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ANALYSIS OF LAND USE CHANGE CHARACTERISTICS BASED ON REMOTE SENSING AND GIS IN THE JIUXIANG RIVER WATERSHED

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Abstract- Based on remote sensing and GIS technology, the remote sensing images from 2003 to 2009 were used to the basic data sources, to analyze the characteristics of land-use change in Jiuxiang River watershed. Results showed that watershed land use structure were changed greatly from 2003 to 2009; the proportion of arable land decreased from 34.86% to 19.52%, whereas other types of land use increased. The area of construction land increased most rapidly, from 17.80% to 25.80%.Spatial differentiations of land use changes were very obvious in Jiuxiang River watershed. The arable land was mainly converted to forestland and grassland in upstream region, and was mainly converted to construction land and forestland in midstream region. However, in downstream region, this type of land use was mainly converted to construction land. High farmland conversion

rate in current period was contributed to rapid urbanization in Jiuxiang River watershed. Therefore, some measures must be initiated to achieve land resources sustainable use.

Index terms: Land use characteristic, Jiuxiang River watershed, remote sensing, Geographic Information System (GIS).

I. INTRODUCTION

Land-use activities—whether converting natural landscapes for human use or changing management practices on human-dominated lands—have transformed a large proportion of the planet's land surface[1]. Land use change is the result of the interaction of the natural environment and human society, and it is also an important manifestation of the ecological environment changes of the earth's surface [2,3]. Land use change not only has an important impact on regional biodiversity, actual and potential primary productivity, soil quality, river runoff and sedimentation rate, but also is one of the main driving forces of global and regional climate change [4-7]. In the last 10 years, much more attention has been paid to urban land use/land cover change because ecosystems in urban areas are strongly affected by human activities and have close relations with the life of almost half of the world's population [8-10]. Jiuxiang River watershed is located in eastern Nanjing City. Xianlin area in the northern watershed of Jiuxiang River is one of three New Urban Areas in Nanjing, and it is also new economic development space for Nanjing. After a few years of development, the level of urban modernization and urbanization was improved significantly. Xianlin area also gradually developed into a first-class, open-type, ecotype University Town; meanwhile, watershed land use has also been changed significantly. Compared to the region, the watershed is relatively independent natural complex of the earth's surface, and it is also a relatively complete ecological processes unit. Considering the watershed as comprehensive research and management unit is the best way to coordinate resource development and environmental protection. Therefore, in this paper, taking the Jiuxiang River watershed as the study area, the spatial and temporal characteristics of land-use variations were analyzed using multi-temporal remote sensing data and GIS technology, which could provide a basic information for the rational use of land resources in Jiuxiang River watershed.

Ⅱ. STUDY AREA

The Jiuxiang River watershed lies east of the Nanjing city(118°52′—119°1′E , 32°1′—32°10′N), with a total area of 106km^2.Jiuxiang River watershed lies generally on very flat and low-lying land, with the exception of some hills in its southern regions. The altitude of this area is about 45m, decreasing from south to north. The watershed experiences a northern subtropical monsoon climate, with an annual rainfall of 1106.5 mm and an annual average temperature of 15.3◦C. With the rapid urbanization process, the watershed has consequently experienced a tremendous transformation in land use from a rural to urban area, while the urban fringe has constantly advanced outward into the surrounding agricultural land.

Ⅲ. MATERIALS AND METHODS

a. Data preparation

Tow cloud-free Quick Bird images were collected and used to evaluate land use/cover change in Jiuxiang River watershed between 2003 and 2009. Layer stacking and mosaic processing were carried out on the data using Erdas Imagine8.7 software, to obtain multi-band composite images. Rectified topographic1:50,000-scale map of Nanjing city was used as a reference to perform geometric correction on the images, using Erdas Imagine 8.7 and ArcGIS9.3 software. Approximately, 40 ground control points (GCPs) were selected to register the images to the Universal Transverse Mercator coordinate system using a global positioning system. GCPs were dispersed throughout the images, to make sure the RMS error less than 0.5pixels. Finally, by means of the GIS watershed boundaries layer, the territory of watershed was extracted from the images using the ‘Extract by Mask’ function in the “Spatial Analyst Tools” module of ArcGIS9.3software. A land cover classification system was designed in which multi-source land cover data were reclassified into water, arable land, grass land , forest land, construction land, unused land. A total of 200 stratified random samples were selected to check the accuracy of each classified map. Accuracy assessment of the LULC maps was then performed using aerial photographs and field data with the help of a GPS. The resulting overall classification accuracy was 0.86 and 0.88(Kappa values) for 2003and 2009 images, respectively. This accuracy level meets the standards recommended by Lucas et al [11]. Kappa Index was calculated as:

$$K = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+}x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+}\, x_{+i})} \tag{1}$$

where N is the number of ground control points; r is the number of land use types; x_{ii} is the total number of verification points of i land use type validation correctly; x_{i+} is the actual total number of verification points of i land use type, x_{+i} is the total number of verification points divided into type I; K is *Kappa* index.

b. Land use assessment

Co-registered digital maps were overlaid to generate change maps and transition matrices, and to calculate rates of changes. Two sets of data have been produced a conventional statistical report of areas and its corresponding rate of change ,and the transition matrix, or change matrix, which reports the class-to-class changes observed and its mapping[12]. Once the areas of land use/cover types were obtained for each period, the rate of change, H, was calculated using the following equation:

$$H = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \tag{2}$$

where U_a is the area covered by a given land use/cover at time 1; U_b is the area at time 2 and T is the number of years for the period of analysis; U_b- U_a is the amount of change. The transition matrices were derived by means of the Markova chain property (Eq. (3)) to give the annual transition rates in order to project the trends of change on an annual basis [13].

$$P^t = HV^tH^{-1} \tag{3}$$

where P is the original transition matrix; H and V are its eigenvector and eigenvalue matrices, and t is a fraction or a multiple of its time span.

VI. RESUITS

a. Land use structure and its changes

The total area of each land use category and percentage of each class of the study region area between 2003 and 2009 were calculated and presented in Table1. Forestland, arable land and construction land were the major land use types in the watershed, and the total area of three kinds of types accounted for 90.92 percent and 84.43 percent of watershed area, respectively. From 2003 to 2009, watershed land use pattern changed dramatically. One of the most marked changes were the rapid decrease in arable land, from 34.86 percent of the study area in 2003, to 19.52 percent in 2009.This was matched by a dramatic increase in construction land, which occupied 17.80 percent of the study area in 2003, increased to 25.80 percent in 2009.Other important changes were in unused land, which grew from 3.45 percent in 2003 to 7.76 percent in 2009.Unused land, construction and grassland between 2003 and 2009 have increased at an average rate of 20.77, 19.92 and 19.80 percent, respectively. While farmland decreased by 1625.96 hectares at an average rate of 7.33 percent.

Table1. Land use structure and its changes in Jiuxiang River watershed from 2003 to 2009 (hectare)

Land use types	2003		2009		2009-2003	
	Area	%	Area	%	Area	%
Water body(WAT)	484.50	4.57	562.69	5.31	78.19	2.69
Arable land(ARL)	3695.53	34.86	2069.57	19.52	-1625.96	-7.33
Forest land(FOL)	4054.93	38.25	4144.53	39.10	89.59	0.37
Grass land(GRL)	129.74	1.22	283.84	2.68	154.10	19.80
Construction land(COL)	1887.26	17.80	2735.10	25.80	847.83	19.92
Unused land(UNL)	366.05	3.45	822.28	7.76	456.23	20.77

b. Land use transition characteristic

Digital maps were overlaid in order to generate change map describing the change which occurred during the 2003–2009 periods. The change matrix was done by grouping classes, aggregating polygons and summing areas (Table 2). Tables 2 showed the change matrix for 2003–2009 expressed in the area.

According to the interchange of gains and losses among land use/cover classes, a large area of arable land was converted to man-made covers (principally construction land and unused land). More than 620 hectares, 350 hectares, 270 hectares,160 hectares of arable land was converted into construction land, unused land, forest land and water body, respectively.

Table2. Transition matrix expressed in hectare for the 2003-2009 periods

Year	types	2009						
		WAT	ARL	FOL	GRL	COL	UNL	Total
2003	WAT	332.38	28.42	12.26	18.86	47.33	30.51	484.50
	ARL	169.76	1998.05	275.30	128.30	622.01	356.93	3695.53
	FOL	19.07	22.20	3786.77	7.66	106.62	97.45	4054.93
	GRL	0.62	0.69	8.02	67.59	30.83	18.80	129.74
	COL	28.08	16.54	35.79	43.20	1365.06	87.41	1629.17
	UNL	5.22	2.47	20.78	15.32	84.30	225.26	366.05
	Total	562.69	2069.57	4144.53	283.84	2270.04	822.28	10600.00

Conversely, a small amount of man-made areas were reconverted to arable land covers, therefore, arable land exhibited a significant decline with respective rates of decrease of 15.34 percent over the same period. However, construction land areas have increased by approximately 2,270 hectares at an average rate of 141 hectares per year.

c. Spatial differences of land use change

In order to reveal the spatial differences in watershed land-use change, the watershed was divided into three parts: the upper, middle and lower reaches, based on land use / land cover status and hydrological conditions. The region south of the S122 Provincial Highway was upstream, between the S122 Provincial Highway and Xianlin Avenue midstream, and north of Xianlin Avenue downstream. On this basis, the space differences in the upstream, midstream and downstream watershed were analyzed.

(1) Land use structure

Figure1 showed the watershed land use structure and its changes from 2003 to 2009. It could be seen that inter-regional differences were significant in dominant land use type.

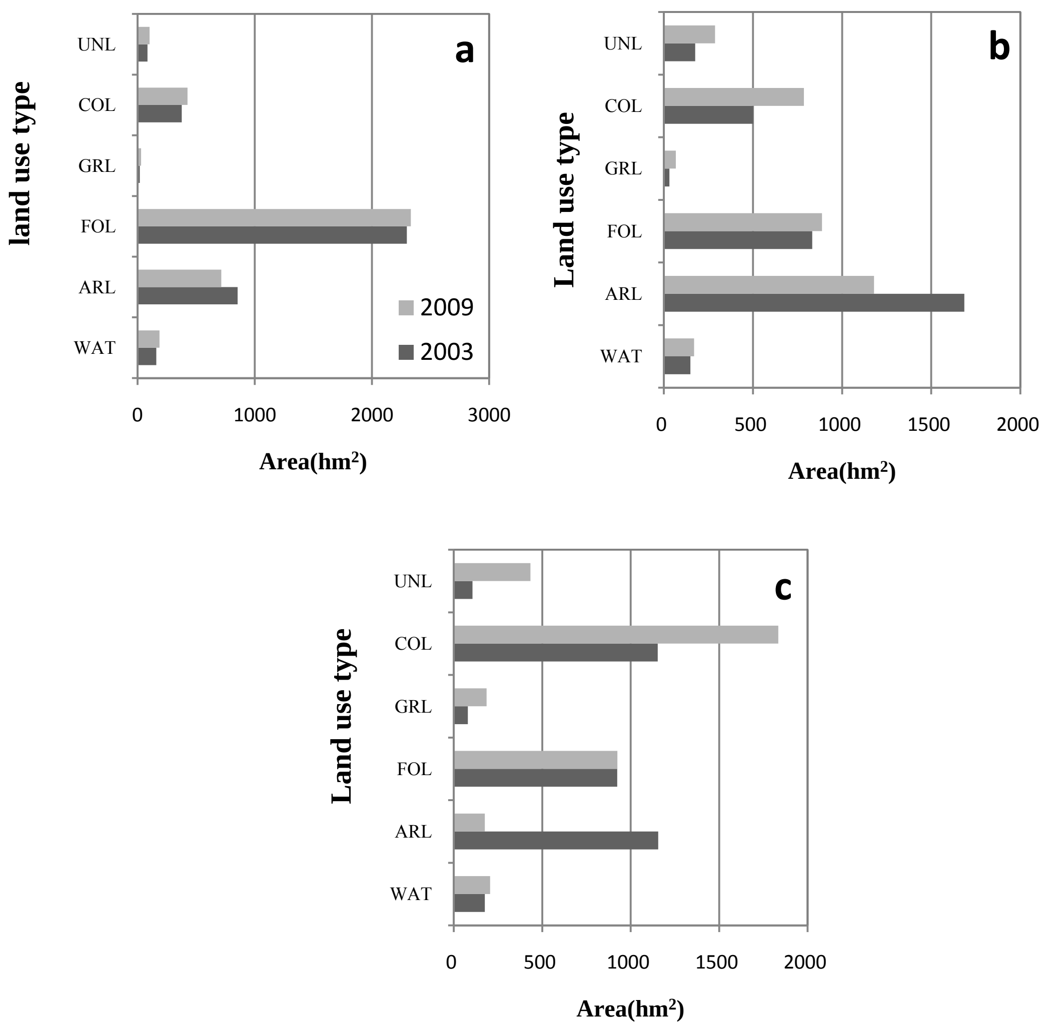

Figure1. Land use structure and its change in different sections of Jiuxiang River basin from 2003 to 2009. a=upstream, b=midstream, c=downstream.

The dominant land use type was forestland in upstream region, and the dominant type was farmland and forestland in midstream, whereas, in downstream, the dominant type was urban construction land. The change direction of land-use structure in different regions had a certain similarity. From 2003 to 2009, the area of farmland reduced in upstream, midstream and downstream, while other land use classes increased with different degrees.

(2) Land use change speed

Figure2 showed the land use change amount and land use change ratio in different regions. As shown in this figure, in construction land variation, between 2003 and 2009, the increasing amount and change ratio of urban construction land showed upstream <midstream

<downstream. In non-construction land variation, the most significant change was the area of arable land, and its reducing amount and change ratio showed downstream> midstream> upstream. Similar changes were observed in the grassland and unused land. However, forestland variation in the amount and rate of change showed the characteristics of the midstream> upstream> downstream.

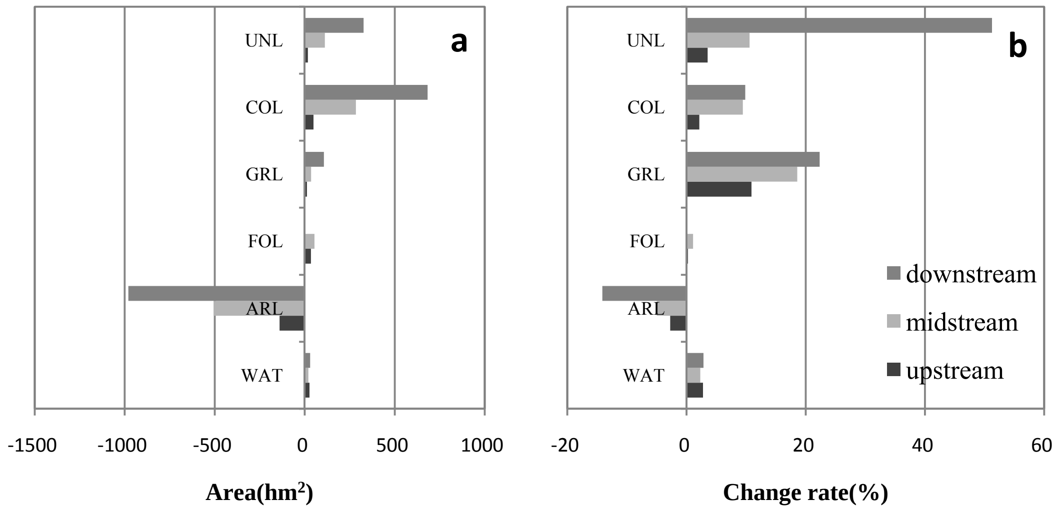

Figure2. The land use net change (a) and annual change rate (b) in 3 different sections of Jiuxiang River watershed

(3) Land use transition characterization

The change matrix based on the post-classification method for the period of 2003 to 2009 was obtained, with a summary of the major land use conversions shown in Table3. This calculation indicated that land use conversions had a large space differences. In the upstream, the majority of water body was acquired by converting areas that were previously farmland and forestland due to Longshang Lake Reservoir build-up. In addition, large areas of farmland were used for forestland, grassland and construction land in order to meet the growing needs of tourism development. In the midstream, land use conversions occurred mainly between cultivated land and construction land, forestland. More than 220 ha of farmland changed to construction land, 150 ha of farmland changed to forest land between 2003 and 2009, which represented an annual average loss of farmland areas of 85 ha. In the downstream, land use

Table3. Land use transition matrix of the Jiuxiang River watershed (hectare)

year	Sections	types	2009						
			WAT	ARL	FOL	GRL	COL	UNL	Total
2003	Upstream	WAT	131.98	16.31	4.37	4.18	1.13	1.92	160.03
		ARL	36.55	685.75	75.88	10.40	42.54	2.97	854.39
		FOL	11.89	9.50	2234.68	1.13	26.57	14.04	2297.91
		GRL	0.34	0.01	2.94	14.97	0.30		18.55
		COL	2.55	2.71	8.50		306.87	12.29	332.97
		UNL	3.03		6.22		4.10	70.87	84.22
		Total	186.49	714.34	2332.61	30.68	381.50	102.10	3792.82
	Midstream	WAT	112.39	11.20	4.14	3.18	11.15	4.74	149.17
		ARL	35.12	1141.15	147.53	23.49	221.87	83.27	1685.86
		FOL	6.18	11.81	713.57		34.24	63.02	832.84
		GRL	0.26	0.68	0.36	18.59	8.86	2.27	31.81
		COL	14.32	13.54	12.10	19.36	355.53	10.06	433.90
		UNL	0.98		8.61	2.59	38.65	121.95	175.59
		Total	169.83	1179.51	887.34	67.25	674.99	287.06	3376.69
	Downstream	WAT	87.94	0.92	3.75	11.49	35.05	23.85	175.36
		ARL	97.16	171.15	51.90	94.42	357.61	270.69	1155.54
		FOL	1.00	0.90	838.52	6.53	45.81	20.38	924.18
		GRL	0.03		4.72	34.03	21.67	16.53	79.43
		COL	11.22	0.29	15.19	23.84	701.09	65.06	860.86
		UNL	1.21	2.47	5.95	12.73	41.55	32.43	106.31
		Total	205.37	175.72	924.58	185.92	1213.56	433.12	3449.09

conversions occurred mainly between farmland and construction land, unused land. Approximately 36 percent of the farmland changed to construction land, and 27 percent of the farmland changed to unused land from 2003 to 2009. However, because of the transforming effect of urban greening and the construction of large-scale artificial forests, a significantly positive change was also observed, with some farmland transformed back to grass land.

Ⅴ. DISSCUSSION AND CONCLUSION

The Geographical Information System (GIS) and remote sensing (RS) in the assessment of changes of land use have been widely applied and considered as powerful and cost-effective tools for detecting and analyzing the spatio-temporal dynamics of process and patterns of land use/land cover change at local, regional and global scales [8-14]. Remote sensing could provide valuable and timely information that covered study areas with both position spatial detail and high temporal frequency [15-16]. The percentage of land use/land cover types were calculated using GIS. The integrative use of GIS and RS technology may play a vital role at the stages of exploration and analysis of local resources, planning and evaluation. Current land use was studied using GIS, satellite RS, and field observations. GIS analysis was carried out to create land use database.

Significant changes of the land use occurred in Jiuxiang River watershed were mainly attributable to the process of rapid urbanization. Before 2000, Jiuxiang River watershed was a typical agricultural area. However, after 2000, influenced by the strategy of "Xianlin new area", especially the build-up of the Xianlin university town, the process of urbanization was started. Since 2000, in order to achieve the development goal of building an international first-class, open-type, ecotype university town, the process of urbanization was accelerated with the large-scale construction of universities, and function areas in the university town. With the increase of the number of university in university town, the population of university town also increased to 0.2 million by 2009. In order to provide effectively the necessary services facilities, large areas of land were taken over for public infrastructure, housing, and commercial uses.

The spatial difference of land-use change in the watershed was related to combined effects of natural and anthropogenic factors. In general, the area where there was relatively flat terrain, adequate water, and suitable climatic conditions was more suitable for the survival of mankind and towns. In the upstream, there was greatly undulate terrain, a large amount of mountainous and hilly land , and in the midstream， the terrain showed gradually gentle, in the downstream, however, most of the area was flat land. The spatial differentiation of the natural conditions was consistent with the gradually increasing in the level of urbanization and the gradually declining in the proportion of agricultural and forest lands from upstream to downstream. Furthermore, the industry positioning of eco-tourism in the upstream had direct relationship with the more woodland and continuous increase in the water area. In the midstream and downstream, the build-up progresses of Xianlin new area had a direct relationship with the dramatic increase in construction land, as well as a significant reduction in arable land.

This study adopted a combined methodology of multi-temporal remote sensing image interpretation and GIS spatial analysis to qualitatively characterize the changes of land use in Jiuxiang River during 2003 and 2009.The results showed that the land use and land cover in the study area experienced significant changes, particularly in terms of construction area. Over the past 6-year, the construction areas increased by 2270.04 hectares about 1.39 times the built-up area in 2003, resulting in a substantial reduction in the area of arable land. Spatially, the land use change in upstream and midstream was relatively minor, but became increasing significant in downstream. In upstream, midstream and downstream, construction area increased from 3.14 %, 4.09% and 8.12 % to 3.60 %, 6.37% and 11.45 %, respectively, while arable areas decreased from 8.06%, 15.90% and 10.90% to 6.74%, 11.13% and 1.66%, respectively.

Urbanization process and subsequent land use change driven by economic development and population growth. In order to achieve the sustainable use of land resources, policy makers should consider appropriate adaptation options, based on the past and present land use changes. Above all, land use planning should be made to protect water bodies, wetlands, vegetation, and eco-environmentally sensitive areas. In addition, the density of construction land should be restrained, and some engineering measures must be initiated to repair degraded area, including urban afforestation, pollution control.

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