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DYNAMIC CHANGE OF LAND USE STRUCTURE IN HAIKOU BY REMOTE SENSING AND GIS *

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ABSTRACT: By interpretating TM imagery in 1986,1996 and 2000, the land use structure change in Haikou city was gotten.The cultivated land? water? unused land and forest was converted into the urban? rural settlement and construction land.The land use source and destination was analyzed by conversion matrix.The natural landscape such as forest and water was disturbed by the human activities and the fractal dimension decreased.The fractal dimension of the cultivated land decreased with the acreage decreasing.The urban land concentrated with the extension and the decrease of the patches.The rural settlement and construction dispersed and its complexity increased.The general trend in Haikou city was the deepening and the urban? rural setttlement land encroached the natural land.

Urbanization is perhaps one of the most important human activities that creats enormous impacts on the environment at the local, regional and global scales(Turner et al.,1990). The urbanization process is the urban sprawl and the conversion of the rural area into cities. In China owing to the limit of the registered permanent residence and the employment opportunities, the immigration from the rural residence to the cities is fewer than that of the developed countries. With the building of the province and the implementation of the favorable policies in 1988, a great amount of capital from abroad and other provinces was invested in Haikou. The real estates development stimulated the urban sprawl as the capital and political?economic?cultural and transportation center of Hainan province. The paper studied the land use structure change during the rapid urbanization process.

1 STUDY AREA

Haikou is located in latitude 19°57'04?~ 20°05'11? north and longitude 100°10'18?~ 110°23'05? east. It is in the north of Hainan island and border to the Qiongzhou strait. The climate is tropical monsoon with the annual precipitation of 1639 mm and average temperature 23.8°C. The main morphology of the terrain is step and high in south, low in north(HSBC,1998). As the capital and the political? economic? cultural and transportation center of Hainan province, the building-up area sprawled up with the rapid economic development after the implementation of the reformation and open policy in 1979. Its GNP(Gross national product) was $4.8 \cong 10^9$ Yuan in 1986 and $4.39 \cong 10^{10}$ Yuan in 1996 and the growth rate was 20% per year. During this period the population increased from $3 \cong 10^5$ to $5.28 \cong 10^5$ whose growth rate was 4.8 % per year. The rural population increased from $8.22 \cong 10^4$ to $8.96 \cong 10^4$ and the growth rate was 0.72% per year far lower than 5.99%, that of the urban population. At the same time the urbanization level increased from 72.59% to 83.03%(HSBC,1996,1998) .Therefore the rapid extension of the built-up area induced the land use structure change.

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2 STUDY METHOD

2.1 Data Source

The spatial resolution of TM imagery was 30≅30 m and three periods in 1986-11-1? 1996-10-1 and 2000-4-30 were adopted and the weather was cloud-free. The imagery of 1996 was geo-rectified based on 1:100,000 DEM and interpretated using the software MGE. The land use change map was gotten by interpreting TM of 1986 and 2000 grounded on the vector map of 1996. If the land use was not changed, the label was same;if changed, the label was altered. For example, it was labeled as 10052 if the cultivated land was converted into city. ARC/INFO was applied to process the land use map. The land use type was divided into cultivated? forest? grass? water? urban? rural? construction and unused according to the national standard.

2.2 Study Method

In order to study the land use structure change in the urban area, the land use conversion matrix was used to analyze the source and destination of the land. A series of the indicators were chosen.

(1) Basic statistic indicators A_i was the total area of the land type i; P_i was the percentage of the land type i; n was the number of the patches.

(2) Fragmentation index Pa was the mean area of the land type i. The fragmentation was the fragmented degree of the landscape. The bigger Pa was , the more fragmented the land type i was. The equation was as follows:

$$Pa = \frac{A_i}{n} \tag{1}$$

(3) Fractal Dimension The fractal geometry was applied widely in the landscape structure analysis(P. Peralta, Mather,2000). The fractal dimension D described the fractal relationship between the perimeter and the area of the landscape i.e. the complexity of the landscape. If the boundary of the landscape was rough, the fractal dimension would be near 2;if smooth, it would be 1. Therefore it was between 1 and 2. The fractal dimension of all landscape was calculated by the regression analysis. The bigger the fractal dimension was, the more complex the patch was; the smaller, the less complex the patch was. It appeared in the ecological studies and was defined as follows:

$$P=A^{0.5D} \tag{2}$$

Where D was the fractal dimension. P was the perimeter of the patches and A was the area of the patches of land i in the study area.

Turned into the log as follows:

$$ln(P) = ln(c) + 0.5\ D\ ln(A) + e \tag{3}$$

(4) Diversity index The diversity was the abundance and the complexity of the land components(Chen Liding,1996,2001,Sui Daniel Z,2001). The diversity was expressed by the Shnnon equation as follows:

$$H = -\sum_{i=1}^{n} P_i * log\ (P_i) \tag{4}$$

Where H was the landscape diversity index; P_i is the percentage of the landscape i; n is the number of the land type. The higher H was, the diversity of the landscape was.

3 RESULT AND ANALYSIS

3.1 The land use change

The conclusion could be drawn that the land use change in Haikou city was rapid from Table 1. From 1986 to 1996

the cultivated land? water and unused land decreased while the urban? rural settlement and the construction site increased. From 1996 to 2000 the cultivated and construction land increased while the forest decreased. The unused land was encroached completely. During the period of 1986~2000 the cultivated land decreased by 37.87% and annual decrease rate was 3.34%. The forest lessened by 8%. The water decreased by 84% and annual decrease rate was 12.4%. The built-up area increased by 211% and the growth rate was 8.43% per year. The rural area increased by 94.76% and the growth rate was 4.87% per year. The construction increased by 51.95% and the growth rate was 3% per year.

Table 1 The land use structure change in Haikou in 1986, 1996, 2000 /hm^2, %

Land Type	1986		1996		2000		1986~1996	1996~2000	1986~2000
	A_i	P_i	A_i	P_i	A_i	P_i	A_i	A_i	A_i
Cultivated	8178.86	36.07	4572.62	20.08	5081.91	22.32	-3606.24	509.29	-3096.95
Forest	6474.92	28.56	6493.24	28.51	5955.12	26.15	18.32	-538.12	-519.80
Grass	377.41	1.66	377.41	1.66	377.41	1.66			
Water	2479.07	10.93	418.33	1.84	389.59	1.71	-2060.74	-28.74	-2089.48
Urban	2805.21	12.37	8719.26	38.29	8719.26	38.29	5914.05		5914.05
Rural	253.31	1.12	493.34	2.17	493.34	2.17	240.03		240.03
Construction	1155.08	5.09	1535.11	6.74	1755.14	7.71	380.03	220.03	600.06
Unused	950.92	4.19	162.46	0.71			-788.46	-162.46	-950.92
Total	22674.77		22771.76		22771.76		96.99		96.99

3.2 The Land Use Conversion Matrix

The conversion matrix was gotten to study the land use source and destination. The data in column was the land of *i* year and the line was that in *i*+1 year in Table 2. From 1986 to 1996 the cultivated land was converted mainly into the urban and construction land. The unused land and forest were converted into the construction and rural settlement and cultivated land. Some of the foreshore near the sea was filled and turned into the urban land. The construction was mainly turned into the urban land. The unused land was turned into the forest and cultivated land. During the past 15 years the urban land was derived from the cultivated land and the foreshore near the sea; the rural settlements were derived from the forest and construction land came from the forest and the cultivated land.

Table 2 The land-use conversion matrix from 1986~2000 in Haikou /hm^2

Year	Land type	Cultivated	Forest	Urban	Rural	Construction	Unused
1986~1996	Cultivated			3692.08	9.85	194.73	139.45
	Forest	201.91		30.03	218.62	244.8	
	Water		5.67	2055.07			
	Urban		19.62				
	Contruction			59.5			
	Unused	227.96	688.39		11.56		
	Sea			96.99			
1996~2000	Forest	509.29				220.03	
	Water		28.74				
	Unused		162.46				

3.3 The Landscape Characteristics of the Land Use Change

In table 3 the total area of the forest decreased and the number of the patches increased, so the mean area of the forest decreased. The number and mean area of the grass patches kept stable. The total area of water decreased and the number of the patches increased, so the mean area of the patches decreased.

The urban land concentrated with the conglomeration of urban patches with the decrease of the number. The rural settlement area doubled and the mean area of the patches increased. The total area of the construction increased and the number increased, so the mean area of the construction increased. Therefore the urban? rural settlment and construction land extended and became bigger. The forest? cultivated land and water were turned into the urban? construction land and rural settlement.

That *D* of forest decreased reflected the decrease of the forest complexity. During the past years a great amount of the forest land was transited into the cultivated? urban? rural and construction land. At the same time some forest land was built up by the unused land and the man-made forest boundary was more smooth. Therefor the complexity decreased.

D of the cultivated land decreased because some cultivated land was turned into urban and construction land.A great amount of the forest was transited into the cultivated land and the complexity decreased. The total area of the water decreased and its complexity decreased. The fractal dimension of the urban land decreased with the agglometration the patches. But that of the rural settlement and the construction land increased because their boundaries were rougher.

The diversity index of the landscape was calculated by equation (4).During the period of 1986~1996, H decreased from 0.705 to 0.657 because the unused land was converted into other land type.During the period of 1996~2000, H increased to 0.662 because the extension of the urban land.

Table 3 The landscape characteristics of the land use change in Haikou city

Year	1986				2000			
Land type	A_i	n	Pa	D	A_i	n	Pa	D
Cultivated	8178.86	30	272.63	1.302	5081.91	33	154.00	1.298
Forest	6474.92	43	150.58	1.328	5955.12	49	121.53	1.252
Grass	377.41	13	29.03	1.394	377.41	13	29.03	1.386
Water	2479.07	17	145.83	1.326	389.59	18	21.64	1.258
Urban	2805.21	19	147.64	1.296	8719.26	6	1453.21	1.212
Rural	253.31	19	13.33	1.273	493.34	23	21.45	1.285
Construction	1155.08	19	60.79	1.326	1755.14	20	87.76	1.390
Unused	950.92	5	190.18	1.258				

4 THE DRIVING FORCES OF LAND USE CHANGE

The spatial and temporal change of the land use was dependent of the economic? technological? social and the political factors and appeared as the landscape change.

Extension of the urban land was the main driving forces of the land use change. With the building-up of Hainan province and the implementation of more favorable policies in 1988, the real estates high-rised and a great amount of the administration units were built. The investment was up-and-down. The annual growth rate of the real estate in 1991~1998 was 156.8%? 168%? 49.7%? -72.8%? 126.2%? -59.6%? -51.6% and 67.9%. The annual growth rate of the construction area of the commercial real estates was 39.6%? 87.8%? 20.7%? 12%? -18.9%? -26.5%? -13.2%? -8.6%. The weight of the real estate investment even took up 50% in 1992[2]. The urban land increased by 192% during the period of 1986~2000 and the annual growth rate was 7.95%. The urban growth took up 84.7% of the total land use increment and the rapid urban expansion was the main factors.

The increment of the construction and rural settlement was the second factor. The increment of the construction took up 9.7% of the total increment owing to the construction of the international airport. The rural settlement area doubled although the rural population increased slowly and the average residential area increased from 30 m^2 to 55 m^2 per capita. The increasing rural land derived mainly from the forest land and threated the ecological environment.

The land use had the deepening trend. The forest and cultivated land was turned into the construction and urban land. At the same time the unused land was turned into the forest. The forest was converted into the cultivated land. With the rapid urbanization and the immigrants from the outside, the urban land would increase and a great amount of the forest and cultivated land was converted into the urban land. The bare land was exhausted at present. The intensive land use should be encouraged to improve the economic benefit because the blindness of the real estate development had used up a great amount of the cultivated land.

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