elements include land-use type, vegetation coverage, slope, distance to industrial land, distance to town, distance to construction land, and distance to transportation lands;
2. Five single landscape security patterns were constructed, including water-soil conservation security pattern, water source protection security pattern, biodiversity conservation security pattern, local culture protection security pattern, and recreation security pattern. The comprehensive landscape security pattern of Dafeng District is obtained by overlaying the five single patterns and classified into three security levels: high, medium, and low. The areas of high and medium-security level account for 66.35% of the study area;
3. Based on the comprehensive landscape safety pattern, the villages in the study area are categorized into land consolidation zone I, II, and III, which accounting for 25.62%, 58.04%, and 16.34% of the study area, respectively. According to their unique characteristics, the land consolidation must stress ecological protection in land consolidation zone I, either ecological protection or ecological restoration in land consolidation zone II, and ecological restoration in land consolidation zone III;
4. The application of the theory of landscape security pattern in land consolidation zoning represented the idea of ecological priority. Specific suggestions on ecological protection and restoration are put forward in every land consolidation zone, which can guide land consolidation and regulation in coastal tidal areas. Still, there are some drawbacks to this article. First, the impact of other landscape processes on the land consolidation was not considered; this may influence the accuracy of the comprehensive landscape security pattern. Second, adopting the common method used

in previous research, the natural breaks method was used in the classification of some resistance elements and landscape security patterns in this study. Although natural breaks classes are based on natural groupings inherent in the data, their applicability still needed to be verified. Furthermore, due to the limitation of data availability, this paper only constructs the landscape security pattern of the study area based on the data of 2016. Further research may enrich the subsequent data to study the temporal and spatial dynamic changes of landscape security patterns, investigate other landscape processes, and put forward classification methods more scientific and reasonable.

Author Contributions: Conceptualization, M.X. and Z.Q.; methodology, M.X. and B.W.; investigation, L.W.; data curation, W.O.; writing—original draft preparation, Z.Q.; writing—review and editing, M.X.; supervision, W.Z.; project administration, Z.Q.; funding acquisition, M.X. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Key R&D Program of China (2018YFD1100103); Key Project of the National Social Science Fund (18AGL014); Youth Project of the National Social Science Fund (20CGL048); the MOE (Ministry of Education in China) Project of Humanities and Social Sciences (18YJAZH071, 20YJCZH178); and the Social Science Fund of Jiangsu Province (18GLD009).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data available on request due to privacy.

Acknowledgments: All authors gratefully acknowledge the support of the funding. In addition, all the authors are very grateful to the local government and the villagers who helped us in the process of data collection.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Vitikainen, A. An overview of land consolidation in Europe. *Nord. J. Surv. Real Estate Res.* **2004**, *1*, 25–43.
2. Uyan, M. Determination of agricultural soil index using geostatistical analysis and GIS on land consolidation projects: A case study in Konya/Turkey. *Comput. Electron. Agric.* **2016**, *123*, 402–409, doi:10.1016/j.compag.2016.03.019.
3. Demetriou, D.; Stillwell, J.; See, L. Land consolidation in Cyprus: Why is an Integrated Planning and Decision Support System required? *Land Use Policy* **2012**, *29*, 131–142, doi:10.1016/j.landusepol.2011.05.012.
4. Gallent, N.; Kim, K.S. Land zoning and local discretion in the Korean planning system. *Land Use Policy* **2001**, doi:10.1016/S0264-8377(01)00017-5.
5. Ertunç, E.; Çay, T.; Haklı, H. Modeling of reallocation in land consolidation with a hybrid method. *Land Use Policy* **2018**, *76*, 754–761, doi:10.1016/j.landusepol.2018.03.003.
6. Pašakarnis, G.; Maliene, V. Towards sustainable rural development in Central and Eastern Europe: Applying land consolidation. *Land Use Policy* **2010**, *27*, 545–549, doi:10.1016/j.landusepol.2009.07.008.
7. Wójcik-Leń, J.; Leń, P.; Mika, M.; Kryszk, H.; Kotlarz, P. Studies regarding correct selection of statistical methods for the needs of increasing the efficiency of identification of land for consolidation—A case study in Poland. *Land Use Policy* **2019**, *87*, 104064, doi:10.1016/j.landusepol.2019.104064.
8. Zhou, Y.; Guo, L.; Liu, Y. Land consolidation boosting poverty alleviation in China: Theory and practice. *Land Use Policy* **2019**, *82*, 339–348, doi:10.1016/j.landusepol.2018.12.024.
9. Wen, D. Land Mosaics: The Ecology of Landscapes and Regions. *J. Environ. Quality* **1997**, doi:10.2134/jeq1997.00472425002600030047x.
10. Yu, K. Security Patterns in Landscape Planning with a Case Study in South China. Ph.D. Thesis, Harvard University, Cambridge, MA, USA, 1995.
11. Yu, K. Security patterns and surface model in landscape ecological planning. *Landsc. Urban Plan.* **1996**, *36*, 1–17, doi:10.1016/S0169-2046(96)00331-3.
12. Zhou, W.; Huang, G.; Cadenasso, M.L. Does spatial configuration matter? Understanding the effects of land cover pattern on land surface temperature in urban landscapes. *Landsc. Urban Plan.* **2011**, *102*, 54–63, doi:10.1016/j.landurbplan.2011.03.009.
13. Peng, J.; Li, H.; Liu, Y.; Hu, Y. Identification and optimization of ecological security pattern in Xiong'an New Area. *Acta Geogr. Sin.* **2018**, *73*, 701–710.

14. Wang, D.; Chen, J.; Zhang, L.; Sun, Z.; Wang, X.; Zhang, X.; Zhang, W. Establishing an ecological security pattern for urban agglomeration, taking ecosystem services and human interference factors into consideration. *PeerJ* **2019**, *7*, e7306, doi:10.7717/peerj.7306.
15. Yuanjing, Z.; Binyang, Y.; Ashraf, M.A. Ecological security pattern for the landscape of mesoscale and microscale land: A case study of the Harbin city center. *J. Environ. Eng. Landsc. Manag.* **2015**, *23*, 192–201, doi:10.3846/16486897.2015.1036872.
16. Asgarian, A.; Amiri, B.J.; Sakieh, Y. Assessing the effect of green cover spatial patterns on urban land surface temperature using landscape metrics approach. *Urban Ecosyst.* **2015**, *18*, 209–222, doi:10.1007/s11252-014-0387-7.
17. Peng, J.; Pan, Y.; Liu, Y.; Zhao, H.; Wang, Y. Linking ecological degradation risk to identify ecological security patterns in a rapidly urbanizing landscape. *Habitat Int.* **2018**, *71*, 110–124, doi:10.1016/j.habitatint.2017.11.010.
18. Li, F.; Wang, Y.; Hu, Y.; Yao, X. Research on Yancheng Coastal Beach Reclamation Development and Ecological Environment Protection. *J. Green Sci. Technol.* **2013**, 09, 155–157.
19. Ruiz, R.S. Documento base para la elaboración de la "política nacional de ordenamiento integrado de las zonas costeras Colombianas": Documento de consultoría. 1997. Available online: http://www.invemar.org.co/redcostera1/invemar/docs/1008PoliticaZonasCosterasE.pdf (accessed on 1 February 2021).
20. Milanés Batista, C.; Suárez, A.; Botero Saltarén, C.M. Novel method to delimitate and demarcate coastal zone boundaries. *Ocean Coast. Manag.* **2017**, *144*, 105–119, doi:10.1016/j.ocecoaman.2017.04.021.
21. Balaguer, P.; Sardá, R.; Ruiz, M.; Diedrich, A.; Vizoso, G.; Tintoré, J. A proposal for boundary delimitation for integrated coastal zone management initiatives. *Ocean Coast. Manag.* **2008**, *51*, 806–814, doi:10.1016/j.ocecoaman.2008.08.003.
22. Brenner, J.; Jimenez, J.A.; Sardá, R. Definition of Homogeneous Environmental Management Units for the Catalan Coast. *Environ. Manag.* **2006**, *38*, 993–1005, doi:10.1007/s00267-005-0210-6.
23. Amir, S. Classification of coastal resources: A Mediterranean case study. *Landsc. Urban Plan.* **1987**, *14*, 399–414, doi:10.1016/0169-2046(87)90052-1.
24. Sardá, R.; Avila, C.; Mora, J. A methodological approach to be used in integrated coastal zone management processes: The case of the Catalan Coast (Catalonia, Spain). *Estuar. Coast. Shelf Sci.* **2005**, *62*, 427–439, doi:10.1016/j.ecss.2004.09.028.
25. Liang, D.; Teng, L.; Huang, L.; Xie, X.; Zuo, Y.; Zhao, J. Dynamic Analysis of Urban Landscape Patterns of Vegetation Coverage Based on Multi-temporal Landsat Dataset. *Comput. Comput. Technol. Agric. IX* **2016**, *478*, 300–316, doi:10.1007/978-3-319-48357-3_30.
26. Knaapen, J.P.; Scheffer, M.; Harms, B. Estimating habitat isolation in landscape planning. *Landsc. Urban Plan.* **1992**, *23*, 1–16, doi:10.1016/0169-2046(92)90060-D.
27. Zhu, K.; Chen, Y.; Zhang, S.; Yang, Z.; Huang, L.; Lei, B.; Li, L.; Zhou, Z.; Xiong, H.; Li, X. Identification and prevention of agricultural non-point source pollution risk based on the minimum cumulative resistance model. *Glob. Ecol. Conserv.* **2020**, *23*, e01149, doi:10.1016/j.gecco.2020.e01149.
28. Friedrich Michael Dimpel Wertungsübertragung und Kontiguität. Mit zwei Beispielen zur Wertung des Frageversäumnisses im Parzival. *J. Lit. Theory* **2012**, doi:10.1515/jlt-2014-0016.
29. Zhang, Y.; Bi, Z.; Zhang, X.; Yu, Y. Influence of Landscape Pattern Changes on Runoff and Sediment in the Dali River Watershed on the Loess Plateau of China. *Land* **2019**, *8*, 180, doi:10.3390/land8120180.
30. Lee, S.-H.; Kim, S.; Kim, H.-J. Effects of thinning intensity on understory vegetation in *Chamaecyparis obtusa* stands in South Korea. *For. Sci. Technol.* **2018**, *14*, 7–15, doi:10.1080/21580103.2017.1409661.
31. Jaeger, J.A.G. Landscape division, splitting index, and effective mesh size: New measures of landscape fragmentation. *Landsc. Ecol.* **2000**, *15*, 115–130, doi:10.1023/A:1008129329289.