RESEARCH OF SPATIAL AND TEMPORAL VARIATIONS OF WETLAND IN PEARL RIVER ESTUARY (1978 ~ 2005)

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ABSTRACT: During the period of 1978~2005, substance changes have taken place of coastal wetland in Pearl River Estuary as the result of interaction of human and natural factors. To investigate the spatial and temporal variations of coastal wetland in Pearl River estuary, Landsat-MSS images in 1978 and Landsat-TM images of 1995 & 2005 year were processed, and wetland database of the three periods was established based on these remote sensing images. The result showed that: (1) area of natural wetlands decreased while the area of construct wetland increased distinctively; (2) in the period of 1978~1995, coastal wetland area decreased by 3.3%, while it decreased by 18.3% in period of 1995~2005; (3) Among 6 administrative districts in the study area, the wetland dynamic degree can be sorted in a descending order as: Zhuhai, Shenzhen, Macao, Dongguan,Zhongshan and Guangzhou; (4) the centroids of wetland in Pearl River Estuary coastal zone moved to north by a linear distance of 0.6 km during 1978~2005, and move to south east during 1995~2005 by a linear distance of 6.1 km; (5) according to the changes of coastlines in Pear River Estuary, area of sea reclamation during 1978~2005 along coastline inland in Zhuhai, Macao, Zhongshan, Guangzhou Dongguan, Shenzhen are 12439.29，502.60，2946.45，5372.21，1815.96，6317.88 hectares respectively.

1. INTRODUCTION

Wetlands which are honoured as "kidney of the globe", "species gene pool" and “the cradle of humanity”(SUN,2000). They are the most productive ecosystems in the world compared to terrestrial ecosystems and marine ecosystems. They provide important ecosystem functions such as nursery habitats for fish and crustaceans, resting and feeding area for migratory birds, they also support biodiversity, filter containments, dissipate water energy, and offer intrinsic values such as aesthetics and education.(GOODWIN,2001) Coastal wetland is an important kind of wetland and natural landscape with abundant natural resources and unique environmental effect (AN,2007), but about 30% to 50% of the area of earth's major coastal environments has been degraded during past decades(VALIELA,2008). It become a common sense that coastal wetland is the most vulnerable resource which affected by the sea level rise (SLR), so it is of great importance to learn the changes of coastal wetland. Wetland is one of the most important natural resources of Pearl River delta. During the period of 1978~2005, substance changes have taken place in the coastal wetland of Pearl River Estuary as the result of natural and anthropogenic factors. Many researchers choose one part of Pearl River delta for research (LIU,2005, LI,2006, WANG,2007). However, few studies have focused on the spatial and temporal changes of coastal wetland in Pearl River Estuary. Based on GIS and RS, the spatial and temporal changes of coastal wetland in Pearl River Estuary in the past three decade are researched.

2. STUDY AREA

The study area, Pearl River Estuary coastal zone covers an inland area of 5 km buffers from the costal line, and extends to the -6m depth line in shallow sea, and the area is about 390,000 hectares. It is located at the middle south of Gongdong Province in China (Figure 1.). The bell-shaped Pearl River Estuary receives and carries most of the outflow from the Pearl River, eventually flow into the South China Sea. The climate here is summer and winter monsoon alternating, year-round high temperatures. Since economic liberalization was adopted in the late 1970s, the area has become one of the leading economic regions and a major manufacturing center of China. Including two Special Economic Zone: Zhuhai and Shenzhen; an Open Coastal City: Guangzhou.

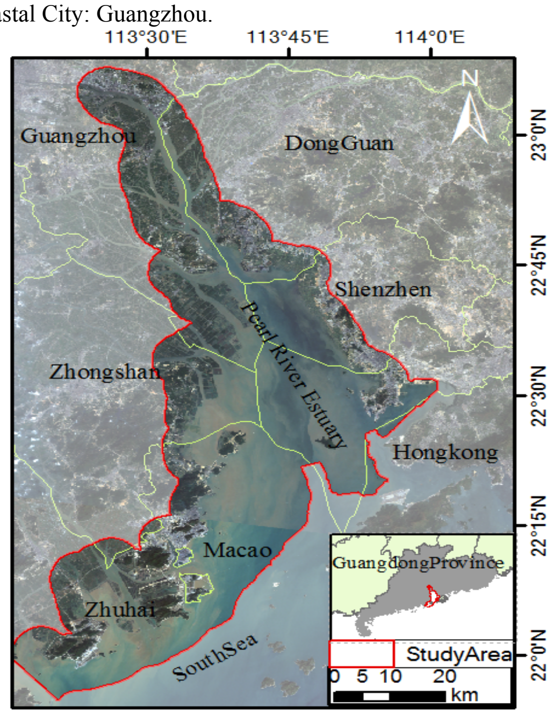


Figure 1 study area

3. DATA and METHODS

3.1 Data

In order to study the spatial and temporal changes of Pearl River Estuary in the past three decades, three periods data sources are collected, including Landsat MSS images in 1978; Landsat TM in 1995 and 2005(the remote sensing images were downloaded from the USGS website: http://glovis.usgs.gov). Each scene Landsat MSS image has 4 bands with 78m spatial resolution; and each scene Landsat TM images has 7 bands with 30m spatial resolution.

3.1.1 Data Processing

Remote sensing images processing, including pre-processing and false colour composite, and this was carried out by means of PCI Geomatica10.0. To deal with the unsystematically geometric errors, geometric rectification is needed, in this research all the remote sensing images were rectified to WGS-84 coordinate system, and the spatial rectify error is less than 1.5 pixels. Because of the uncertainty of the supervised or unsupervised classification, the wetland data of the year 1978, 1995 and 2005 were extracted by visual interpretation based on these geometric rectified remote sensing images. To ensure the interpretation accuracy, I carried on a field investigation with my research group in 2006 January, collected 135 sample sites , and record the position by GPS device, and interpretation symbol library was set up by the collected wetland type and position point according to landsat TM image of 2005. A field-prove work was carried out in 2008 January, the interpreted precision of 2005 was higher than 93%, and 1995 and 1978 was 90% and 88% respectively. The data processing packages mainly included ArcGIS9.0, SPSS 16.0 and PCI Geomatica10.0.

3.1.2 Wetland classification system:

According to the ecological classification principles and the classification of China and abroad (COWARDIN,1979, SADER,1995, SCOTT,1995, YANG,2002, SCHMIDT,2003), wetland in Pearl River Estuary is divided into natural wetland and constructed wetland according to the interfering degree of human activities. Natural wetland also divided into mud flat, mangrove, lake, river and shallow sea; and constructed wetland is divided into reservoir, aquaculture water, paddy field and pond.

3.2 Methods

In order to research the changes of wetland in the Pearl River Estuary, land use changes methods, land use transition matrix and land use dynamic degree model is applied.

3.2.1 Spatial and temporal dynamic of wetland:

To determine the change rate of coastal wetland in Pearl River Estuary change, the study period 1978~2005 is divided into two sub-periods and the wetland changes of the two sub-periods are compared. The period of 1978~1995 calls earlier stage, and the period of 1995~2005 calls later stage. In order to understand the change rate of each wetland type, wetland dynamic degree is calculated by the rate of land use change model as follows(SHENG-HE,2002):

$$S = (A_i - UA_i) / A_i (T_2 - T_1) \times 100\% \qquad (1)$$

Where S is the rate of the ith type wetland during the monitoring period T_1 to T_2;A_i is the area of the ith type wetland at the beginning of the monitoring period; and UA_i is the area of the ith type wetland that remains unchanged during the monitoring period. (A_i- UA_i) is the changed wetland area during the period, *i.e.* the total area of the ith type wetland converted into the other types of wetland or non-wetland

In order to understand the rate of regional wetland changes and their characteristics differences, the wetland dynamic degree was calculated by administrative districts in Pearl River Estuary. Regional difference in wetland change characteristic can be determined by using the land use dynamic degree model that could be mathematically expressed by the following relationship(LIU,2000):

$$S = \sum_{ij}^{n} (\Delta S_{i-j} / S_i) \times (1/t) \times 100\% \qquad (2)$$

Where S is the wetland dynamic degree over time t; S_i is the ith type wetland area at the beginning of the monitoring period, n is the number of the wetland types, and ΔS_{i-j} is the total area of the ith type wetland that is converted in to others (other wetland types or non-wetland).

3.2.2 Spatial changes of wetland

Spatial changes of wetland can be described by the centroid of land use resource distribution(JUNHONG,2008). The cenctrids of wetland distributions in 3 periods can be calculated as follows:

$$X_t = \sum_{i=1}^{n} (C_{ti} \times X_i) / \sum_{i=1}^{n} C_{ti} \qquad (3)$$

$$Y_t = \sum_{i=1}^{n} (C_{ti} \times Y_i) / \sum_{i=1}^{n} C_{ti} \qquad (4)$$

Where X_t and Y_t are the abscissa and ordinate centroid of wetland distribution in t period respectively. X_i and Y_i are the abscissa and ordinate of the centroid of wetland type i in the same period; C_{ti} denotes the area of each wetland patch; $\sum_{i=1}^{n} C_{ti}$ denotes the total wetland area in t period.

3.2.3 Coastline changes of Pearl River Estuary

In the past three decades, due to natural and man-made factors, especially the role of man-made factors, significant changes of coastlines in Pearl River Estuary have taken place. There area many successful studies to monitor coastline changes by using multi-temporal satellite image (HE,2006, ALESHEIKH,2007, SESLI,2009). In this study coastlines of 1978 and 2005 in Pear River Estuary were both extracted from satellite images by using PCI Geomatica10.0. In order to keep same spatial scale, Landsat-MSS images was sampled into 30-meter pixel size. Since boundaries of land and water are clear on band7 of MSS. And in the band TM5, water reflection rate is almost zero, so by take these advantages, coastline can be extracted. Water boundaries of 1978 and 2005 were extracted by unsupervised via ISODATA method, and then processed on ArcGIS9.0.

4. RESULT

4.1 Wetland distribution and dynamic degree

The spatial-temporal changes of wetland in the three periods are showing in Figure.2 and table1. It can be concluded that the wetland coverage rate in 1978, 1995 and 2005 is 81.6%, 78.9% and 64.5% respectively. All the spatial data and is processed on the platform of ArcGIS9.0, and the area data is calculated by SPSS16.0. As table1 shows, among the earlier and later stages, the area of mud flat, mangrove, shallow sea and paddy field wetland types continue to decrease, while the area wetland types of pond and aquaculture water continued to increase. Total in all, the wetland lost during the later stages was five times more than that lost during the earlier stage. Wetland changes and conversation during the two stages are difference from each other, which can be reflected by table1, table2 and table 3.

According to the spatial and temporal changes of coastal wetland in Pearl River Estuary, wetland dynamic degree of each wetland type in the earlier and later stages can be calculated by equation (1), dynamic degree of each wetland type in the earlier and later stages as figure 3 shows.

The conversion of natural wetland and constructed wetland reflects that it undergone a large-scale movement of enclosing tideland for cultivation in the earlier stage, but it slowed down in the later stage; And the dynamic degree of all wetland types (except for shallow sea and reservoir) in the later stage is higher than the earlier stage.

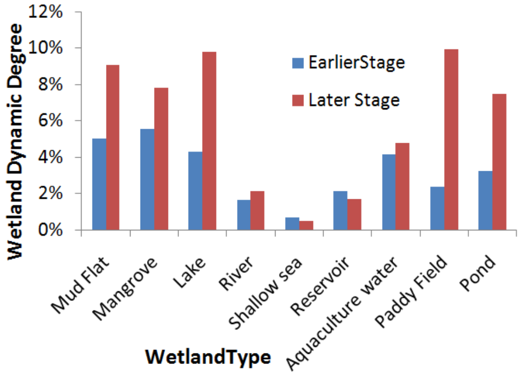


Figure 3. Dynamic degree of each wetland types in both earlier and later stages.

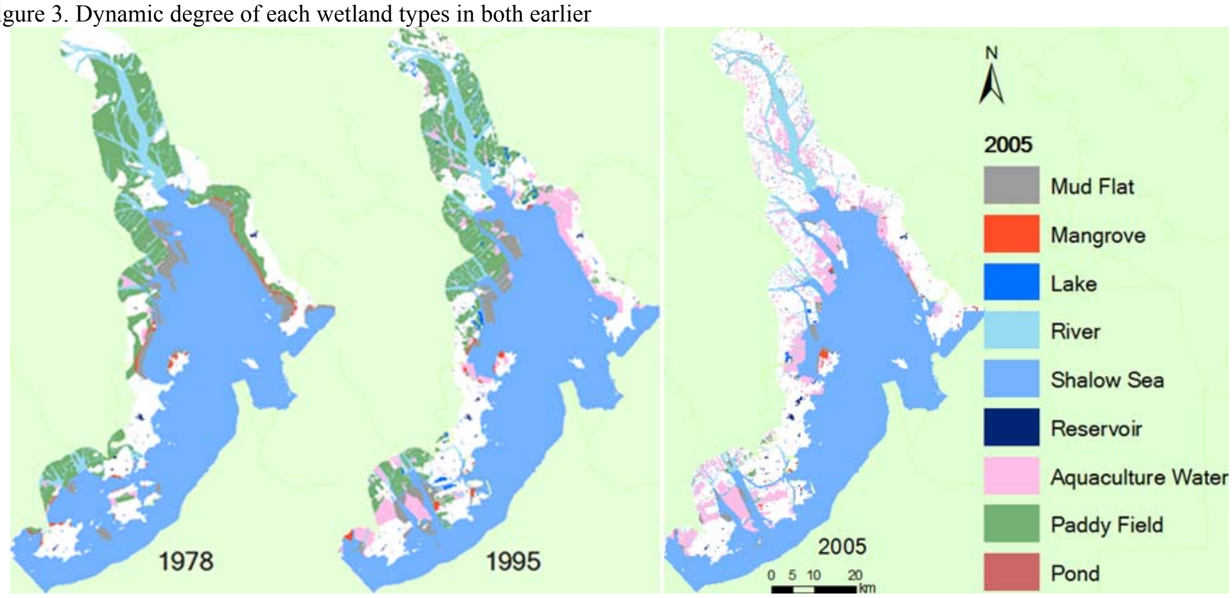


Figure2. Distribution of wetland in the periods of 1978, 1995 and 2005

Table1. composition of wetland in different periods and wetland changes in the two stages. (Units: ha)

	1978		1995		2005		Wetland change	
	Area (ha)	Percent (%)	Area (ha)	Percent (%)	Area (ha)	Percent (%)	1978~1995 (ha)	1995~2005 (ha)
Mud Flat	15300.19	4.79	11961.30	3.87	4851.57	1.92	-3338.89	-7109.73
Mangrove	2675.19	0.84	1120.03	0.36	580.34	0.23	-1555.16	-539.68
Lake	201.54	0.06	2563.96	0.83	740.82	0.29	2362.41	-1823.14
River	22851.44	7.15	23110.12	7.48	22391.22	8.87	258.68	-718.89
Shallow Sea	210860.72	65.99	192339.57	62.26	184808.25	73.22	-18521.14	-7531.32
Reservoir	394.62	0.12	410.27	0.13	663.20	0.26	15.64	252.94
Aquaculture Water	3954.71	1.24	23686.43	7.67	35930.89	14.24	19731.71	12244.46
Paddy Field	63181.82	19.77	53069.66	17.18	809.16	0.32	-10112.16	-52260.50
Pond	92.72	0.03	684.67	0.22	1617.04	0.64	591.95	932.37
Total	319512.95	100.00	308946.01	100.00	252392.50	100.00	-10566.95	-56553.51

Table2. The transition matrix of wetland types (units: ha): 1978~1995 in the study area. Value in bold: wetland types without change during 1978~1995.

		1995										
	Wetland type	Mud Flat	Mangrove	Lake	River	Shallow Sea	Reservoir	Aquaculture water	Paddy Field	Pond	Total	Non-wetland
1978	Mud Flat	**2224.95**	264.15	189.43	524.65	5520.95	0	2735.43	3008.70	35.01	14503.28	796.91
	Mangrove	52.20	**155.83**	53.06	30.98	92.07	0	1512.99	152.48	9.67	2059.27	615.92
	Lake	0	0	**53.68**	0	0	1.90	0	0.12	0	55.70	145.84
	River	205.35	0	82.05	**16434.70**	36.73	0	821.19	3590.26	16.21	21186.50	1664.94
	Shallow sea	9294.74	651.48	482.29	844.01	**186086.36**	0	6752.22	1573.10	255.10	205939.29	4921.43

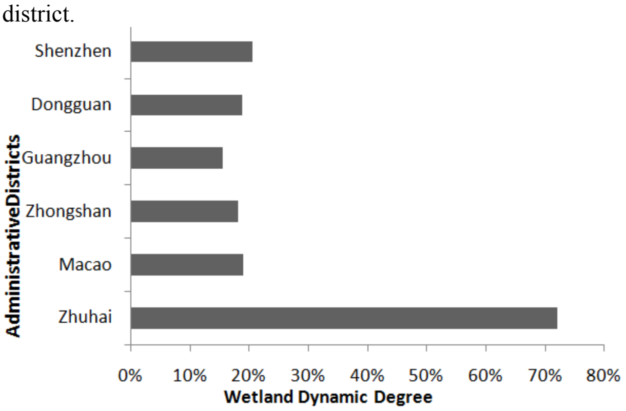
Reservoir	0	0	12.54	0	0	**252.72**	0	0	0	265.26	129.36
Aquaculture water	2.54	0.14	33.46	327.84	9.48	0	**1162.10**	1848.72	4.24	3388.51	566.20
Paddy Field	41.45	13.17	798.40	4218.32	40.52	0	9065.04	**37487.22**	126.1	51790.22	11391.60
Pond	0	0	8.02	0	0.17	0	0	0	**41.24**	49.43	43.29
Total	11821.23	1084.78	1712.9	22380.5	191786.27	254.62	22048.98	47660.59	487.6	299237.5	20275.49

Table 3 the transition matrix of wetland types (units: ha): 1995~2005 in the study area. Value in bold: wetland types without change from 1995~2005.

		2005										
	Wetland type	Mud Flat	Mangrove	Lake	River	Shallow Sea	Reservoir	Aquaculture water	Paddy Field	Pond	Total	Non-wetland
1995	Mud Flat	**1096.43**	90.06	174.47	564.53	1181.27	0	5290.14	37.92	46.24	8481.07	3480.23
	Mangrove	85.98	**243.63**	3.84	31.17	47.78	0	593.92	0	15.92	1022.26	97.77
	Lake	13.35	0	**47.71**	62.55	3.96	31.00	988.02	68.87	36.74	1252.21	1311.75
	River	539.29	1.46	0.25	**18214.13**	72.38	0	1060.54	5.94	40.90	19934.90	3175.22
	Shallow sea	1931.81	163.10	28.09	550.12	**182411.77**	0	3702.48	0.36	283.18	189070.90	3268.67
	Reservoir	0	0	6.08	0	0	**340.31**	0	0	0	346.39	63.88
	Aquaculture water	437.78	42.05	36.03	722.27	413.96	0	**12306.40**	0	151.03	14109.52	9576.91
	Paddy Field	345.95	0.01	10.64	1599.95	129.29	0.12	10015.54	**375.76**	317.29	12794.55	40275.11
	Pond	70.20	7.86	12.32	4.12	6.13	0.41	120.16	0	**171.93**	393.14	291.53
	Total	4520.78	548.17	319.44	21748.84	184266.54	371.85	34077.21	488.86	1063.25	247404.93	61541.08

4.2 Regional difference

Coastal wetlands in Pearl River Estuary are divided into six regions: Zhuhai, Macao, Zhongshan, Guangzhou, Dongguan and Shenzhen. The dynamic degree during the period of 1978~2005 in each administrative district as figure 4 shows. It is obviously that the dynamic degree of coastal wetland in the district of Zhuhai is highest, while it is lowest in Guangzhou district.



Figture4. Dynamic degree of coastal wetland in each administrative district in the period of 1978~2005.

4.3 Spatial changes of wetland

Spatial and temporal changes of coastal wetland in the two stages are processed by ArcGIS9.0, the results as figure5 shows. Compared by the spatial changes of wetland in the two stages, there was more wetland changed into other wetland types in the early stage than that in the later stage while there was more wetland changed into non-wetland in the later stage than that in the early stage. The wetland changes mainly along the coastline in the early stage while changes became widely distribute inland in the late stage.

The centroids of each wetland patch were extracted from wetland vector data based on ArcGIS9.0, and the centroids coordinates of each periods were calculated by equation (3) and (4). The centroids of wetland in the three different periods as figure6 show. The cenrtoids of coastal wetland moved 0.005° to the north direction and 0.001° to the east direction from 1978~1995, by a linear distance of 0.6km, which was related to the large-scale movement of enclosing tideland for cultivation. However, during 1995~2005, the wetland centroids moved 0.055° to the south direction and 0.01° to the east direction, by a linear distance of 6.1km, which was mainly because of inland wetland changed into non-wetland.

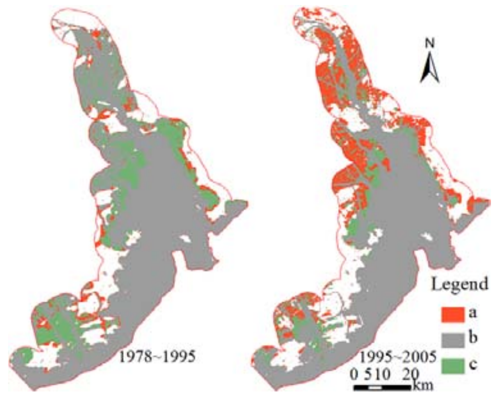


Figure5. Spatial changes of wetland in the two stages. a: wetland that changed into non-wetland; b: wetland that unchanged; c: wetland that changes into other types of wetland.

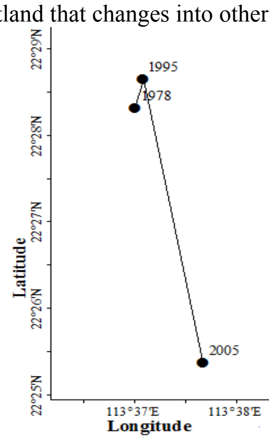


Figure6. Spatial changes of coastal wetland in Pearl River Estuary.

4.4 Coastline changes

The coastlines of Pearl River Estuary in 1978 and 2005 as figure7 show. The sea reclamation can be processed by ArcGIS9.0, and the area of sea reclamation (1978~2005) along the inland coastline in Zhuhai, Macao, Zhongshan, Guangzhou, Dongguan and Shenzhen are 12439.29，502.60，2946.45，5372.21，1815.96，6317.88 hectares respectively.

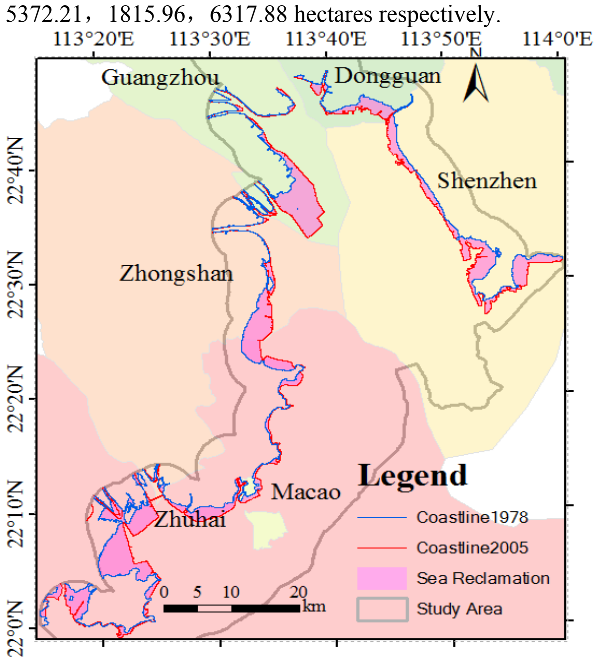


Figure7. Changes of coastlines inland and the distribution of sea reclamation of 1978~2005 in Pearl River Estuary.

5. DISCUTION

After the analysis of coastal wetland spatial and temporal change in the nearly three decades, and the comparison between early and late stages, we can see that coastal wetlands in Pearl River Estuary have been significantly changed. This change is mainly caused by wetlands changed into non-wetland (such as construction site or factories). These changes reflect an accelerating depletion of wetland. Coastal wetland depletion disturbed the ecological functions of wetland, which will cause a series of environmental problems, such as flood, coastal erosion, loss of habitat for aquatic species and so on. Wetland protection measures and long-term planning for the study area is an urgent task.

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