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Assessment of Landscape Change in the Coastal Zone of Nam Dinh Province (Vietnam) Using Remote Sensing Data and Landscape Metrics

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Abstract: Landscape units in the coastal zones are changed over time due to human impact and natural forces. The changes in landscape are reflected in landscape structure. Change, in this case, encompasses any modification occurring in the landscape over time. Landscape structure investigates the mosaic of land patches defined by their measure, number, size and shape. This paper explores the linkage between landscape and future land use land cover (LULC) conditions in a coastal zone of Nam Dinh province, a northern region of Vietnam, in an effort to identify landscape change. Remote Sensing and landscape metrics are important tools, used to understand landscape structure and landscape change. In order to use metrics, numeric data on land use are obtained from Landsat satellite images of two points in time (2000 and 2017) showing seven land use types including agricultural land, residential area, mangrove forest, aquacultural land, water bodies, sandy beaches, and salty

fields. Those landscape metrics are used in combination with GIS to evaluate landscape structure.

Keywords: Landscape change; landscape metrics; coastal zone; Remote Sensing; Nam Dinh province; Vietnam

1. Introduction

During the last twenty years, it has been considered essential to use a landscape scale approach for understanding ecological processes and analyzing sustainability. The research outcomes based on landscape approaches have been adopted by international and national organizations to summarize pressures and threats, and development policies for sustainability. The shift towards these approaches has prompted the development of landscape units at regional, national and provincial scales [1]. Aspects of natural entities including landform, soil, vegetation and their attributes influenced by humans are constantly evolving within the landscape. The landscape also is a mirror of man's actions upon the terrain, a constantly changing reflection of actions and non-actions [1]. The landscapes in the coastal zones have been strongly changed under the influences of both natural processes and human activities. Both natural conditions and human needs are usually changed over time, which continuously leads to complex changes of the landscape structure [2], [3]. Because of impacts of climate change and sea level rise, coastal zones will become more dynamic as they respond to these changed conditions [4]. Natural processes and human activities create the driving forces for a change in mosaic structure, and shape and size of patches in the landscape. All these changes can be seen on different scales and in different frequencies [3]. Landscape change can be described as a comparison of the status of a landscape at least two different points in time. Landscapes possess a mixture of different characteristics and consist of inherent dynamics. Depending on these dynamics, landscape change can take place at different speed and scale [5]. Landscape pattern and functions affect each other. In previous studies the application of landscape indices has been a common method to analyze landscape functions [6], [7]. Quantification and analysis of landscape pattern change would provide an additional level of knowledge on top of the current baseline of research on landscape and its possible future dynamics [8]. Therefore, understanding landscape structure and functions requires multi-scale information. Scaling functions are the most precise and concise way of quantifying multi-scale characteristics explicitly [9]. It is increasingly recognized that more sustainable approaches are needed for planning and managing landscape worldwide. New tools are needed to effectively apply sustainable principles for planning and management [10].

Landscape change can be detected by extracting information from aerial photography and satellite images in combination with land use status maps, using various techniques. There are some challenges related to landscape change studies. For example, if the data of previous years are of different type and quality, it is difficult to get qualified data to compare [3]. Landscape metric tools are used in landscape ecology to support landscape planning and management decisions. In this study landscape metrics were used to measure the landscape structure and the complexity of this structure. The complexity of the landscape structure, landscape metrics used for measuring and mosaic structure and related information can be obtained. Even though remote sensing data are widely employed in landscape ecology research, their current and potential roles have not been evaluated critically. The predominant application of remote sensing data used to be for thematic mapping purposes. The role of remote sensing in landscape ecology might be strengthened by closer collaboration between researchers in the two disciplines, by greater integration of diverse remote sensing data with ecological data, and by increased recognition of the value of remote sensing beyond land-cover mapping and pattern description. Remote sensing is a fast and inexpensive tool for assessing the landscape and landscape change. Remotely sensed images have become a popular data source for comparative studies of environmental change assessment [9], [11], [12], [13], [14].

Landscape metrics for analyzing land use/land cover (LULC) change patterns have been considered a useful tool for environmental impact assessment and landscape change detection studies [5], [8], [15], [16], [17], [18], [19], [20], [21], [22], [23]; landscape monitoring [24], [25]; and landscape design and planning [10], [26], [27]. Moreover, the landscape metrics approach can also be used for selection of protected areas [28] and assessing water quality [1], [29].

Vietnam is a developing country with rapid transformation of LULC during its social and economic development periods (renewal) since 1986. However, detailed assessments of LULC change in the coastal zone areas from a landscape perspective are rare in Vietnam. These changes are characterized by rapid conversion from agricultural land (paddy land) and mangrove forest to aquacultural land, industrial land, residential area, etc. There is only a limited number of publications that have addressed landscape change monitoring and landscape assessment in Vietnam. This paper will quantify landscape change through LULC change with respect to its temporal characteristics using remote sensing and landscape metrics in the coastal zone of Nam Dinh province in the northern region of Vietnam. Remote sensing and landscape metrics are important tools which are used to understand landscape structure and landscape change. In order to use metrics, numeric data on land use were obtained from Landsat's satellite images. Landscape metrics are useful in association with GIS to assess the landscape structure of the study area.

2. Study Area

Nam Dinh is a coastal province in the Red River delta of northern Vietnam, bordering the Gulf of Tonkin. The total area of the province is 1,668.54 km² and the population is 1,852,850 people, and the population density is 1,110 people per km² (2017). The Nam Dinh province consists of 10 administrative units: nine districts and one city [30]. The whole Nam Dinh province belongs to the Northern Key Economic Zone of Vietnam.

The study area is the coastal zone of the Nam Dinh province including three coastal districts of Nghia Hung, Hai Hau and Giao Thuy. The total area of these districts is approximately 753 km², and is characterized by typical land use types of the large river flood plain in the north of Vietnam (Fig. 1). The terrain of the study area is relatively flat, with 72 km of coastline, which is divided quite distinctly by the large estuaries of the Red river, Day river and Ninh Co river. Because of the coastal plain, soil resources are fertile and hold potential for agricultural production activities such as culture of annual crops, aquaculture, livestock, shipbuilding, and marine tourism.

This coastal zone is strongly influenced by the Red River system. The Red river system has a total annual flow volume of 114,109 m^3 of water and a sediment flow of 115 million tons $year^{-1}$. This flow has contributed to silting up the Red River delta with an average speed of 17 - 83 meters $year^{-1}$ towards the sea, depending on distance from the river mouth to the deposited area and formation of coastline. During the flooding season, the annual water flow accounts for 75 - 90% out of the total water volume and brings 90% of the total sediment in each year. Subsequently, the river delta is inundated, estuarine canals are silted and freshened. Conversely, in the dry season, the estuarine area recedes. When the tide comes in, it brings seawater through the rivers and canals penetrating deeply into the mainland, increasing the saline area (nearly 20 km backward into the mainland). Depending mainly on the flood and hydrology regime of the Red River system, the salinity in this area varies much. In the winter, the average salinity is fairly homogeneous, about 28 - 30‰ and in summer, the average salinity is about 20 - 27‰ [31].

Most of the study area belongs to the Red River Delta Biosphere Reserve (established in 2004) that is a UNESCO's Biosphere Reserve in the northern coastal region of Vietnam. Mangroves and intertidal habitats of the Red River delta form wetlands of high biodiversity, especially in the Xuan Thuy and Tien Hai districts. These wetlands are of global importance as migratory sites for several bird species. The reserve's surface area (terrestrial and marine) is 137,261 hectares. The core zone of the Biosphere Reserve is 14,842 hectares, the buffer zone 36,951 hectares and the transition area 85,468 hectares [32]. The mangrove ecosystem comprises the mangrove forest and the adjacent intertidal area. There are 26 mangrove species found in the coastal zones, of which the most dominant are *Kandelia candel* and *Sonneratia caseolaris*. During spring and autumn migrations, huge numbers of birds stop on their route from northern Asia to southern Asia. A total of 78 species of water birds have been recorded in the Red River delta including 38 species of shorebirds.

The Xuan Thuy National Park is located on the right side of the Ba Lat estuary of the Red River, which belongs to Giao Thuy district, which is about 40 km from Nam Dinh city and 130 km from Hanoi. It is a river estuary in a coastal plain with a large area of wetlands, which is the most typical coastal ecosystem, not only in Nam Dinh province but in the whole North of Vietnam. Internationally, the Xuan Thuy National Park is an important bird "station" for international migratory birds, including Black-faced Spoonbill - a rare bird in the IUCN's Red Listof Threatened Species. In recognition of the fundamental ecological functions performed by its wetlands, the Xuan Thuy National Park was declared first Vietnamese RAMSAR site in 1982 and in October 2004, UNESCO recognized the Xuan Thuy National Park as the most important zone of the biosphere reserve in the Red River delta, confirming the international special position of the Xuan Thuy National Park.

In this area, there are many proposed economic development projects. Firstly, the Ninh Co Economic Zone, which located at the mouth of Ninh Co river, with it's area of about 500 ha, including works of seaport, ship building industry, mechanical engineering, processing, transport services, tourism services and various forms of business services along the Ninh Co river estuary in Hai Hau and Nghia Hung districts. Secondly, it is the Rang Dong Textile company and Garment Industrial Zone. At the completion of the project, the industrial park will have an area of over 600 hectares, attracting about 500 enterprises and 150,000 employees.

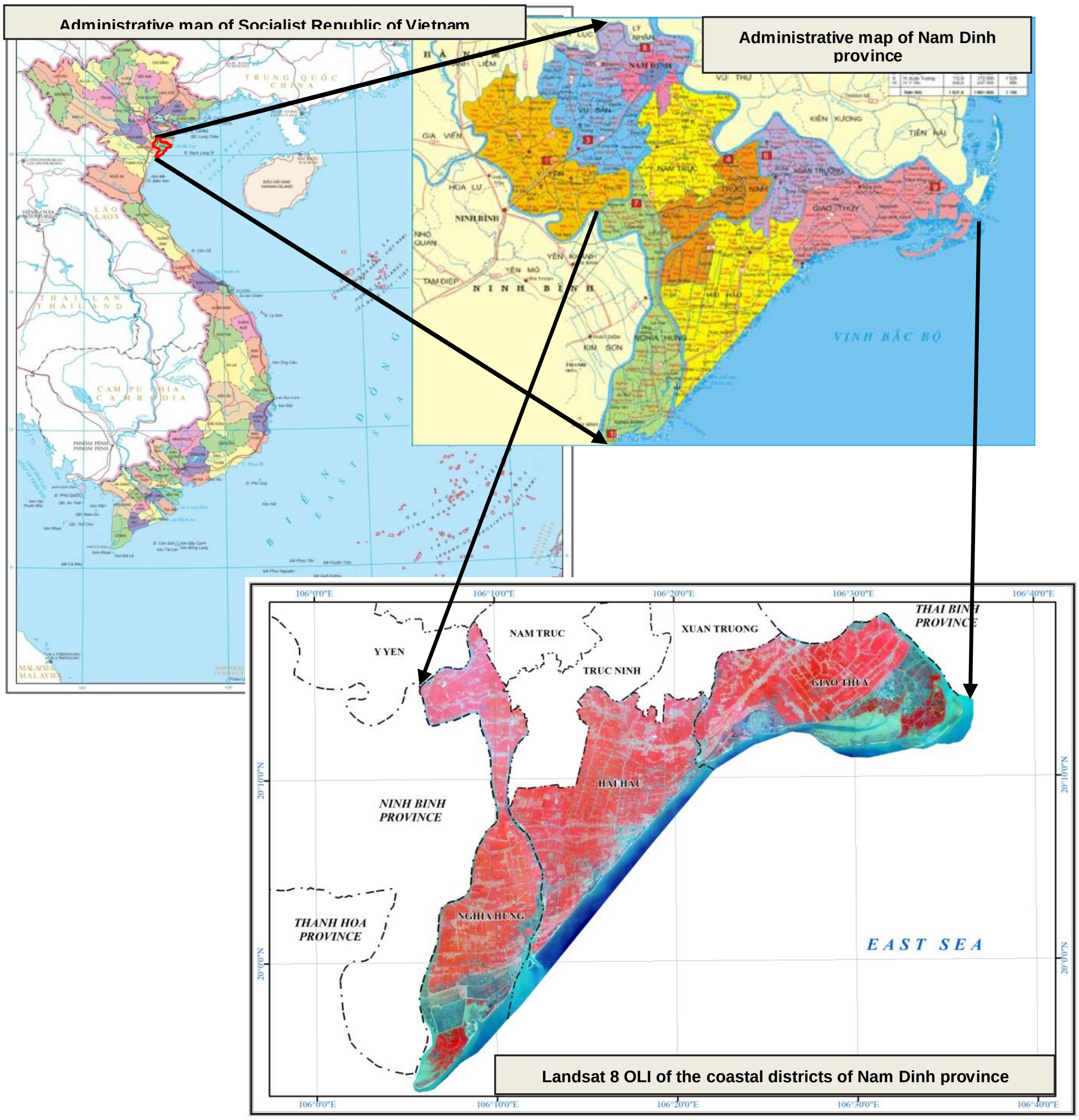


Fig. 1 **The study area of the coastal districts of Nam Dinh province**

3. Materials and methods

To answer the above question about landscape change in the study area, LULC maps were generated from Landsat satellite images of two times of 2000 and 2017, including Landsat ETM+ (captured in November 2000) and Landsat 8 OLI (captured in September 2017). These images were downloaded from earth explorer.usgs.gov and processed to achieve surface reflectance value. These processed images were then used in the classification. Different band combination was employed to aid the interpretation phase. For Landsat ETM+, band combination (4,5,3) were used. For Landsat 8 OLI, band combination (5,6,4) and (6,5,4) were used. The LULC maps of the year 2000 and 2017 of the study area were established based on the supervised classification method using ERDAS IMAGINE software (Ver. 8.4). In order to associate the textures of images with the proper real objects, seven interpretation keys were established including residence, agriculture, mangrove forest, aquaculture, sand beach, water body and salt field (Table 1).

Landscape metrics are used in conjunction with assistance of Geographic Information Systems (GIS). GIS has made a major contribution to the study of landscape metrics. In order to quantify the landscape metrics in the study area, FRAGSTATS software program was used to calculate eleven landscape metrics for classification, presented in Table 2. The original software (Version 2) was released into the public domain in 1995 in association with the publication of a technical report of the General Services USDA Forest [33]. Recently, this program has been upgraded to be compatible with the ArcGIS software (Ver. 10.3). Landscape metrics can be classified into three categories [34]:

- Patch level: To calculate every patch type in a mosaic.
- Class level: To calculate every patch type class.
- Landscape level: All of the mosaic is calculated.

Table 1 Image interpretation key

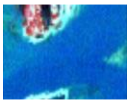
Sample	**Object interpretation**	**Sample**	**Object interpretation**
	Residence		Sand beach
	Agriculture		Water body
	Mangrove forest		Salt field
	Aquaculture		

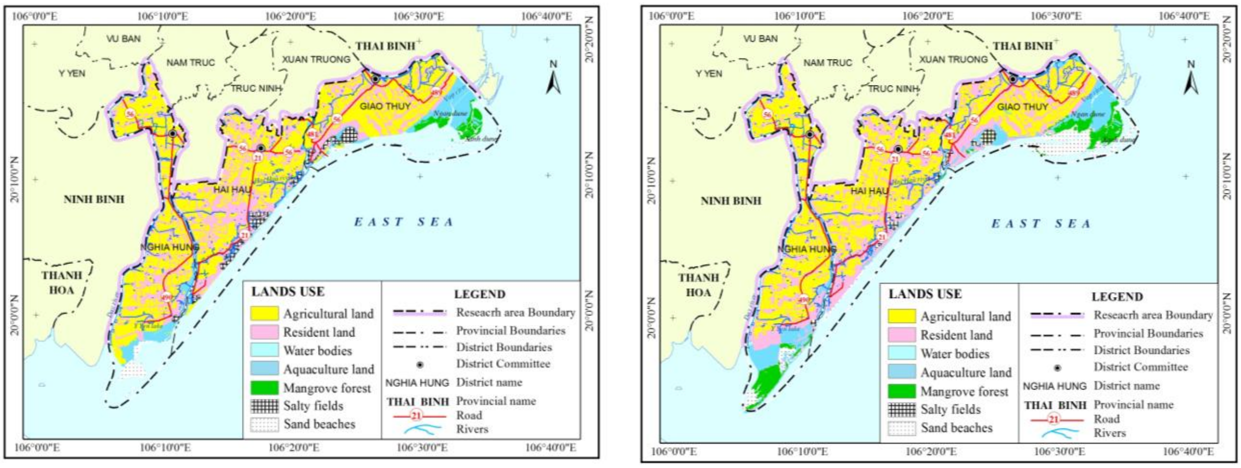
Table 2 Landscape metrics used in case study

Abbreviation	Landscape Metric	Description	Units	Value
CA	Area	Total class area	Hectare	
LPI	Largest Patch Index	LPI equals the area (m^2) of the largest patch in the landscape divided by total landscape	Percent	0 < LPI ≤ 100
PD	Patch Density	Number of forest patches per unit of area	Number per 100 hectares	PD > 0
NP	Number of Patches	Total number of patches in the landscape	None	NP ≥ 1, without limit
PLADJ	Percentage of Like Adjacencies	PLADJ equals sum of the number of like adjacencies for each patch type, divided by the total number of cell adjacencies in the landscape	Percent	0 ≤ PLADJ ≤ 100
LSI	Landscape Shape Index	LSI equals the total length of edge in the landscape divided by the minimum total length of edge possible	None	LSI ≥ 1, without limit
PAFRAC	Perimeter-Area Fractal Dimension	PAFRAC equals 2 divided by the slope of regression line obtained by regressing the logarithm of patch area against the logarithm of patch perimeter.	None	1 ≤ PAFRAC ≤ 2
DIVISION	Landscape Division Index	DIVISION equals 1 minus the sum of patch area (m^2) divided by total landscape area (m^2), quantity squared, summed across all patches in the landscape	Percent	0 ≤ DIVISION < 1
SHDI	Shannon's Diversity Index	SHDI equals minus the sum, across all patch types, of the proportional abundance of each patch type multiplied by that proportion. Note, Pi is based on total landscape area (A) excluding any internal background present.	Information	≥ 0, without limit
SIDI	Simpson's index	SIDI equals 1 minus the sum, across all patch types, of the proportional abundance of each patch type squared. Note, Pi is based on total landscape area (A) excluding any internal background present.	None	0 ≤ SIDI < 1
MSIDI	Modified Simpson's Diversity Index	MSIDI equals minus the logarithm of the sum, across all patch types, of the proportional abundance of each patch type squared. Note, Pi is based on total landscape area (A) excluding any internal background present.	None	≥ 0, without limit

4. Results and Discussion

4.1. Land Use/Land Cover Maps

In this study, Landsat satellite images of two points in time including Landsat ETM+ (captured in November 2000) and Landsat 8 OLI (captured in September 2017) were used to identify the land use and land cover (LULC) change of the three coastal districts of Nghia Hung, Hai Hau and Giao Thuy of Nam Dinh province. There are seven LULC types, which were identified and used including agricultural land, residential area, mangrove forest, aquacultural land, water bodies, sandy beaches, and salty fields. LULC maps of year 2000 and 2017 are shown in Fig. 2.



(a) **(b)**

Fig. 2 Land use/Land cover map of the coastal districts in 2000 (a) and in 2017 (b) of Nam Dinh province

The change of areas of LULC types is large. According to the result of image interpretation, during the above mentioned time, the types of land use varied. The total natural area of the coastal districts of Nam Dinh province in 2017 increased by 2,006.6 hectares compared to 2000, due to the accretion process at three main estuaries, namely Ba Lat, Ninh Co and Day (Table 3). This result is consistent with studies on erosion and accretion of coastal area in Vietnam. This change is mainly due to tidal (sandy) beach. Mangrove forest land has increased significantly as a result of reforestation of the Vietnam Government under "National five million hectare reforestation program" of Vietnam in the year 2000. Agricultural land and water surface have been significantly reduced turning into aquaculture and residential land. The area of salt production also decreased considerably due to the lack of economic efficiency.

Table 3 Land cover change between year of 2000 and 2017

No.	Name of LULC types	Year 2000 (21/11/2000)		Year 2017 (23/05/2017)		Change (ha): Increase (+) Decrease (-)
		Area (ha)	Percentage (%)	Area (ha)	Percentage (%)	
1	Agricultural land	31,489.9	41.8	30,273.2	39.1	-1,216.7
2	Residential area	22,995.0	30.5	24,081.6	31.1	+1,086.6
3	Water bodies	12,010.2	15.9	9,452.9	12.2	-2,557.3
4	Aquacultural land	4,877.8	6.5	6,267.3	8.1	+1,389.5
5	Mangrove Forest	1,154.6	1.5	3,216.5	4.2	+2,061.9
6	Salt fields	1,610.9	2.1	846.7	1.1	-764.1
7	Sandy beaches	1,222.2	1.6	3,229.0	4.2	+2,006.8
	Total	75,360.6	100.0	77,367.2	100.0	+2,006.6

Accuracy assessment in identification of land cover and land cover change. Table 4 and Table 5 present results of the confusion matrix for the classification result of 2000 and 2017 (in percent); Table 6 and Table 7 show Producer's accuracy and User's accuracy for image classification of 2000 and 2017.

Table 4 Confusion matrix for the classification result in 2000

No.	Name of LULC types	Agricultural land	Residential land	Aquacultural land	Water bodies	Mangrove forest land	Salt fields	Sandy beaches	Commission Error
1	Agricultural land	95.0	5.1	0.0	0.0	0.0	0.5	0.6	6.1
2	Residential area	0.0	90.8	0.0	0.0	1.2	0.0	0	1.2
3	Water bodies	0.0	0.0	100.0	0.0	4.0	0.1	1.0	5.1
4	Aquacultural land	0.0	0.0	0.00	90.0	0.0	0.00	0	0
5	Mangrove forest	0.0	0.0	0.0	0.0	94.8	0.00	0	0
6	Salt fields	3.73	4.1	0.0	10.0	0.0	80.9	8.2	16.3
7	Sandy beaches	2.27	0.0	0.0	0.0	0.0	17.5	90.2	19.8
	Total	100,0	100,0	100,0	100,0	100,0	100,0	100,0	-
	Omission Error	5.0	9.2	0	10.0	5.2	18.1	9.8	Kappa = 0.91

Table 5 Confusion matrix for the classification result in 2017

No.	Class Name	Agricultural land	Residential land	Aquacultural land	Water bodies	Mangrove forest land	Salt fields	Sandy beaches	Commission Error
1	Agricultural land	80.0	14.3	0.0	0.0	27.3	0.0	0.0	23.1
2	Residential area	4.0	71.4	0.0	14.3	0.0	8.3	18.2	28.6
3	Aquacultural land	4.0	14.3	20.0	71.4	0.0	16.7	9.1	50.0
4	Water bodies	0.0	0.0	80.0	14.3	0.0	0.0	0.0	14.3
5	Mangrove forest	12.0	0.0	0.0	0.0	72.7	0.0	0.0	27.3
6	Salt fields	0.0	0.0	0.0	0.0	0.0	66.7	0.0	0.0
7	Sandy beaches	0.0	0.0	0.0	0.0	0.0	8.3	72.7	11.1
	Total	100	100	100	100.0	100	100	100	100
	Omission Error	20.0	28.6	20.0	28.6	27.3	33.3	27.3	Kappa = 0.69

Table 6Producer's accuracy and User's accuracy for image classification in 2000

No.	Class name	Reference total	Classified total	Correctly classified	PA (%)	UA (%)
1	Agricultural land	27	27	24	88.9	88.9
2	Residential area	16	22	14	87.5	63.6
3	Water bodies	6	5	5	83.3	100
4	Aquacultural land	11	14	11	100	78.6
5	Mangrove forest	8	8	6	75	75
6	Salt fields	11	7	7	63.6	100
7	Sandy beaches	14	10	10	71.4	100
	Total	93	93	77		

Table 7Producer's accuracy and User's accuracy for image classification in 2017

No.	Class name	Reference total	Classified total	Correctly Classified	PA (%)	UA (%)
1	Agricultural Land	26	25	20	80.0	76.9
2	Residential area	21	21	15	71.4	71.4
3	Water bodies	14	15	12	80.0	85.7
4	Aquacultural land	20	14	10	71.4	50.0
5	Mangrove forest	11	11	8	72.7	72.7
6	Salt fields	8	12	8	66.7	100.0
7	Sandy beaches	9	11	8	72.7	88.9
	Total	109	109	81		

The confusion matrices show the high confusion between land cover types. The biggest confusion occurs in Aquaculture (50%) and residential area (28.6%). The kappa index was used to evaluate the accuracy of image classification. Between the two classified images, the accuracy obtained for 2017 (kappa = 0.69) is lower than for 2000 (kappa = 0.91). This is because the type of land covers which make the most confusion have changed over time. In 2000, the aquacultural area was 4994 ha, but in 2017, the aquacultural area had increased to 6265 ha. On the contrary, the surface water area decreased from 12,010.2 ha in 2000 to 9452.9 ha in 2017.

4.2. Landscape metrics

For quantifying the landscape metrics, FRAGSTATS software program was used to calculate a variety of landscape metrics for classification. The result is presented from Table 8 to Table 10. At landscape level, FRAGSTATS computed several statistics that quantify diversity (Table 10). These metrics quantify landscape composition at the landscape level. They are not affected by the spatial configuration of patches. The most popular diversity index is Shannon's Diversity Index (SHDI). The value of this index represents the amount of information per patch. The absolute magnitude of Shannon's diversity index is not particularly meaningful; therefore, it is used as a relative index for comparing different landscapes or the same landscape at different times.

Table 8Landscape metrics of landscape class in 2000

No.	Type	CA (ha)	PLADJ (%)	NP (none)	PD (number /100 ha)	LPI (%)	LSI (none)	PAFRAC (none)	DIVISION (proportion)
1	Agricultural land	31,349.9	41.6	303	0.402	3.84	32.71	1.3557	17,155.5
2	Residential area	23,004.8	30.5	105	0.139	13.14	40.68	1.4298	9,227.7
3	Water bodies	11,992.1	15.9	25	0.033	15.48	13.96	1.4628	8,479.5
4	Aquacultural land	4,994.2	6.6	33	0.044	3.01	10.89	1.3737	3,112.9
5	Mangrove forest	1,163.3	1.5	8	0.011	0.58	7.43	N/A	555.8
6	Salt fields	1,625.9	2.2	11	0.015	0.48	6.82	1.3648	920.1
7	Sandy beaches	1,229.7	1.6	21	0.028	1.03	7.60	1.3256	672.2

Table 9 Landscape metrics of landscape class in 2017

No.	Type	CA (ha)	PLADJ (%)	NP (none)	PD (number /100 ha)	LPI (%)	LSI (none)	PAFRAC (none)	DIVISION (proportion)
1	Agricultural land	31,287.5	40.3	84	0.108	4.27	30.54	1.5869	16,486.8
2	Residential area	24,080.7	30.9	877	1.129	16.97	43.29	1.3324	10,304.3
3	Water bodies	8,111.7	10.4	30	0.039	3.21	16.70	1.4482	4,575.3
4	Aquacultural land	6,265.7	8.1	238	0.306	2.67	16.96	1.3012	3,693.5
5	Mangrove forest	3,216.2	4.1	33	0.043	1.51	9.10	1.3516	2,012.6
6	Salt fields	845.6	1.2	10	0.013	0.46	5.42	1.1252	464.1
7	Sandy beaches	3,880.9	5.0	79	0.102	1.88	13.25	1.3896	2,180.9

The value of SHDI in the year 2017 is bigger than in the year 2000. This suggests a bigger evenness in distribution of the landscape in 2017. SIDI is another popular diversity measure that is not based on information theory (Simpson 1949). Simpson's index is less sensitive to the presence of rare types and has an interpretation that is much more intuitive than Shannon's index. Specifically, the value of Simpson's index represents the probability that any two cells selected at random would be different patch types. Thus, the higher the value the greater the likelihood that any 2 randomly drawn cells would be different patch types. Because Simpson's index is a probability, it can be interpreted in both absolute and relative terms. However, in this case, SIDI can simply be used to infer the diversity of the landscape. Similarly to SHDI, the value of SIDI was higher in 2017 than in 2000, denoting a bigger evenness in the landscape distribution. FRAGSTATS also computed a Modified Simpson's Diversity Index (MSIDI) based on Pielou's (1975) modification of Simpson's diversity index; this index was used by Romme (1982). The modification eliminates the intuitive interpretation of Simpson's index as a probability, but transforms the index into one that belongs to the same general class of diversity indices to which Shannon's diversity index belongs (Pielou 1975). Thus, the modified Simpson's and Shannon's diversity indices are similar in many respects and have the same applicability. The results generated by FRAGSTATS for 2000 and 2017 shows the same trends as SIDI. MSIDI in 2017 is 1.2729 while MSIDI in 2000 is 1.2143.

Table 10 Landscape diversity metrics of the landscape in two periods of 2000 and 2017

Year	TA (ha)	TE (m)	SHDI (information)	MSIDI (none)	SHEI (none)
2000	75,359.8	2,863,830	1.4137	1.2143	0.7265
2017	77,688.4	3,141,420	1.499	1.2729	0.7704

At class level, the study computed the following metrics: CA, PLADJ, NP, PD, LPI, LSI, PAFRAC, DIVISION. The CA (class area) shows a stable trend in agricultural land. While the area of agricultural land in the year 2000 was 31349.9 ha, it was 31287.5 ha in 2017, amounting to a reduction of 126 ha in the course of 17 years. The strongest increase was observed in sandy beach, which increased by 2651.3 ha. Similar to the area of agricultural land, the number of patches in 2017 decreased compared to that of 2000, from 303 patches to 84 patches. In consequence, the patch density reduced from 0.40 in the year 2000 to 0.10 in 2017. On the contrary, residential area increased by 180 ha over the course of 17 years, from 23004.8 ha in 2000 to 24080.7 ha in 2017. The number of residential land patches increased much compared to that of 2000, from 105 patches to 877 patches. The Largest Patch Index (LPI) is also bigger than in the year 2000, in accordance with population growth. The PAFRAC metric shows that the shape of residential area patches became more complex than in the year of 2000. This is understandable because people expand their territory without planning, making the living area expand in many directions. Similar to the residential area, the area of aquacultural land increases from 4994 ha to 6265 ha. The number of aquaculture patches also increased from 33 patches to 238 patches. This matches the current situation in the study area, where people convert their land into fish and shrimp farms. The area of mangrove forest also increased within the period, from 1163.3 ha in 2000 to 3,216.2 ha in 2017. The number of patches increased from 8 to 33. This is a result of the “Five million hectare reforestation program" started in the year 2000. The salt land area shows a decreasing trend over time, reducing from 1,625.8 ha in 2000 to 845.6 ha in 2017. The size of salt patches also decreased, as shown in the LPI metric. In 2000, the largest patch is 0.48 ha, while in 2017, the largest patch is 0.46 ha. The complexity of patches decreased, as shown in the PAFRAC metric. In 2000, the PAFRAC value was 1.36, while it was 1.12 in 2017. Lastly, the coastal land area shows a big jump over time, from an area of 1,229.7 ha in 2000 to 3880.9 ha in 2017. The number of coastal land patches also increased, from 21 patches to 79 patches. The Landscape Patch Index drastically changed from the largest patch being 0.48 ha in 2000 to it being 1.87 ha in 2017. The complexity of patches also increased, as shown in the PAFRAC metric.

5. Conclusion

In this case study, Remote Sensing data and landscape metrics were used to detect LULC change between 2000 and 2017. The results show that the sandy beach (intertidal area), mangrove forest and residential areas increased, with intertidal and mangrove forest areas increase by an amount of more than 2,000 ha each year, during the past 17 years. Conversely, agricultural land decreased. The result shows that the LULC in the coastal area of Nam Dinh province changes rapidly over the time. Mean patch size decreased over time, while fragmentation increased.

In the study area, the Red river is important for controlling the water and mineral nutrient flows. Due to annual sediment flow, the increasing areas of intertidal and mangrove forest are extremely important for wild life as well as for the protection of dykes. The socio-economic development projects strongly impact the change of landscape ecology. Increasing fragmentation is harmful for species living in the area because their habitats and traversing areas are restricted.

Hence, Remote Sensing and landscape metrics are an important approach for landscape ecology research in order to obtain useful information about landscape function and structure over time. Using calculation of landscape metrics, effects of humans on the landscape can be detected at the same time. The results of landscape metrics in 2000 and 2017 (Table 8, Table 9) indicate that there are some huge differences on metric values among landscape types in each year and between those two times in one landscape type. The CA metric fluctuates significantly from around 1000 hectares to 31.000 hectares. That means landscape composition has decreasing rate in the landscape. The NP metric is also fluctuates sharply among landscape types from 8 to 303 in 2000 and from 10 to 877 in 2017. Its values show that the fragmentation is large in landscape types of agricultural, residential area, aquacultural land. Moreover, comparing the value of each landscape metric between two point of year 2000 and 2017, CA metric is changed sharply in types of Sandy beaches (2,651.20ha), mangrove forest (2,052.90 hectares), aquacultural land 1,271.50 hectares) and salt fields (780.30 hectares). On another hand, NP metric is also drastically changed in types of residential area (772 in difference), agricultural land (219 in difference) and aquacultural land (205 in difference). That means these landscape types have fragmentation is happened strongly.

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