

Article

Spatial Pattern of Construction Land Distribution in Bays along the Coast of Vietnam

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Received: 15 October 2020; Accepted: 23 November 2020; Published: 26 November 2020



Abstract: Current studies of urban spatial morphology have rarely focused on the particularity of coastal cities, such as sea–land gradient features and bay types. In this paper, we provide a method to analyze the spatial and vertical distribution of construction land in the bay area and discuss the influence of bay type on the distribution characteristics. Landscape indexes and a clustering algorithm were used to identify the spatial pattern of construction land distribution. Strip division was used to analyze the landscape features of construction land in the sea–land direction. We established eight large bays in Vietnam as the study area. According to the formation and geomorphology of the bay, the eight bays were divided into five types: delta bay, lagoon bay, structural bay, bedrock erosion-stacking bay and estuary bay. The construction land data were generated from Landsat images captured in 1988 and 2015 or so. The study effectively identified five spatial patterns of construction land distribution in bays without prior knowledge. Danang Bay (a bedrock erosion-stacking bay) had a typical high intensity-high concentration pattern, and Hai Loc Bay (a delta bay) had a typical high intensity-low concentration pattern. In the sea–land gradient, the proportions of construction land in the 0–2 km zone were greatest. In Danang Bay, the proportion generally decreased in the sea–land direction; while in Hai Loc Bay, the proportion increased.

Keywords: bay type; construction land; landscape index; spatial pattern; sea–land gradient

1. Introduction

Urbanization is a spatial process. As a result of urbanization, the change of urban spatial form clearly reflects the process of urbanization. The evolution of urban spatial morphology has always been a hot topic in urban geography. A bay city is a special kind of city type, characterized by three characteristics: highly developed, greatly affected by the ocean, and greatly affected by the type of the bay. First, located at the interface between the sea and the land, bays are a high-value, highly developed and highly fragile ecosystem. Since ancient times, bays have been the gateway to overseas transportation and have acted as industrial centers, playing an extremely important strategic role in economic and social development [1,2]. Many of the world's famous ports, such as the Port of Los Angeles, Shenzhen Port and Bangkok Port, have developed in bays. Second, throughout the history of coastal cities [3], the development of coastal cities often depends on the marine economy. The siting and development of urban centers are influenced by the distance from the ocean and coastal geography. Finally, influenced by the formation of the bay, the types of the bay are various, and the topographical morphology varies greatly. It will affect city orientation and city form. Nowadays, as the population continues to converge to the coastal zone, the demand and scale of construction land in bays is expanding, and the built-up area is expanding rapidly. Quantitative analyses of the development

intensity and changing characteristics of construction land in bays are of great significance for urban development, urban planning and ecological, environmental protection in bay areas [4].

Scholars worldwide have conducted much research on the evolution of urban spatial morphology. The urban spatial form is the visual appearance of urban space expansion [5]. The essence of urban space expansion is the renewal and combination of urban land, which is mainly manifested in the sprawl of outer space boundary and the reorganization of inner space structures [6]. The current research on urban landform was conducted in two ways, including empirical analysis and quantitative measure. On one hand, empirical analysis relies on theoretical analysis (urban morphology) or basic data statistics to elucidate the process of urban expansion and its characteristics. The research on urban morphology originated in the 19th century. The classical urban spatial structure includes the concentric ring model (proposed by E.W. Burgess), sector model (proposed by H. Hoyt) and multi-core model (proposed by C.D. Harris) [7]. Nowadays, the typical urban forms can be divided into block, strip, radial, constellation, group and checkerboard patterns [8,9]. The modes of urban land expansion include the compact mode and the loose mode, and the common spatial expansion patterns can be divided into axial, concentric circle, corridor, fan-shaped, filling and spreading growth as well as satellite cities [10–14]. The measurement of urban form is mostly interpreted in a qualitative way. Quantitative identification of urban spatial extension types has also been carried out in recent years. Liu used the convex hull principle to identify two types of urban land expansion, including filling type and extension type [15]. Moreover, some simple data statistics were also used in the analysis of urban expansion form. For example, the European research territorial projects Otremed and OSDDT (Occupation des sols et développement durable sur l'arc méditerranéen) have developed important territorial tools important with a number of variables for analysis and advanced diagnostics in urban planning [16].

On the other hand, quantitative measure relies on designing the indexes to measure the geometrical morphology and spatial relation of urban land. Common measurement methods include mathematical, statistical methods, fractal dimensions and landscape index methods. Mathematical statistics methods describe the geometric features, size, density and distribution of a city by calculating its shape, circumference, area and distance. Common mathematical indexes include circularity ratio, compactness, shape index and radial shape index etc. [17–19]. The application of fractal theory to urban expansion began in the 1980s. Batty M et al. [20] proposed the boundary fractal characteristics of urban morphology and the calculation method of boundary fractals. In the evolutionary process of urban formation, the fractal dimension of the boundary of urban construction land reflects the compactness and change mode of the urban external form [21]. Guo [22] extracted the built-up areas of 29 major cities in China from 2000 to 2013 and measured the expansion speed, compactness, fractal dimension and shape index of each city. The results showed that the fractal dimension indexes of the cities and the fragmentation of urban space increased. Landscape pattern is the spatial arrangement and combination of landscape spatial units with different sizes, shapes and properties. The landscape pattern method introduces landscape indexes to analyze the spatial pattern and characteristics of urban land use and expansion by using the theoretical method of landscape ecology. In general, landscape pattern index can be described on three levels: patch level, class level and landscape level. Over the past decades, there has been a proliferation of statistical measures of landscape indices, including patch density, largest patch index, landscape shape index, fractal dimension index, contiguity index, aggregation index, landscape diversity index, landscape heterogeneity index and landscape homogeneity index, etc. [17,23,24]. Based on landscape indexes, Liu et al. [25] proposed the landscape expansion index (LEI), which can be used to analyze dynamic changes in two or more temporal landscape patterns and applied them to Dongguan City. The results showed that LEIs could identify the types of urban expansion, i.e., filling type, edge type and enclave type. Jiao et al. [26] proposed an improved spatial metric, multi-order landscape expansion index (MLEI), to measure the expansion degree of newly grown urban patches by considering their relationships with old patches and their spatial context in the process of urban expansion.

The land-sea gradient and elevation differentiation are two of the most basic spatial pattern characteristics of many geographical elements [27]. As the distance from the sea increased, the physiographic features, biogenic features, and physiochemical features shows a tendency of gradient [28]. Accordingly, the land-use patterns vary in the sea–land direction. Strip division was a common method, and it involves parallel divisions moving the coastline inland with consistent spacing. Hou et al. [27] conducted strip segmentation at an interval of 2 km perpendicular to the coastal zone and chose 15 strips on the landward side as the research areas to analyze the land structure characteristics and differentiation characteristics of different strips. The results showed that the 4–6 km strip had a peak value of the comprehensive land use index, which was followed by the 2–4 km strip and 8–10 km strip. Ding et al. [29,30] developed a model, called sequence-based clustering of coastal land use pattern (SCCLUP), to mine the coastal land use sequence patterns (CLUSPs) along the sea–land direction. The research in the major coastal zone of Bohai Bay and the Yellow River Delta showed that the artificial level of CLUSPs was continuously increasing, and new CLUSPs tended to distribute around port areas. To a certain extent, topography has shaped the distribution pattern of land use [31]. Especially in the coastal areas, the geomorphologic differences in different regions are rather significant. Zhang et al. [32] divided the coastal zone surrounding the South China Sea into 51 zones according to the coastal landform and discussed the spatiotemporal characteristics of construction land expansion based on different geomorphologic backgrounds. The results showed that in areas where there were good conditions for water transport and wide hinterlands, construction land on the delta plain coast and estuary plain coast expanded rapidly.

According to the results of a literature search, the typical urban forms come from empirical exploration. Studies are deficient in the quantification of the spatial pattern of construction land without prior knowledge. Furthermore, current studies of urban spatial morphology rarely focused on the particularity of coastal cities, such as sea–land gradient features and bay types. In this paper, we provided a method to analyze the spatial pattern of construction land in the bay area. It included two parts: spatial analysis and vertical analysis. Landscape indexes and a clustering algorithm were used to identify the spatial pattern of construction land distribution. Strip division was used to analyze the landscape features of construction land in the sea–land direction. The bay type is defined according to the factors underlying the bay formation and is used to analyze the influence on the spatial and vertical distribution of construction land. In order to exclude the influence of different national policies as well as taking into account the richness of bay types, we chose eight bays along the coast of Vietnam as the research areas.

2. Materials and Methods

2.1. Study Area

The study area is located along the coast of Vietnam, roughly between the latitudes of 8 °N and 24 °N and the longitudes of 104 °E and 109 °E (Figure 1). Vietnam is located on the eastern coast of the Indochina Peninsula and bordered by China to the north, Laos and Cambodia to the west, and the South China Sea to the east. Vietnam can be considered a marine nation. The main characteristics are as follows:

- (1) Hot and humid climate. Vietnam has a tropical monsoon climate with abundant rainfall and perennially high temperatures. The average annual rainfall is approximately 1680 mm on the Red River Delta, with 1650 mm along the central coast and 1980 mm in the Mekong Delta [33]. The annual average temperature is 24 °C.
- (2) Long coastline. Vietnam presents an S-shaped pattern in a north-south vertically long strip [34]. Vietnam is long from south to north and narrow from east to west. The long coastline is unusually sinuous with many bays, lagoons, estuaries, mangroves and outlying islands [35].
- (3) Fertile plains. Topographically, the terrain is high in the west and low in the east. Three-quarters of the region is covered by mountains. There are two great rivers flowing through the region that

- form two vast low-lying delta plains: the Red River Delta in the north and the Mekong River Delta in the south. In addition, some small and narrow plains are distributed in the coastal zone. The coastal plains were created by deposits of alluvial soils by rivers [33]. The fertile soil and good climate conditions make Vietnam the second-largest agricultural country in Southeast Asia.
- (4) Rich resources. Vietnam is rich in coal mineral resources, oil and gas, fisheries resources and port resources. Vietnam currently has 3.5 billion tons of coal reserves, and vast coal mines are located in the Red River Delta and northern Quang Ninh Province [34]. The large nearshore oil–gas basins include the Yinggehai basin and Mekong basin [36]. Vietnam has a long tradition in both inshore and deep-sea fisheries, and aquaculture production rose to the third greatest globally (behind only China and India) in 2010 [35,37]. Topographically, the mountains extend directly into the sea, creating a number of protected harbors, including those of the port cities of Da Nang, Qui Nhon, and Nha Trang [33].



Figure 1. Location of bays along the coast of Vietnam.

Bays are sea areas with obvious coastal curvature that extends into the mainland or islands. The line connecting the two headlands at the mouth of the bay marks the boundary between the bay and the sea [38]. According to the factors underlying bay formation, bays can be categorized as primary bays or secondary bays (Table 1). The primary bay is formed in the depression basin, river valley, crater and other depressions dominated by bedrock. Once a primary bay is formed, its morphology changes very slowly. A secondary bay is the sea area enclosed by the accumulation

of oceans, rivers, or organisms. The secondary bays are relatively unstable and evolve much faster than the primary bays. Primary bays can be subdivided into structural bays, bedrock erosion-stacking bays, estuary bays and crater bays. Secondary bays can be subdivided into lagoon bays, tombolo bays, delta bays and atoll bays [39].

Table 1. The bay category [40].

Level 1	Level 2	Characteristics
Primary bay	Structural bay	Controlled by faulted structures.
	Erosion-stacking bay	Sandy/tidal beach in the top, bedrock cape in the two sides.
	Estuary bay	Formed when the sea flooded the mouth of the river.
	Crater bay	Formed when the crater of the dead was flooded.
Secondary bay	Lagoon bay	Sand bank at the mouth of the sea.
	Tombolo bay	Sediment accumulates between the island and the land.
	Delta bay	Formed in the plains where big rivers flow into the sea.
	Atoll bay	Located in the coral atoll.

There are many bays along the coast of Vietnam, and the bay types vary dramatically. Through the water area of the bay, eight bays with a water area, over 50 square kilometers were established as the study area (Table 2). From north to south, the bays are Hai Loc Bay, Dam Ha Trung Bay, Danang Bay, Xuan Dai Bay, Vinh Van Phong Bay, Cam Ranh Bay, Ganh Rai Bay and Rạch Giá Bay. Geographically, seven bays are located on the eastern coasts of Vietnam. Rạch Giá Bay is the only bay located on the western coast of Vietnam and bounded by the Gulf of Thailand. In terms of the water area, the largest bay, Rạch Giá Bay, covers a water area of 1226 square kilometers. Next, Ganh Rai Bay and Vinh Van Phong Bay cover water areas of 640 and 631 square kilometers, respectively. The water areas of the remaining bays are less than 200 square kilometers. In terms of the bay type, there are five types of bays: (1) delta bay—Hai Loc Bay and Ganh Rai Bay, (2) lagoon bay—Dam Ha Trung Bay and Cam Ranh Bay, (3) structural bay—Xuan Dai Bay and Vinh Van Phong Bay, (4) bedrock erosion—stacking bay—Danang Bay, and (5) estuary bay—Rạch Giá Bay.

Table 2. Major bays along the coast of Vietnam.

Name	City	Location	Water Area (km ²)	Type
Hai Loc Bay	Hai Loc	Northeastern coast	182	Delta bay
Dam Ha Trung Bay	Hue	Central eastern coast	186	Lagoon bay
Danang Bay	Danang	Central eastern coast	123	Bedrock erosion-stacking bay
Xuan Dai Bay	Song Cau	Southeast coast	95	Structural bay
Vinh Van Phong Bay	Ninh Hoa, Nha Trang	Southeast coast	631	Structural bay
Cam Ranh Bay	Cam Ranh	Southeast coast	186	Lagoon bay
Ganh Rai Bay	Vung Tau	Southeast coast	640	Delta bay
Rạch Giá Bay	Rạch Gia	Western coast	1226	Estuary bay

2.2. Data Sources

The data used in this study included the Landsat 5 thematic mapper (TM) images and Landsat 8 operational land imager (OLI) images. The images were downloaded from the US Geological Survey Center for Earth Resources Observation and Sciences (USGS, <https://earthexplorer.usgs.gov/>) at Level 1. TM images were captured in 1988 and 1989. OLI images were captured in 2015–2017. The resolution of the image is 30 m. In total, we collected 9 Landsat 5 TM images and 9 Landsat 8 OLI images. The images are cloudless in most of the bays. In a few bays, the cloud cover is less than 5%. The detailed information of remote sensing images is shown in Table 3. Image clipping and image enhancement were applied before interpretation.

Table 3. Information on remote sensing images.

Path/Row	Date of Pass	Date of Pass
126/46	4 November 1988	10 April 2017
125/48	8 May 1989	3 July 2015
125/49	8 May 1989	3 July 2015
124/49	3 September 1988	1 July 2017
123/51	10 July 1988	18 April 2016
123/52	4 December 1989	7 September 2015
124/53	10 February 1989	17 January 2015
125/53	30 January 1988	24 January 2015
128/52	9 December 1989	15 January 2015

2.3. Data Analysis

The research diagram flow was described in Figure 2. First, we acquired the construction land data from Landsat images. Then, we introduced the method of landscape ecology and analyzed the spatial distribution of construction land in two aspects. In the spatial analysis, the K-means clustering algorithm was used to identify the spatial pattern of construction land distribution. In vertical analysis, the method of coastal buffer division was used to analyze the landscape features of construction land in the sea–land direction. Moreover, the influence of bay type on the spatial and vertical distribution of construction land was discussed.

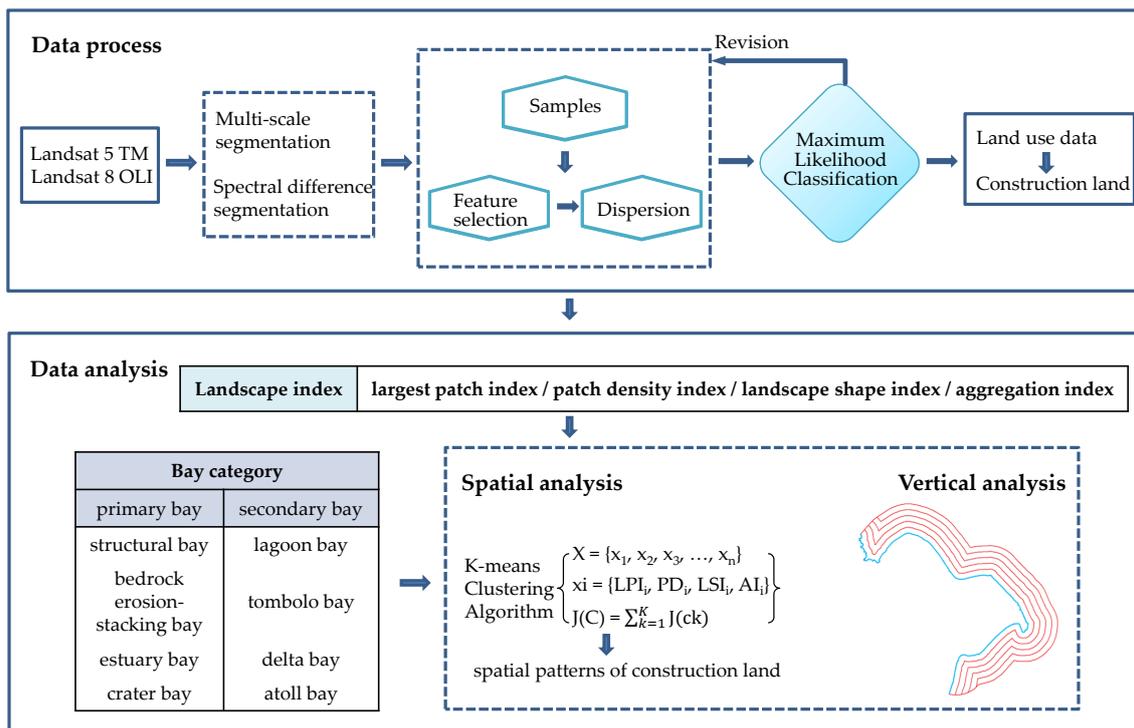


Figure 2. Research diagram flow.

2.3.1. Data Acquisition

The bay area consists of the land area and sea area. The sea area was defined as the waters enclosed by the coastline and the entrance of the bay. For coasts with mangroves, the coastline lies on the landward vegetation line. For coasts of other types, the coastline lies on the edge of the water. The land area was defined as the buffer zone within a certain distance from the coastline. We have adopted a uniform distance for all the bays to ensure a fair assessment. The distribution range of settlement varies in the eight bays. When determining the extent of the land area of the bay, the choice

was based on retaining the larger cities along the bay coast. Therefore, the land area was defined as the landward area extending 10 km from the coastline.

Automatic classification and manual visual interpretation were used to generate the land use data. The classification system included eight primary types: cultivated land, forestland, grassland, construction land, industrial land, water, coastal wetland and unutilized land. Overall, fifteen land-use types were identified at the secondary level [41]. Multiscale segmentation and spectral difference segmentation were performed before classification. Six parameters, including the mean value of the red band/thermal infrared band/mid-infrared band, border index, asymmetry and main direction, were used in the maximum-likelihood supervised classification. Based on the classification result, we checked and corrected any apparent classification errors manually.

Together 900 randomly selected reference pixels (200 points for Ganh Rai Bay and 100 points for every other bay) were used to validate the precision. The overall precision and single precision for the construction land are shown in Table 4. The final overall accuracy for each bay was higher than 85%. The construction data were then generated from the land use data.

Table 4. The precision of the classification.

Name	1988		2015	
	Overall, Precision	Construction Precision	Overall, Precision	Construction Precision
Hai Loc Bay	85%	83.3%	87%	85.7%
Dam Ha Trung Bay	86%	84.2%	85%	89.5%
Danang Bay	86%	87.1%	90%	95.1%
Xuan Dai Bay	98%	100%	97%	100%
Vinh Van Phong Bay	94%	83.3%	92%	90.5%
Cam Ranh Bay	85%	81.3%	85%	88.9%
Ganh Rai Bay	85%	81.8%	87.5%	90%
Rạch Giá Bay	93%	100%	97%	100%

2.3.2. Landscape Analysis

In our study, on the single class of construction land, we analyzed on class level. The correlation between each landscape index is often very high, and it is necessary to make a reasonable choice according to the actual situation. Cushman et al. [42] used principal component analysis (PCA) to identify independent components of landscape structure and cluster analysis to group the components. Seven class-level landscape structure components were found that were particularly strong (Table 5). They are “aggregation”, “large patch dominance”, “shape and correlation length of large patches”, “patch size variation”, “edge/patch density”, “mean patch size”, and “edge + aggregation”.

Table 5. Class-level configuration components of landscape indexes.

Number	Component Name	High Loadings
1	aggregation	AI, PLADJ, CLUMPY, COHESION
2	large patch dominance	LPI, CORE_AM, DCORE_AM, AREA_AM
3	shape and correlation length of large patches	SHAPE_AM, FRAC_AM, GYRATE_AM
4	patch size variation	AREA_CV, CORE_CV, DCORE_CV
5	edge/patch density	ED, LSI, PD, CWED
6	mean patch size	AREA_MN, CORE_MN, GYRATE_MN, DCORE_MN
7	edge + aggregation	ED, CWED, LSI, AI, PLADJ, CLUMPY, FRAC_AM

On this basis, we choose six landscape indexes, including aggregation index (AI), largest patch index (LPI), fractal dimension index (FDI), edge density (ED), landscape shape index (LSI), and patch density (PD). The indexes were calculated in FRAGSTATS 4.2 (<http://www.umass.edu/landeco/research/fragstats/fragstats.html>). We found that ED was more relevant with PD, and the changes of FDI in sea–land gradient were irregular. Therefore, we finally used four indexes, including LPI, PD, LSI and AI, to describe the pattern of construction. The explanation of the landscape indexes is shown in Table 6.

Table 6. Landscape index and descriptions [43].

Name	Description	Meaning
LPI	The area (m ²) of the largest patch in the landscape is divided by the total landscape area (m ²).	Size of dominant plaque
PD	The number of patches of corresponding patch type (class) per unit area.	Fragmentation degree of landscape
LSI	A standardized measure of patch compactness that adjusts for the size of the patch.	Shape complexity of the landscape
AI	The ratio of the observed number of like adjacencies to the maximum possible number of like adjacencies given the proportion of the landscape comprised of each patch type.	Aggregation degree of the homotypic patches

2.3.3. K-means Clustering Algorithm

The K-means clustering algorithm is one of the most widely used partition clustering algorithms and has been proposed for more than 50 years [44]. In the analysis of the spatial pattern of construction land in bays, we classified the bays by K-means clustering. The bays are considered a dataset with four-dimensional data points. It can be described as follows:

$$X = \{x_1, x_2, x_3, \dots, x_n\} \quad (1)$$

$$x_i = \{LPI_i, PD_i, LSI_i, AI_i\} \quad (2)$$

where n is the number of bays and n equals 8 in our study.

The K-means clustering algorithm organizes data objects into K partitions. Each partition represents a class, and each class has a category center. The Euclidean distance was selected as the similarity and distance criterion to calculate the square sum of the distance from each point in the class to the cluster center ($J(c_k)$). The goal of clustering is to minimize the sum of squares of the total distances ($J(C)$) [45].

$$J(c_k) = \sum_{x_i \in C_k} (x_i - u_k)^2 \quad (3)$$

$$J(C) = \sum_{k=1}^K J(c_k) \quad (4)$$

where C is the clustering dataset, k is the clustering number, x_i is the original data point to be classified, and u_k is the category center of class k .

2.3.4. Buffer Division Method

To measure the spatial pattern of construction land in the direction of the coastal zone perpendicular to the coastline, we divided the coastal zone vertically.

The following strategies were used, and the segmentation results are shown in Figure 3.

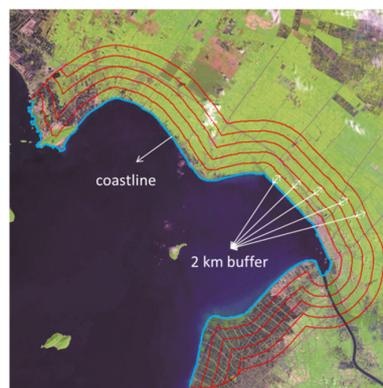


Figure 3. Segmentation buffers of Rạch Giá Bay.

First, land use data were used to generate the coastlines.

Second, 2 km, 4 km, 6 km, 8 km and 10 km buffer zones were generated on the landward side, and the boundary lines were obtained.

Finally, the buffer zone was cut by using the coastline and boundary lines to obtain buffer strips of 0–2 km, 2–4 km, 4–6 km, 6–8 km and 8–10 km on the landward side.

3. Results

3.1. Regional Trends

Table 7 and Figure 4 show the proportions and areas of construction land in each bay. The spatial distributions of construction land in bays for 1988 and 2015 are shown in Figure 5. Across the region, the total proportion was 4.9% in 1988. The built-up area significantly expanded during the following 30 years. In 2015, the proportion more than doubled, with increases of up to 12.5%. The average annual growth rate was 0.25%.

Table 7. Proportions of construction land in each bay.

	Hai Loc Bay	Dam Ha Trung Bay	Danang Bay	Xuan Dai Bay	Vinh Van Phong Bay	Cam Ranh Bay	Ganh Rai Bay	Rạch Giá Bay	Total
1988	15.4%	10.2%	11.3%	0.7%	2.1%	1.8%	3.5%	0.3%	4.9%
2015	24.5%	18.1%	26.5%	6.6%	6.8%	8.3%	15.4%	2.8%	12.5%
change	9.1%	7.9%	15.2%	5.9%	4.7%	6.5%	11.9%	2.5%	7.6%

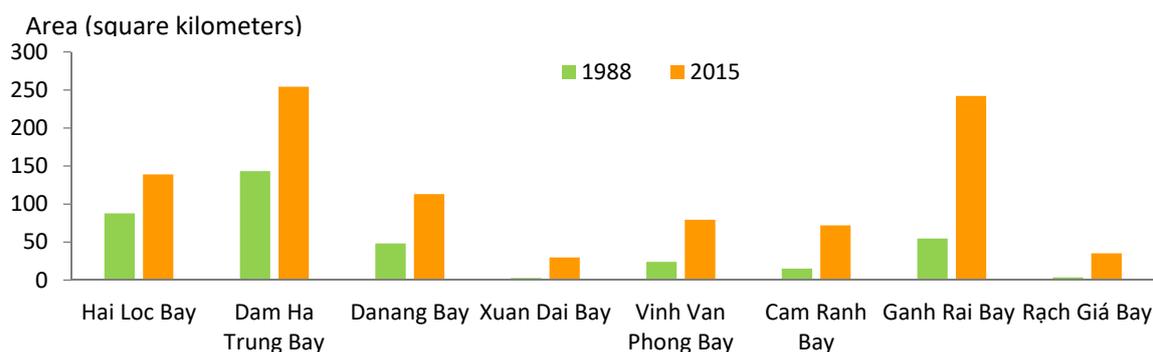


Figure 4. Areas of construction land in bays in 1988 and 2015.

Among the bays, the proportions of construction land in Hai Loc Bay, Dam Ha Trung Bay and Danang Bay were more than 10% in 1988. These three bays are distributed along the northern coast of Vietnam. In contrast, construction land was distributed sparsely in the five southern bays. The proportions were lower than 5%, especially in Xuan Dai Bay and Rach Giá Bay, where the proportions were lower than 1%. In addition to the above three bays, the proportion of construction land in Ganh Rai Bay climbed to 15.4% in 2015. However, these four bays presented growth that exceeded the average growth. The proportion of construction land was greatest (26.5%) in Danang Bay, followed by Hai Loc Bay (24.5%). The highest growth rate was also in Danang Bay (15.2%), which was twice the average growth (7.6%). It is worth mentioning that although the proportion of construction land in Ganh Rai Bay was not too high (3.5% in 1988 and 15.4% in 2015), the growth rate was drastic (11.9%). The net increase of built-up area in Banh Rai Bay was also the largest, up to 187.4 square kilometers. In addition, the net increase of built-up area in Dam Ha Trung Bay was 110.8 square kilometers, which ranked 2nd by area.

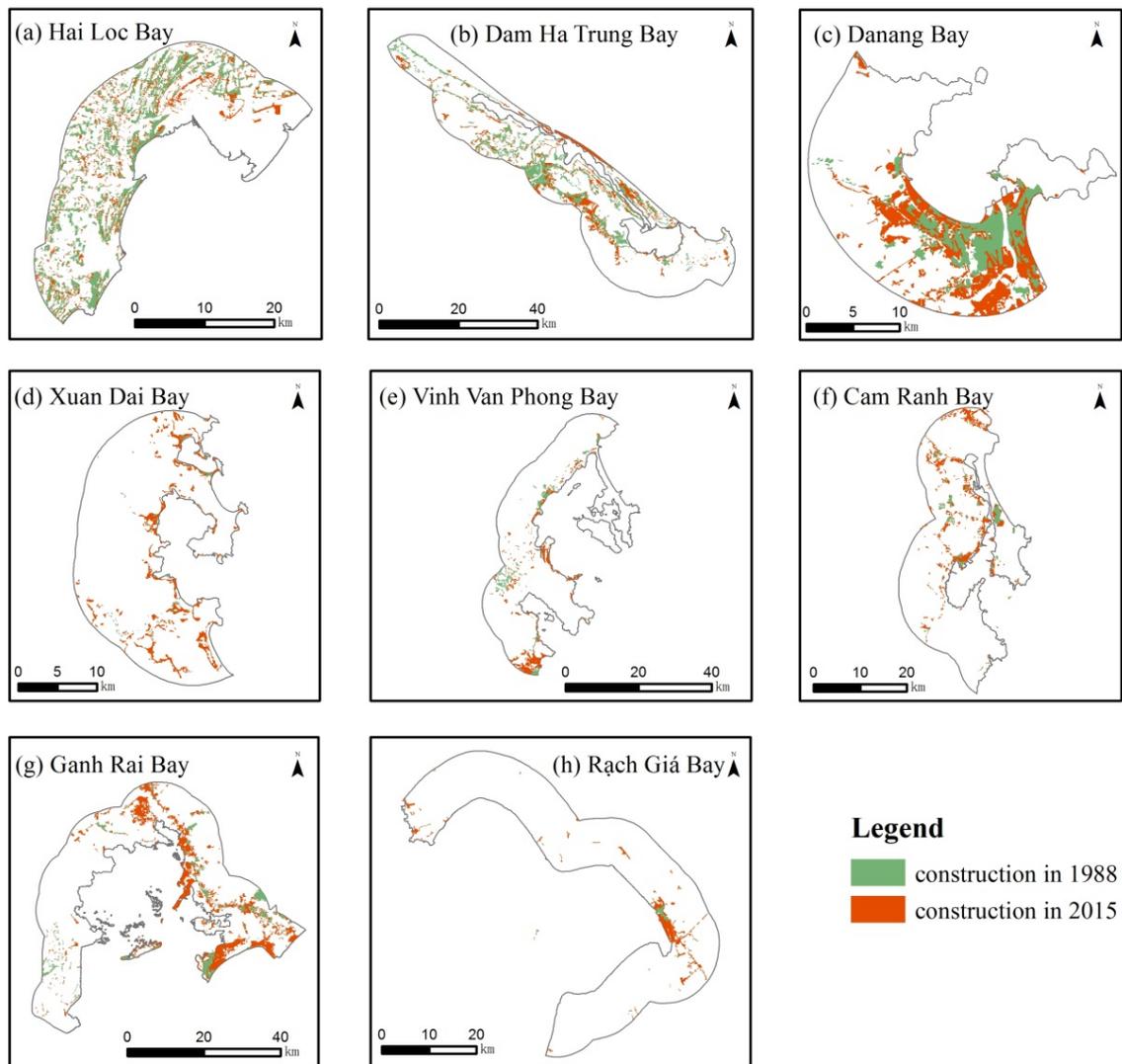


Figure 5. Spatial distribution of construction land in bays. (a) Hai Loc Bay; (b) Dam Ha Trung Bay; (c) Danang Bay; (d) Xuan Dai Bay; (e) Vinh Van Phong Bay; (f) Cam Ranh Bay; (g) Ganh Rai Bay; (h) Rạch Giá Bay.

3.2. Spatial Trends

Figure 6 shows the proportions and areas of construction land in each bay. Except for the AIs, the bay-level LPIs, PDs and LSIs in 2015 were greater than those in 1988. This result indicated that the distribution of construction land became more fragmented, and the shape tended to become more complex over 30 years. There was a significant increase in the LPIs of Hai Loc Bay, Dam Ha Trung Bay, Danang Bay and Ganh Rai Bay. In Danang Bay, the LPIs were significantly greater than in the other bays and increased by more than three times until 2015. In the other four bays, the LPIs were very low with little change. The PDs and LSIs in Hai Loc Bay were much greater than those in other bays in both periods. Especially for the PDs, it increased to 2.0928 in 2015, which was more than 5 times the PDs of the other bays. Moreover, the lowest PDs and LSIs were recorded in Rạch Giá Bay. The changes in the AIs were relatively random. The most obvious change was in Xuan Dai Bay. The AIs increased from 74.6706 to 88.3288, and the ranking increased from 8th to 7th.

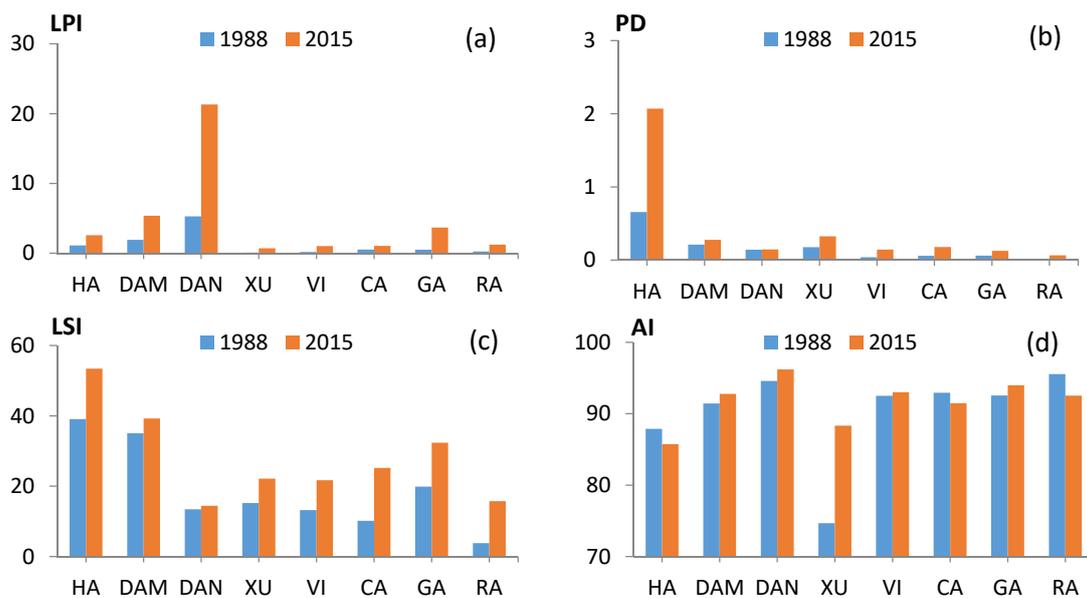


Figure 6. Four landscape indicators of the bays in 1988 and 2015. (a) largest patch index (LPI); (b) patch density (PD); (c) landscape shape index (LSI); (d) aggregation index (AI). Note: The abbreviations of bay names are explained as follows: Hai Loc Bay—HA; Dam Ha Trung Bay—DAM; Danang Bay—DAN; Xuan Dai Bay—XU; Vinh Van Phong Bay—VI; Cam Ranh Bay—CA; Ganh Rai Bay—GA; and Rạch Giá Bay—RA.

We standardized the four indicators (the PD, LPI, LSI and AI) and used the K-mean classification method. After the tests, we divided the bays into four clusters into both periods. The classification results for 1988 can be expressed as follows:

Cluster 1 = {Hai Loc Bay, Dam Ha Trung Bay}

Cluster 2 = {Danang Bay}

Cluster 3 = {Xuan Dai Bay}

Cluster 4 = {Vinh Van Phong Bay, Cam Ranh Bay, Ganh Rai Bay, Rạch Giá Bay}

The classification results for 2015 can be expressed as follows:

Cluster 1 = {Hai Loc Bay}

Cluster 2 = {Dam Ha Trung Bay, Ganh Rai Bay}

Cluster 3 = {Danang Bay}

Cluster 4 = {Xuan Dai Bay, Vinh Van Phong Bay, Cam Ranh Bay, Rạch Giá Bay}

According to the classification results, we identified the following five patterns.

(1) High intensity-high concentration pattern. Typical features of this pattern were high LPIs, high AIs and low LSIs. The construction land in such bays presented an aggregated distribution, and the patches had larger areas and regular shapes. Danang Bay presented this pattern in two periods. The LPI in Danang Bay was much greater than in other bays, and it increased dramatically in the 30 year period. The AIs in Danang Bay were also high among those of all the bays. This result indicated that the construction land in Danang Bay had experienced dramatic outward expansion.

(2) High intensity-low concentration. Typical features of this pattern were high PDs, high LSIs and low AIs. The construction land in such bays was densely distributed with relatively small and complex patches. Hai Loc Bay and Dam Ha Trung Bay presented this pattern in 1988. Dam Ha Trung Bay converted to pattern 3 in 2015. The PDs and LSIs in Hai Loc Bay were much greater than those in other bays. In 2015, the gap had widened, which indicated that the construction land in Hai Loc Bay had expanded dramatically based on the maintenance of a relatively discrete distribution.

(3) Medium intensity-medium concentration pattern. Typical features of this pattern were medium LPis, LSIs and AIs. Dam Ha Trung Bay and Ganh Rai Bay presented this pattern in 2015. The LPis in the two bays were just lower than those in Danang Bay, and the LSIs were just lower than those in Hai Loc Bay. Among them, Dam Ha Trung Bay was converted from pattern 2 (high intensity-high dispersion pattern) to pattern 3 from 1988 to 2015. The change indicated that Dam Ha Trung Bay experienced moderate expansion, and the expansion tended to be clustered.

(4) Low intensity-medium concentration pattern. The PDs, LPis and LSIs were at a low level, while the AIs were at a medium or high level. Vinh Van Phong Bay, Cam Ranh Bay, Ganh Rai Bay and Rạch Giá Bay presented this pattern in 1988. However, Ganh Rai Bay was converted to pattern 3 (medium intensity-medium concentration pattern) in 2015. This result indicated that Ganh Rai Bay experienced moderate expansion based on the maintenance of a relatively concentrated distribution. In addition, Xuan Dai Bay converted to pattern 4 in 2015.

(5) Low intensity-low concentration pattern. The LPis, LSIs and AIs were at a low level. Construction land in such bays was sparsely distributed with small patches. Xuan Dai Bay presented this pattern in 1988. The LPI and AI were the lowest among all bays. In 2015, Xuan Dai Bay converted to pattern 4 (low intensity-medium concentration pattern). This result indicated that Xuan Dai Bay experienced moderate expansion and that the expansion tended to be concentrated in certain areas.

3.3. Vertical Trends

The overall proportions of construction land in each zone are shown in Table 8. In 1988, the proportion of construction land showed a trend of decrease–increase–decrease with two peaks, one in 0–2 km zone and another in 6–8 km zone. After 30 years of rapid construction sprawl, the proportions in all the zones increased greatly. The rapid pace of the construction sprawl occurred in the 0–2 km zone, and the proportion rose to 17.1%. The growth rate was much greater than that in other zones. In the 2–4 km, 4–6 km and 6–8 km zones, the growth rate was approximately 6.5%. The proportions in the 8–10 km zone were relatively low, and the growth rate was the lowest. The results suggested that the proportions of construction land decreased as the distance from the sea increased. The gap has widened over the following 30 years.

Table 8. Proportions of construction land in each zone.

	0–2 km	2–4 km	4–6 km	6–8 km	8–10 km
1988	5.6%	4.3%	4.4%	5.4%	4.6%
2015	17.1%	11.4%	10.7%	11.4%	8.9%
change	11.4%	7.1%	6.3%	6%	4.4%

The proportions of construction land in each zone and each bay are shown in Figure 7. The results can be discussed in two ways according to the proportion of construction land. In the bays with high construction land density, the distributions of construction land in the five zones were similar in the two periods. The results suggested that the construction land expanded inside the zone. In Hai Loc Bay and Dam Ha Trung Bay, the distribution of construction land in each zone was relatively even. The built-up density in the inland zone was slightly greater than that in the seaward zone. In Danang Bay, the construction land was concentrated in the 0–2 km and 2–4 km zones in both 1988 and 2015. From the 4–6 km zone to the 6–8 km zone to the 8–10 km zone, the proportion of construction land decreased successively. Otherwise, in the bays with low construction land density, the distributions of construction land in the five zones in 2015 were different from the distributions in 1988. The rate of construction sprawl in the 0–2 km zone was obviously greater than that in the other zones. In the other zones, the construction land expanded randomly.

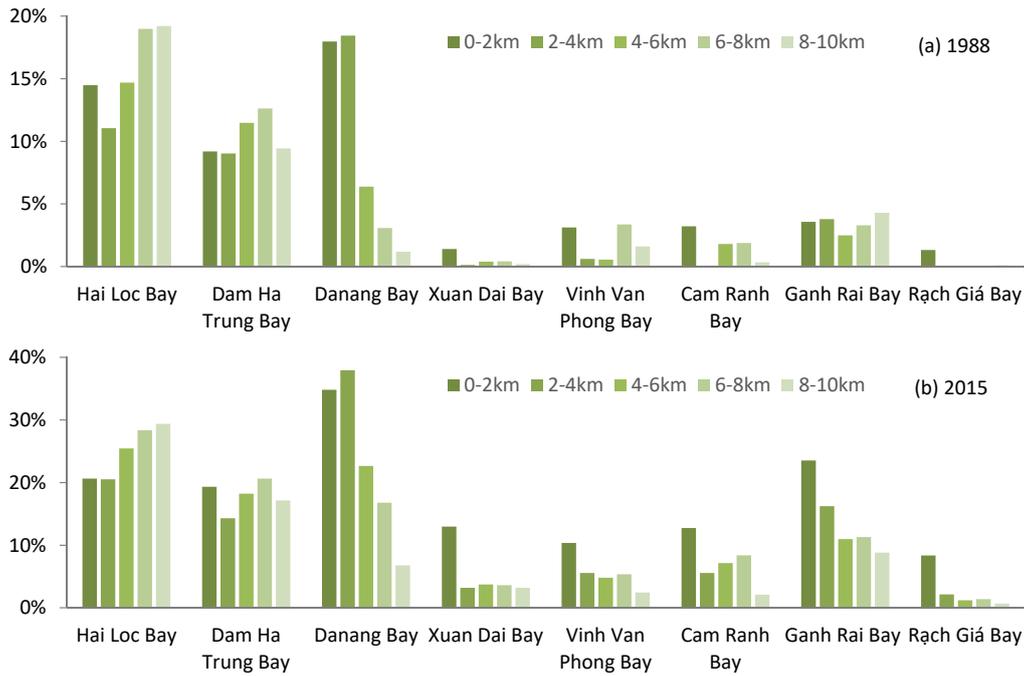


Figure 7. Proportion of construction land in each zone in each bay. (a) Proportion of construction land in 1988; (b) Proportion of construction land in 2015.

3.4. Spatial Trends with Distance from Coast

Figure 8 shows the distribution of the LPIs in the five buffers of the bays in the two periods. In 1988, half of the bays had the greatest LPIs in the 0–2 km zone. In 2015, a total of five bays had the greatest LPIs in the 0–2 km zone. In the remaining three bays (Dam Ha Trung Bay, Cam Ranh Bay and Vinh Van Phong Bay), the LPIs in the 0–2 km zone ranked second. The results suggested that construction tended to be concentrated in the seaward buffer zones. Except for the rapid increase in the LPIs in the 0–2 km zone, the LPIs increased in the other zones. In Hai Loc Bay, Dam Ha Trung Bay and Xuan Dai Bay, the increase in LPIs in landward zones (4–10 km zone) exceeded those in the 2–4 km zone. This result indicated that new construction hotspots were emerging.

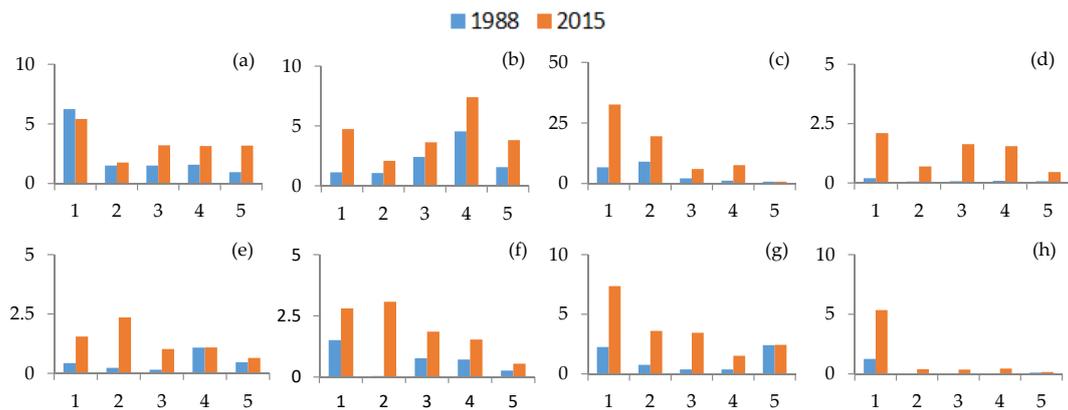


Figure 8. LPIs of the bays in 1988 and 2015. (a) Hai Loc Bay; (b) Dam Ha Trung Bay; (c) Danang Bay; (d) Xuan Dai Bay; (e) Vinh Van Phong Bay; (f) Cam Ranh Bay; (g) Ganh Rai Bay; and (h) Rach Gia Bay. Note: The abscissa values are explained as follows: 1: 0–2 km buffer; 2: 2–4 km buffer; 3: 4–6 km buffer; 4: 6–8 km buffer; and 5: 8–10 km buffer.

Figure 9 shows the distribution of the PDs in the five buffers of the bays in the two periods. Over the study period, the PDs increased in almost all zones and all bays. Among them, the PDs in Hai Loc Bay

were much greater than those in other bays, and the increase of the PDs was also the greatest. From the distribution throughout all zones, the PDs in the 0–2 km zone ranked lowest or second-lowest in Hai Loc Bay, Dam Ha Trung Bay, Danang Bay and Ganh Rai Bay. Accordingly, the four bays had the greatest proportion of construction land. Additionally, the PDs generally showed an increasing trend from the 0–2 km zone to the 8–10 km zone, especially in the first three zones (0–6 km zone). In other bays, the PDs changed little or decreased in the five zones. The results suggested that the fragmentation degree was related to the development degree. In the highly developed bays, the construction land showed an aggregated distribution in the 0–2 km zone. As the distance from the sea increased, the construction land tended to be more fragmented.

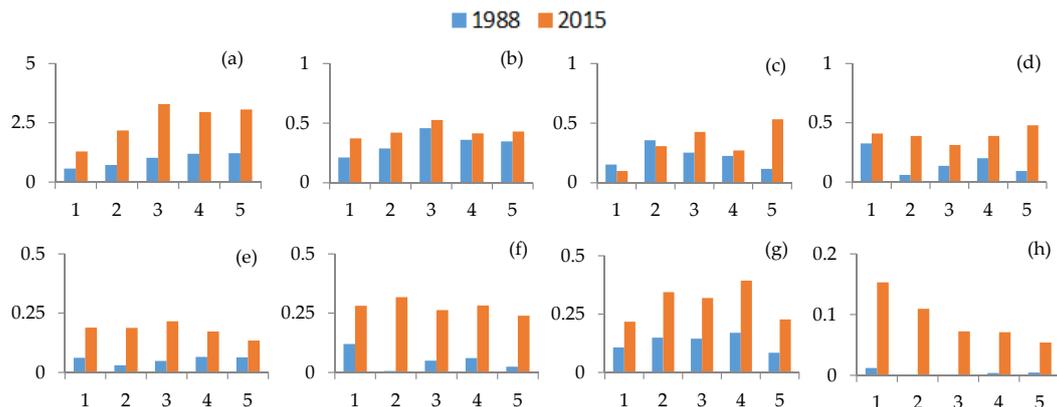


Figure 9. PDs of the bays in 1988 and 2015. (a) Hai Loc Bay; (b) Dam Ha Trung Bay; (c) Danang Bay; (d) Xuan Dai Bay; (e) Vinh Van Phong Bay; (f) Cam Ranh Bay; (g) Ganh Rai Bay; and (h) Rạch Giá Bay. Note: The abscissa values are explained as follows: 1: 0–2 km buffer; 2: 2–4 km buffer; 3: 4–6 km buffer; 4: 6–8 km buffer; and 5: 8–10 km buffer.

Figure 10 shows the distribution of the LSIs in the five buffers of the bays in the two periods. Over the period, the LSIs increased in all zones and all bays except Danang Bay. In Danang Bay, the LSIs in the 0–2 km zone and 2–4 km zone decreased in 1988. As the development degree increased, the construction land tended to gather, and the shape tended to be simple. In most bays except Hai Loc Bay and Danang Bay, the LSIs generally showed a decreasing trend from the 0–2 km zone to the 8–10 km zone. The results suggested that as the distance from the sea increased, the proportion of construction land tended to decrease, and the shape tended to be simpler.

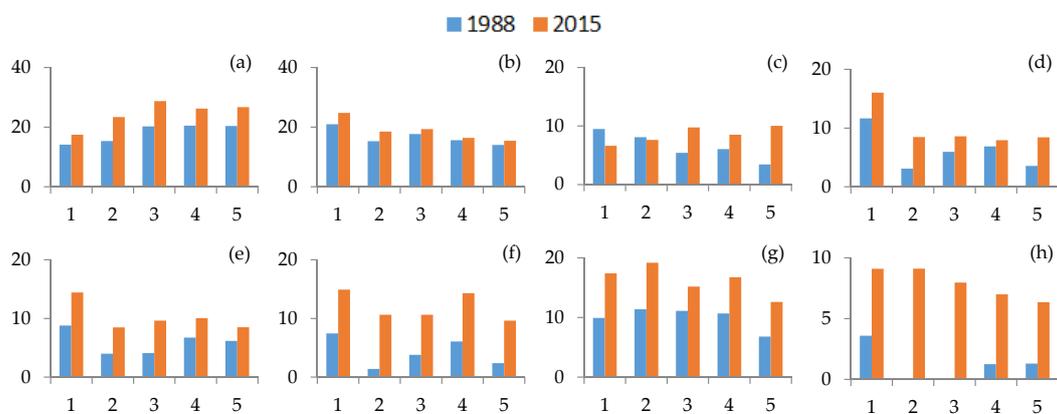


Figure 10. LSIs of the bays in 1988 and 2015. (a) Hai Loc Bay; (b) Dam Ha Trung Bay; (c) Danang Bay; (d) Xuan Dai Bay; (e) Vinh Van Phong Bay; (f) Cam Ranh Bay; (g) Ganh Rai Bay; and (h) Rạch Giá Bay. Note: The abscissa values are explained as follows: 1: 0–2 km buffer; 2: 2–4 km buffer; 3: 4–6 km buffer; 4: 6–8 km buffer; and 5: 8–10 km buffer.

Figure 11 shows the distribution of the AIs in the five buffers of the bays in the two periods. In most bays except Dam Ha Trung Bay, the AIs generally showed a decreasing trend from the 0–2 km zone to the 8–10 km zone. The results suggested that as the distance from the sea increased, the construction land tended to be more discrete.

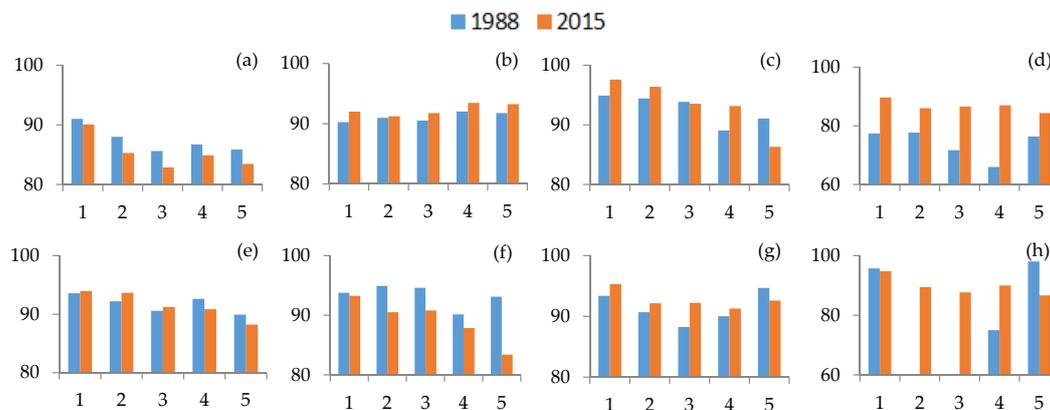


Figure 11. AIs of the bays in 1988 and 2015. (a) Hai Loc Bay; (b) Dam Ha Trung Bay; (c) Danang Bay; (d) Xuan Dai Bay; (e) Vinh Van Phong Bay; (f) Cam Ranh Bay; (g) Ganh Rai Bay; and (h) Rạch Giá Bay. Note: The abscissa values are explained as follows: 1: 0–2 km buffer; 2: 2–4 km buffer; 3: 4–6 km buffer; 4: 6–8 km buffer; and 5: 8–10 km buffer.

4. Discussion

Landscapes influence the proportions and spatial forms of construction land in the bays. Table 9 shows the bay types as well as the proportions and spatial patterns of construction land in each bay. The bays with high construction land proportions belonged to delta bay, bedrock erosion-stacking bay and lagoon bay. The influence of these three types of bays on the distribution of construction land is discussed next.

Table 9. Types, proportions and spatial patterns of construction land in each bay.

Name	Type	Proportion		Spatial Pattern	
		1988	2015	1988	2015
Hai Loc Bay	Delta bay	15.4%	24.5%	HL	HL
Dam Ha Trung Bay	Lagoon bay	10.2%	18.1%	HL	MM
Danang Bay	Bedrock erosion-stacking bay	11.3%	26.5%	HH	HH
Xuan Dai Bay	Structural bay	0.7%	6.6%	LL	LM
Vinh Van Phong Bay	Structural bay	2.1%	6.8%	LM	LM
Cam Ranh Bay	Lagoon bay	1.1%	8.3%	LM	LM
Ganh Rai Bay	Delta bay	3.5%	15.4%	LM	MM
Rạch Giá Bay	Estuary bay	0.3%	2.8%	LM	LM

Note: The abscissa values are explained as follows: HH: high intensity-high concentration pattern; HL: high intensity-low concentration; MM: medium intensity-medium concentration pattern; LM: low intensity-medium concentration pattern; and LL: low intensity-low concentration pattern.

(1) Delta Bay

Deltas are the result of sediment accumulation in estuaries and adjacent areas when rivers enter the sea [46]. Deltas and their estuaries hold both ecological and economic value and are major centers of population and agriculture [47]. A delta bay is a bay formed with the development of a constructive delta [39]. It is easy to convert agricultural infrastructure into urban infrastructure in the urban fringe of deltaic cities [48]. In return, the intensity of development in the delta bay is often high. Hai Loc Bay and Ganh Rai Bay are delta bays located in the two largest deltas in Vietnam—the northern Red River Delta and the southern Mekong River Delta, respectively (Figure 12). These two deltas are

currently agricultural hotspots of Vietnam, contributing 71% of the rice production, 86% of the farmed aquaculture and 65% of the fruit production of the country [49]. Hanoi city and Ho Chi Minh City are the largest cities in the two river deltas, as well as the largest cities in Vietnam. The built-up areas in Hanoi and in Ho Chi Minh have expanded in the past 20 years [50,51]. Correspondingly, the densities of the built-up areas were high in the two bays, and the growth rates of construction land were also very high. The proportions of construction land increased from 15.4% to 24.5% and from 3.5% to 15.4% in Hai Loc Bay and Ganh Rai Bay, respectively.

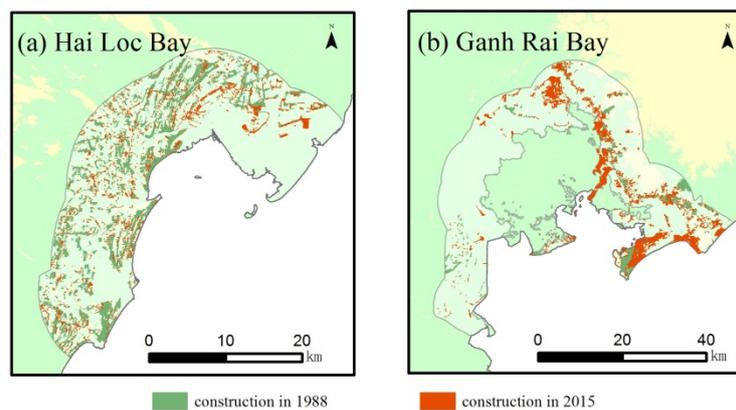


Figure 12. Spatial distribution of construction land in Hai Loc Bay and Ganh Rai Bay. (a) Hai Loc Bay; (b) Ganh Rai Bay.

The terrain of the bay has a great influence on the spatial forms of construction. The delta area often has a dense water network, flat terrain, fertile soil, developed agriculture. The river network in the Red River Delta is quite dense, with a density of about 0.7 km/km² [52]. The Mekong Delta river network is relatively dense and complex and includes natural river systems as well as manmade canals [53]. In this case, it was easy to form dense rural settlements, especially in the narrow border road of the rice field [54]. In terms of spatial form, Hai Loc Bay presented the HL pattern in the two periods. The construction land in Hai Loc Bay had the characteristics of high density and discrete distribution. Meanwhile, the proportion of construction land was even in each zone. At the edge of the bay, there are large uninhabitable depressions, leading to an increase in the proportion of construction land in the sea-land direction. The spatial form of construction land in Ganh Rai Bay was different from that in Hai Loc Bay. Ganh Rai Bay is located in the transitional zone between the southeast platform and the Mekong Delta region. Correspondingly, the construction land in the deltaic area was also relatively discrete, which was similar to that in Hai Loc Bay. In the eastern area of Ganh Rai Bay, the construction land was concentrated in the seaward zone, showing significantly banded distributions.

(2) Lagoon Bay

A lagoon bay is semi-enclosed water composed of a lagoon. The influx of nutrients from many inland rivers entering the lagoon supports high levels of primary productivity in the lagoon. This productivity, in turn, supports fishery production. Aquaculture and fishery capture are considered the most important sources of income in the region [55]. In addition, the sandbanks outside the lagoon can be used as breakwaters, which are suitable for small and medium-sized ports. This has a radiating effect on the mainland economy. Dam Ha Trung Bay and Cam Ranh Bay are located at Tam Giang-Cau Hai Lagoon and Thuy Trieu Lagoon, respectively (Figure 13). In terms of spatial form, Dam Ha Trung Bay and Cam Ranh Bay presented the MM pattern. The proportion of construction land in Dam Ha Trung Bay was greater than that in Cam Ranh Bay. The Tam Giang-Cau Hai Lagoon, where Dam Ha Trung Bay is located, lies along the central coastal line of Vietnam. The lagoon runs nearly 70 km along the coast and covers 219.18 km² of the water surface, forming the largest lagoon system in Southeast Asia [55,56]. Thuy Trieu Lagoon, where Cam Ranh Bay is located, is a narrow enclosed water body in

southeastern Khanh Hoa Province that is approximately 16 km in length, 250 m in width and 0.5 to 6 m in depth [57]. The lagoons experienced the rapid expansion of areas devoted to aquaculture activities (notably, culture ponds) [56,57]. Accordingly, many settlements are scattered along the bay coast. In addition, the developed agriculture in inland areas also gave rise to regional agricultural centers. The distribution of construction land appeared two peaks in 0–2 km zone and 6–8 km zone. From the perspective of the spatial morphology, the construction land in the two bays presented blocked or banded distributions.

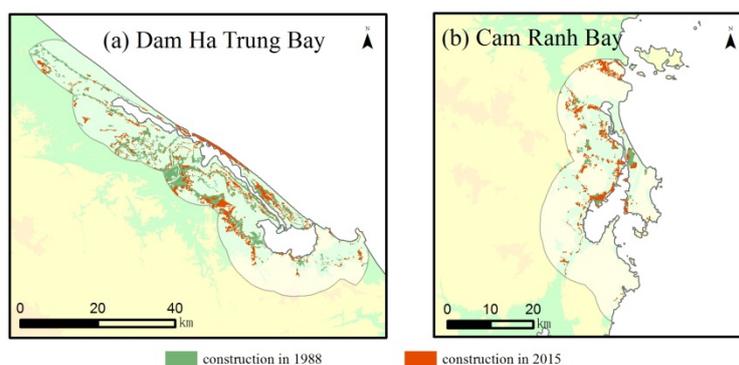


Figure 13. Spatial distribution of construction land in Dam Ha Trung Bay and Cam Ranh Bay. (a) Dam Ha Trung Bay; (b) Cam Ranh Bay.

(3) Bedrock erosion-stacking bay

A bedrock erosion-stacking bay is mainly a depression or valley formed by long-term erosion of the rock fracture zone and seawater intrusion. The top of the bay often forms a sandy or tidal beach, and the two sides have bedrock capes [40]. Semi-enclosed bedrock bays are natural deep-water harbors, and the tidal channels and scour troughs in these bays are natural channels. The urban layout gives priority to the bay, and the economic structure is mainly based on the bay. Port economy drives the development of the marine industry and the inland economy. Such bays have always been the focus of coastal zone development [58]. Danang Bay is a bedrock erosion bay on the central coast of Vietnam (Figure 14). Da Nang city, where Danang Bay is located, is the most dynamic city in the middle of central Vietnam [59]. The proportion of construction land was greatest in Danang Bay in 2015, up to 26.5%. In terms of spatial form, Danang Bay presented the HH pattern in the two periods. The bay has lower terrains in the middle and hills on the two sides. The construction land was concentrated in central coastal plains with a high degree of aggregation. In the past 30 years, the construction land has expanded inland from the original core. The proportions of construction land decreased significantly in the sea–land direction. The major seaport in Vietnam—Da Nang port is located at the river mouth [60]. The greatest density of construction land was also located in this region.

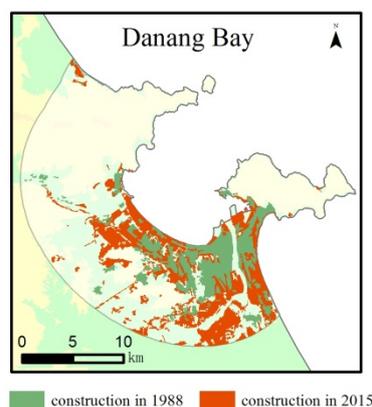


Figure 14. Spatial distribution of construction land in Danang Bay.

5. Conclusions

This study used Landscape indexes, clustering method and strip division to analyze the spatial and vertical distribution of construction land in the bay area. Additionally, the influence of bay type on the distribution of construction land was discussed. Our findings were as follows:

- (1) Across the region, the total proportion of construction land increased from 4.9% to 12.5% from 1988 to 2015. In terms of the spatial distribution, there were significant differences between the northern bays and southern bays. The top three bays with the greatest proportions (Hai Loc Bay, Dam Ha Trung Bay and Danang Bay) were distributed along the northern coast of Vietnam.
- (2) In the process of the expansion of construction land in the bays, the bay-level LPs, PDs and LSIs increased during the 30 year study period. This result indicated that the distribution of construction land became more fragmented, and the shape tended to be more complex in the 30 year period. Especially in Hai Loc Bay, construction land was the most densely and fragmented distributed.
- (3) The method of using the landscape indexes for clustering can identify the spatial pattern of construction land effectively. The eight bays were divided into five patterns (HH, HL, MM, LM and LL) into the two periods. Danang Bay exhibited a typical HH pattern, and Hai Loc Bay exhibited a typical HL pattern.
- (4) The distance from the sea had a significant influence on the distribution of construction land in bays. There was a trend that the proportions of construction land decreased as the distance from the sea increased in general. The proportions of construction land in the 0–2 km zone were greatest, as well as the growth rate. In contrast, the proportions in the 8–10 km zone were relatively low. Moreover, the construction land tended to be more fragmented and discrete, and the shape tended to be simpler.
- (5) The bay type had a significant influence on the distribution of construction land in the bays. The proportions of construction land were high in delta bay, bedrock erosion-stacking bay and lagoon bay. In terms of the spatial distribution, the construction land was densely and fragmented distributed in delta bay, while the construction land was centrally distributed in bedrock erosion-stacking bay.

The study provided a method to analyze the spatial pattern of construction land distribution. In future studies, (i) more bay data should be collected to improve the classification system of the spatial pattern of construction land, and (ii) more landscape indicators should be identified to reveal the pattern of construction land expansion in bays.

Author Contributions: Writing—original draft, Junjue Zhang; writing—review and editing, Fenzhen Su. All authors have read and agreed to the published version of the manuscript.

Funding: This work was funded by the National Natural Science Foundation of China (NSFC) (41890854) and Science and Technology Basic Resources Investigation Program of China (Grant No. 2017FY201401).

Acknowledgments: The authors would like to thank Dongjie Fu for reviewing the manuscript.

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

References

1. Chen, Z.; Wang, W.; Wu, S. *An Introduction to Gulfs in China*; Beijing China Ocean Press: Beijing, China, 2007.
2. Huang, X.; Zhang, L.; Zhang, J.; Jiang, Z. Problems in Development of Chinese Bays and the Protection strategy. *Bull. Chin. Acad. Sci.* **2016**, *31*, 1151–1156. [[CrossRef](#)]
3. Spearritt, P. The 200 Km City: Brisbane, the Gold Coast, and Sunshine Coast. *Aust. Econ. Hist. Rev.* **2009**, *49*, 87–106. [[CrossRef](#)]
4. Güneralp, B.; Seto, K.C. Futures of global urban expansion: Uncertainties and implications for biodiversity conservation. *Environ. Res. Lett.* **2013**, *8*. [[CrossRef](#)]

5. Sturani, M.L.; Vecchio, B.M.L. Urban morphology in the Italian tradition of geographical studies. *Urban Morphol.* **2003**, *7*, 40–42.
6. Qiao, W. Study on Urban Spatial Multidimensional Expansion of Nanjing Based on Land Use Perspective. Ph.D. Thesis, Nanjing Normal University, Nanjing, China, 2013.
7. Xiong, G. Study on the Morphology Evolution of Chinese Cities Since 1990s. Ph.D. Thesis, Nanjing University, Nanjing, China, 2005.
8. Lynch, K. *Good City Form*; MIT Press: Cambridge, MA, USA, 1984.
9. Kuai, Y. A Study on the Spatial Morphology of Northeast Cities. Ph.D. Thesis, Northeast Normal University, Changchun, China, 2004.
10. Bengston, D.N.; Fletcher, J.O.; Nelson, K.C. Public policies for managing urban growth and protecting open space: Policy instruments and lessons learned in the United States. *Landsc. Urban Plan.* **2004**, *69*, 271–286. [[CrossRef](#)]
11. Hall, P. The future of the Metropolis and its form. *Urban Plan. Overseas* **2000**, *31*, 211–220.
12. Berry, B.J.L. Internal structure of the city. *Law Contemp. Probl.* **1965**, 111–119. Available online: <https://scholarship.law.duke.edu/lcp/vol30/iss1/8> (accessed on 25 November 2020).
13. Simmons, J.W. Descriptive models for urban land use. In *Internal Structure of the City*; Larry, S., Ed.; Oxford University Press: New York, NY, USA, 1971.
14. Camagni, R.; Gibell, M.C.; Rigamonti, P. Urban mobility and urban form: The social and environment costs of different patterns of urban expansion. *Ecol. Econom.* **2002**, *40*, 199–216. [[CrossRef](#)]
15. Liu, J.; Wang, X.; Zhuang, D.; Zhang, W.; Hu, W. Application of Convex Hull in Identifying the Types of Urban Land Expansion. *ACTA Geogr. Sin.* **2003**, *58*, 885–892.
16. García-Ayllón, S. Retrospective analysis of urban development in the Spanish Mediterranean coast. *Sustain. City VIII* **2013**, *1*, 291–302. [[CrossRef](#)]
17. Zhao, J.; Song, Y.; Shi, L.; Tang, L. Study on the compactness assessment model of urban spatial form. *Acta Ecol. Sin.* **2011**, *31*, 6338–6343.
18. Colaninno, N.; Cerdà Troncoso, J.; Roca Cladera, J. Spatial patterns of land use—Morphology and demography, in a dynamic evaluation of urban sprawl phenomena along the Spanish Mediterranean coast. In Proceedings of the Conference of European Regional Science Association, Barcelona, Spain, 30 August–2 September 2011; pp. 1–18.
19. Thinh, N.X.; Arlt, G.; Heber, B.; Hennesdorf, J.; Lehrmann, I. Evaluation of urban land-use structures with a view to sustainable development. *Environ. Impact Assess. Rev.* **2002**, *22*, 475–492. [[CrossRef](#)]
20. Batty, M.; Longley, P.A. *Fractal Cities: A Geometry of Form and Function*; Academic Press: London, UK, 1994.
21. Zhan, Q.; Xu, T.; Zhou, J. Research on Urban Morphology Evolution Based on Fractal Theory and Space Syntax: Taking the Fuzhou City as an Example. *Huazhong Archit.* **2010**, *28*, 7–10.
22. Guo, Y.; Tian, G.; Zhao, R.; Shen, X.; Dong, B.; He, R. A study of the changes in urban spatial morphology of major Chinese cities during 2000–2013. *J. Southwest Univ.* **2019**, *41*, 139–148.
23. Che, T.; Li, C.; Luo, Y. Changes in landscape pattern of built-up land and its driving factors during urban sprawl. *Acta Ecol. Sin.* **2020**, *40*, 1–12.
24. Herold, M.; Goldstein, N.C.; Clarke, K.C. The spatiotemporal form of urban growth: Measurement, analysis and modeling. *Remote Sens. Environ.* **2003**, *86*, 286–302. [[CrossRef](#)]
25. Liu, X.; Li, X.; Chen, Y.; Qin, Y.; Li, S.; Chen, M. Landscape Expansion Index and Its Applications to Quantitative Analysis of Urban Expansion. *Acta Geogr. Sin.* **2009**, *64*, 1430–1438.
26. Jiao, L.; Mao, L.; Liu, Y. Multi-order Landscape Expansion Index: Characterizing urban expansion dynamics. *Landsc. Urban Plan.* **2015**, *137*, 30–39. [[CrossRef](#)]
27. Hou, X.; Xu, X. Spatial patterns of land use in coastal zones of China in the early 21st century. *Geogr. Res.* **2011**, *30*, 1370–1379.
28. Crossland, C.J.; Baird, D.; Ducrottoy, J.P.; Lindeboom, H. *The Coastal Zone: A Domain of Global Interactions. Coastal Fluxes in the Anthropocene*; Springer: Berlin/Heidelberg, Germany, 2005; pp. 1–37.
29. Ding, Z.; Liao, X.; Su, F.; Fu, D. Mining Coastal Land Use Sequential Pattern and Its Land Use Associations Based on Association Rule Mining. *Remote Sens.* **2017**, *9*, 116. [[CrossRef](#)]
30. Ding, Z.; Su, F.; Zhang, J.; Zhang, Y.; Luo, S.; Tang, X. Clustering Coastal Land Use Sequence Patterns along the Sea–Land Direction: A Case Study in the Coastal Zone of Bohai Bay and the Yellow River Delta, China. *Remote Sens.* **2019**, *11*, 2024. [[CrossRef](#)]

31. Yu, H.; Zeng, H.; Jiang, Z. Study on Distribution Characteristics of Landscape Elements along the Terrain Gradient. *Sci. Geogr. Sin.* **2001**, *21*, 64–69.
32. Zhang, J.; Su, F.; Zhou, C.; Zuo, X.; Ding, Z.; Li, H. Construction land expansion in coastal zone around the South China Sea based on different geomorphologic backgrounds in the past 35 years. *Acta Geogr. Sin.* **2016**, *71*, 104–117. [[CrossRef](#)]
33. Sekhar, N.U. Integrated coastal zone management in Vietnam: Present potentials and future challenges. *Ocean Coast. Manag.* **2005**, *48*, 813–827. [[CrossRef](#)]
34. Wang, W.; Zhang, J.; Su, F. An index-based spatial evaluation model of exploitative intensity: A case study of coastal zone in Vietnam. *J. Geogr. Sci.* **2018**, *28*, 291–305. [[CrossRef](#)]
35. Pho Hoang Han, M.M.M. Fisheries development in Vietnam—A case study in the exclusive economic zone. *Ocean Coast. Manag.* **2007**, *50*, 699–712. [[CrossRef](#)]
36. Zhang, J. Research on the Spatial-Temporal Differentiation of Coastal Utilization Intensity Surrounding the South China Sea in 35 Years. Ph.D. Thesis, University of Chinese Academy of Sciences, Beijing, China, 2017.
37. FIPS; FAO. *FAO Year Book: Fishery and Aquaculture Statistics 2010*; FAOL: Rome, Italy, 2012.
38. Editorial Board of China Bay Survey. *Survey of China Bays (Volume 2)*; China Ocean Press: Beijing, China, 1997.
39. Wu, S.; Wang, W. Study on the classification system of bays. *Acta Oceanol. Sin.* **2000**, *22*, 83–89.
40. Xia, D.; Liu, Z. Classification of bays in China. *Oceanol. Limnol. Sin.* **1990**, *21*, 185–191.
41. Zhang, J.; Su, F. Land Use Change in the Major Bays Along the Coast of the South China Sea in Southeast Asia from 1988 to 2018. *Land* **2020**, *9*, 30. [[CrossRef](#)]
42. Cushman, S.A.; McGarigal, K.; Neel, M.C. Parsimony in landscape metrics: Strength, universality, and consistency. *Ecol. Indic.* **2008**, *8*, 691–703. [[CrossRef](#)]
43. Sertel, E.; Topaloğlu, R.; Şallı, B.; Yay Algan, I.; Aksu, G. Comparison of Landscape Metrics for Three Different Level Land Cover/Land Use Maps. *ISPRS Int. J. Geo-Inf.* **2018**, *7*, 408. [[CrossRef](#)]
44. Anil, K.J. Data clustering: 50 years beyond K-Means. *Pattern Recognit. Lett.* **2010**, *3*, 651–666.
45. Wang, Q.; Wang, C.; Feng, Z.; Ye, J. Review of K-means clustering algorithm. *Electron. Des. Eng.* **2012**, *20*, 21–24. [[CrossRef](#)]
46. Fan, Y. Seabed Erosion and Its Mechanism in the Littoral Area of Yellow River Delta. Ph.D. Thesis, East China Normal University, Shanghai, China, 2019.
47. Syvitski, J.P.M.; Saito, Y. Morphodynamics of deltas under the influence of humans. *Glob. Planet. Chang.* **2007**, *57*, 261–282. [[CrossRef](#)]
48. Yokohari, M.; Takeuchi, K.; Watanabe, T.; Yokota, S. Beyond greenbelts and zoning A new planning concept for the environment of Asian mega-cities. *Landsc. Urban Plan.* **2000**, *47*, 159–171. [[CrossRef](#)]
49. Nguyen, M.T.; Renaud, F.G.; Sebesvari, Z. Drivers of change and adaptation pathways of agricultural systems facing increased salinity intrusion in coastal areas of the Mekong and Red River deltas in Vietnam. *Environ. Sci. Policy* **2019**, *92*, 331–348. [[CrossRef](#)]
50. Pham, H.M.; Yamaguchi, Y. Urban growth and change analysis using remote sensing and spatial metrics from 1975 to 2003 for Hanoi, Vietnam. *Int. J. Remote Sens.* **2011**, *32*, 1901–1915. [[CrossRef](#)]
51. Kontgis, C.; Schneider, A.; Fox, J.; Saksena, S.; Spencer, J.H.; Castrence, M. Monitoring peri-urbanization in the greater Ho Chi Minh City metropolitan area. *Appl. Geogr.* **2014**, *53*, 377–388. [[CrossRef](#)]
52. Bui, D.D.; Kawamura, A.; Tong, T.N.; Amaguchi, H.; Nakagawa, N.; Iseri, Y. Identification of aquifer system in the whole Red River Delta, Vietnam. *Geosci. J.* **2011**, *15*, 323–338. [[CrossRef](#)]
53. Renaud, F.G.; Kuenzer, C. *The Mekong Delta System*; Springer: Berlin/Heidelberg, Germany, 2012.
54. Hara, Y.; Takeuchi, K.; Okubo, S. Urbanization linked with past agricultural landuse patterns in the urban fringe of a deltaic Asian mega-city: A case study in Bangkok. *Lands. Urban Plann.* **2005**, *73*, 16–28. [[CrossRef](#)]
55. Tuan, T.H.; Van Xuan, M.; Nam, D.; Navrud, S. Valuing direct use values of wetlands: A case study of Tam Giang–Cau Hai lagoon wetland in Vietnam. *Ocean Coast. Manag.* **2009**, *52*, 102–112. [[CrossRef](#)]
56. Disperati, L.; Viridis, S.G.P. Assessment of land-use and land-cover changes from 1965 to 2014 in Tam Giang-Cau Hai Lagoon, central Vietnam. *Appl. Geogr.* **2015**, *58*, 48–64. [[CrossRef](#)]
57. Quang, N.; Sasaki, J.; Higa, H.; Huan, N. Spatiotemporal Variation of Turbidity Based on Landsat 8 OLI in Cam Ranh Bay and Thuy Trieu Lagoon, Vietnam. *Water* **2017**, *9*, 570. [[CrossRef](#)]
58. Bian, S.; Xia, D.; Lv, J. Tidal Geomorphology Patterns and Their Dynamic Sedimentary Characteristics in the Bedrock Bays of China. *Adv. Mar. Sci.* **2003**, *21*, 298–307.

59. Linh, N.H.K.; Erasmi, S.; Kappas, M. Quantifying land use cover change and landscape fragmentation in Danang City, Vietnam 1979–2009. In Proceedings of the International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Melbourne, Australia, 25 August–1 September 2012; pp. 501–506.
60. Kuo, K.-C.; Lu, W.-M.; Le, M.-H. Exploring the performance and competitiveness of Vietnam port industry using DEA. *Asian J. Shipp. Logist.* **2020**, *36*, 136–144. [[CrossRef](#)]

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