Current Situation of Land Use in Three-gorges Reservoir Region in 2010

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Abstract Land is rare natural resource. Production and construction of all sectors in a region must be based on land. Thus, overall research and analysis on current situation of land use can reveal scope, depth and reasonableness of land use, is helpful for analyzing internal mechanism land use change, and can reflect production scale, level and characteristics, and also can provide basis for optimization and adjustment of land use structure. Based on RS and GIS technologies, with the aid of TM image data of the Three-gorges Reservoir Region in 2010, the data of current situation of land use in Three-gorges Reservoir Region was obtained, and current land use situation was analyzed using geographimetrics and landscape ecology methods. Results show that since natural, social and economic conditions are different, land type diversity, combination type and location index of counties in the Three-gorges Reservoir Region are varied. In the land use diversity index, Xingshan County has the most single land use type (mainly forest land); in land use degree, Yuzhong District has the highest land use degree; in the integrated index of land use, Changshou District has the lowest integrated index of land use. This study is expected to provide reference and basis for formulating policies of protecting ecological environment of the Three-gorges Reservoir Region.

Key words Land use, RS, GIS, Geographimetrics, Three-gorges Reservoir Region

Land is the fundamental element for human survival and development, and also means of production and source of agriculture and industry. The human - land conflict is outstanding in the Three-gorges Reservoir Region. Reasonable use of land directly relates to improvement of residents' living conditions, economic construction, and ecological protection of the Three-gorges Reservoir Region. Analysis of current land use situation is the process of evaluation and study on land use type, quantity, and distribution and combination characteristics, and the analysis results can reflect characteristics, weakness and strength of land in the Three-gorges Reservoir Region, which is helpful for diagnosing whether land use is proper[1]. Selecting the Three-gorges Reservoir Region as the study region has following considerations. Firstly, it is expected to find out characteristics and trend of land use changes in the Three-gorges Reservoir Region, to provide guidance for land use planning. Secondly, it is intended to reflect functions of social and economic indicators to land use changes from the perspective of quantitative analysis. Besides, it is expected to enrich studies on land use changes and verify applicability of traditional study methods. In this study, with the aid of theories of geographimetrics and landscape ecology, we made an overall analysis on current land use situations in the Three-gorges Reservoir Region, in the hope of providing basis for optimization and adjustment of land use structure.

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1 Overview of the study area

The Three-gorges Reservoir Region (106°16′E - 111°28′E, 28°56′N - 31°44′N) is located in the upstream of the Yangtze River at the boundary of Chongqing Municipality and Hubei Province with the area of 57 336 km^2 and with the population of 34.509 7 million in the end of 2010 (including 23.173 6 million agricultural population, accounting for 67.15%). It stretches along the Yangtze River from Jiangjin District of Chongqing to Yiling District in Yichang City of Hubei, which is very narrow and where the geography is complex. The permanent resident population of the Three-gorges Reservoir Region is 30.324 96 million. The urbanization rate reached from 28.42% in 2009 to 32.85% in 2010. Per capita GDP of the Three-gorges Reservoir Region was 23 796.2 yuan in 2010.

2 Data source and data processing

In this study, we used Landsat TM images as data source. The ground resolution of TM is 30 m. In the whole Three-gorges Reservoir Region, it involves 9 images with orbit number 125038, 125039, 126038, 126039, 127038, 127039, 127040, 128039, and 128040 respectively. Since original images have such problems as geometric distortion, indistinct spectral characteristics, and separation of several wave bands, it is necessary to take technical processing of original images, such as geometric correction, image enhancement, and image fusion[2-3]. After a series of processing, we carried out artificial visual interpretation of remote sensing images and obtained vector data of current land use situation of the Three-gorges Reservoir Region in 2010.

3 Analysis on structure of current land use

With the aid of GIS software, we analyzed interpreted data of cur-

rent land use and the results are listed in Table 1. The whole Three-gorges Reservoir Region covers an area of 57 336 km^2, including 28 987.95km^2 forest land (accounting for 50.56%), 22 554.3 km^2 cultivated land (accounting for 39.34%), 3 184.43 km^2 grassland (accounting for 5.55%), 1 293.97 km^2 waters (accounting for 2.26%), 286.89 km^2 construction land (accounting for 2.24%), and 28.46 km^2 unused land (accounting for 0.05%).

Table 1 Land use situation of districts or counties in the Three-gorges Reservoir Region in 2010

District or County	Item	Cultivated land	Forest land	Grass land	Waters	Construction land	Unused land
Jiangjin	Area//km^2	1611.45	1388.60	55.46	84.40	67.07	0.00
	Percentage//%	50.25	43.30	1.73	2.63	2.09	0.00
Jiulongpo	Area//km^2	206.34	102.66	0.14	19.69	72.70	0.00
	Percentage//%	51.39	25.57	0.03	4.90	18.11	0.00
Yuzhong	Area//km^2	1.89	2.83	0.00	10.97	54.48	0.00
	Percentage//%	2.69	4.03	0.00	15.64	77.64	0.00
Dadukou	Area//km^2	41.61	14.73	0.00	12.17	35.24	0.00
	Percentage//%	40.11	14.20	0.00	11.73	33.97	0.00
Ba'nan	Area//km^2	1038.23	680.22	11.65	36.08	55.33	0.22
	Percentage//%	56.99	37.34	0.64	1.98	3.04	0.01
Nan'an	Area//km^2	111.39	55.82	0.54	11.25	61.16	0.00
	Percentage//%	46.38	23.24	0.22	4.68	25.47	0.00
Shapingba	Area//km^2	158.28	106.79	1.41	7.16	92.95	0.00
	Percentage//%	43.18	29.13	0.39	1.95	25.35	0.00
Jiangbei	Area//km^2	103.68	46.72	0.69	33.01	57.50	0.00
	Percentage//%	42.91	19.34	0.29	13.66	23.80	0.00
Yubei	Area//km^2	857.11	319.43	89.59	31.01	145.36	0.43
	Percentage//%	59.40	22.14	6.21	2.15	10.07	0.03
Beibei	Area//km^2	392.02	265.52	8.08	17.03	61.94	0.24
	Percentage//%	52.63	35.65	1.08	2.29	8.32	0.03
Changshou	Area//km^2	952.77	360.73	13.11	79.45	54.03	0.00
	Percentage//%	65.25	24.71	0.90	5.44	3.70	0.00
Fuling	Area//km^2	1386.58	1146.16	243.00	86.88	46.67	0.15
	Percentage//%	47.66	39.39	8.35	2.99	1.60	0.01
Wulong	Area//km^2	1173.64	1370.27	261.58	22.71	19.89	0.00
	Percentage//%	41.21	48.11	9.18	0.80	0.70	0.00
Fengdu	Area//km^2	1353.88	1276.59	203.52	61.80	20.16	0.00
	Percentage//%	46.43	43.78	6.98	2.12	0.69	0.00
Shizhu	Area//km^2	857.36	1856.85	240.40	17.27	13.97	0.00
	Percentage//%	28.71	62.19	8.05	0.58	0.47	0.00
Zhongxian	Area//km^2	1209.79	734.57	134.17	96.78	15.03	0.00
	Percentage//%	55.23	33.54	6.13	4.42	0.69	0.00
Wanzhou	Area//km^2	1706.39	975.52	608.22	97.26	48.35	0.00
	Percentage//%	49.67	28.39	17.70	2.83	1.41	0.00
Kaixian	Area//km^2	2056.93	1403.22	452.75	35.43	29.28	0.00
	Percentage//%	51.71	35.28	11.38	0.89	0.74	0.00
Yunyang	Area//km^2	1431.23	1761.08	304.14	121.85	24.33	1.02
	Percentage//%	39.28	48.33	8.35	3.34	0.67	0.03
Fengjie	Area//km^2	1367.10	2523.29	114.56	79.41	40.82	1.07
	Percentage//%	33.13	61.15	2.78	1.92	0.99	0.03
Wuxi	Area//km^2	813.76	2918.99	235.87	24.89	15.37	0.38
	Percentage//%	20.30	72.81	5.88	0.62	0.38	0.01
Wushan	Area//km^2	970.86	1785.02	83.64	62.44	26.56	0.55
	Percentage//%	33.15	60.94	2.86	2.13	0.91	0.02
Badong	Area//km^2	1045.53	2170.22	1.96	55.04	60.00	7.09
	Percentage//%	31.30	64.98	0.06	1.65	1.80	0.21
Zigui	Area//km^2	802.94	1327.56	1.48	92.89	54.61	2.66
	Percentage//%	35.18	58.17	0.06	4.07	2.39	0.12
Xingshan	Area//km^2	299.73	1895.01	33.61	39.19	46.45	6.87
	Percentage//%	12.91	81.65	1.45	1.69	2.00	0.30
Yiling	Area//km^2	603.84	2499.53	84.86	57.93	67.63	7.78
	Percentage//%	18.18	75.25	2.55	1.74	2.04	0.23
Total area	Area//km^2	22554.3	28987.95	3184.43	1293.97	1286.89	28.46

4 Analysis on quantity structure of current land use

The analysis on quantity structure of land use is to study diversity, combination type and location significance of quantity combination of various land types, so as to analyze the difference in current land use.

4.1 Diversity analysis The diversity index of land quantity structure is used to characterize completeness of various land types, and the major analysis method is Gibbs – Mirtin index (GM) model[4]. The mathematical formula of this model is as follows:

$$GM = 1 - \sum_{i=1}^{n} f_i^2 / (\sum_{i=1}^{n} f_i)^2 \quad (1)$$

where f_i denotes total area of the i-th land use type.

From Formula (1), GM value is 0 – 1; when GM∝1, it indicates that centralization degree of land use is high; otherwise, when GM∝0, it indicates low degree of centralization. If the type is rich and land area of different types is balanced, GM∝1; if the land use type is single, GM∝0. Therefore, GM model can reflect the completeness of land use types.

Using the data in Table 1, we can calculate the diversity index of current land use situation of the Three-gorges Reservoir Region and 26 districts or counties (as listed in Table 2). Analysis results show that the overall land use diversity index of the Three-gorges Reservoir Region is 0.59 and the land use type is relatively rich. Jiangbei, Dadukou, Shapingba and Nan'an District have the highest diversity index, respectively 0.7, 0.69, 0.66 and 0.66; Yubei, Zhongxian, Jiangjin, Zigui, Ba'nan, Shizhu, Wushan, Fengjie, Changshou, Wuxi, Yuzhong and Xingshan have lower diversity index. Xingshan County has the lowest diversity index of land use (0.32), indicating that its land use type is single.

Table 2 Land use diversity index of Three-gorges Reservoir Region and districts or counties

District or County	Diversity index	District or County	Diversity index
Reservoir Region	0.59	Fengdu	0.59
Jiangjin	0.56	Shizhu	0.52
Jiulongpo	0.64	Zhongxian	0.58
Yuzhong	0.37	Wanzhou	0.64
Dadukou	0.69	Kaixian	0.60
Ba'nan	0.53	Yunyang	0.60
Nan'an	0.66	Fengjie	0.52
Shapingba	0.66	Wuxi	0.43
Jiangbei	0.70	Wushan	0.52
Yubei	0.58	Badong	0.48
Beibei	0.59	Zigui	0.54
Changshou	0.51	Xingshan	0.32
Fuling	0.61	Yiling	0.40
Wulong	0.59		

4.2 Analysis on combination types In recent years, Weaver – Tomas combination model is deemed as the best method for solving land structure problem. Its basic principle is to compare actual distribution and assumed uniform distribution of land use types one by one, to find out one uniform distribution closest to the actual distribution, and the combination type of such distribution is the desired combination type[5].

Firstly, rank land use types from high to low area of percentage. Secondly, assume land is allocated to one type, two types, etc. When the land is allocated to the first type, the distribution is 100%, and the distribution of other types is 0; when the land is allocated to the first two types, the distribution is 50% respectively, and the distribution of other types is 0, and so on and so forth, till land is evenly allocated to all types. Next, calculate the combination coefficient through square sum of difference of corresponding items according to each type of assumed distribution and actual distribution. Finally, the assumed distribution corresponding to minimum combination coefficient is the land use combination type of the corresponding region. According to the above principle, we can obtain land use combination types of the Reservoir Region and districts and regions, as listed in Table 3. From Table 3, we can see that there are two land use combination types in the Three-gorges Reservoir Region, *i. e.* "forest land – cultivated land" combination type. As to single district or county, Dadukou, Shapingba, Nan'an and Jiangbei have three combination types, other districts or counties have one or two combination types, showing that most districts or counties have weak overall land use function, especially, Yuzhong, Wuxi, Xingshan and Yiling have single land use function.

4.3 Analysis of location index The location is specific manifestation of organic combination of natural geographical position, economic geographical position, and traffic geographical position in space. Through analysis on the location index of land use, it is able to reflect relative centralization of various land use types of a region at a higher level of regional space. The calculation formula for specific location index (Q_i)[4] is as follows:

$$Q_i = (f_i / \sum f_i) / (F_i / \sum F_i) \quad (2)$$

where f_i is the total area of the i-th land use type; F_i is the total area of corresponding land use type in higher level region; Σf_i is the sum of land area in this region; ΣF_i is the sum of land area in higher level region. If $Q_i > 1$, it indicates that the location significance of land use type is relatively obvious; the higher the Q_i, the greater significant it is.

From Table 4, cultivated land has location significance in most districts and counties. Thus, cultivated land is the major land use type in the Three-gorges Reservoir Region. In Yuzhong District, the construction land has the highest location index (34.5922), showing Yuzhong District has the highest degree of land construction and use; in Fengjie, Wuxi and 4 districts (counties) of Hubei Province, forest land has location significance, indicating that these areas are rich in forest resources; in Yubei, Fuling, Wulong, Fengdu, Shizhu, Zhongxian, Wanzhou, Kaixian, Yunyang and Wuxi, the grassland has location index greater than 1, showing obvious grassland advantage.

4.4 Analysis on land use degree Land use degree mainly reflects influence degree of human factors in land system, while land system is a natural and social complex. The land use degree can be graded as follows: agricultural land, forest land and grassland, urban community land, and unused land levels. The land use grading index of cultivated land is 1; the land use grading index of forest land, waters and grassland is 2; the land use grading index of construction land is 3; the land use grading index of unused land is 4; the composite index of land use degree (La) can be expressed by following formula[6]:

$$L_a = 100 \times \sum_{i=1}^{n} A_i \times C_i \quad L_a \in [100, 400] \quad (3)$$

where A_i is the grading index of land use degree of a certain land use type in a region; C_i is the area percentage of this land use type. From formula (3), it is known that the composite index of land use degree is a continuous function with value in the range of [100, 400]. In certain unit of network region, the value of com-

posite index reflects degree of land use. The land use degree of any region can be obtained through calculating its composite index. Since driving factor of land use changes comes from nature and society, using the composite index of land use degree can better manifest the influence of natural and social factors on land use.

Table 3 Combination types of land use in districts or counties of the Three-gorges Reservoir Region in 2010

Area	Number of combination types	Combination types	Combination coefficient
Reservoir Region	2	Forest land – cultivated land	114.01
Jiangjin	2	Cultivated land – forest land	44.96
Jiulongpo	2	Cultivated land – forest land	598.93
Yuzhong	1	Construction land	499.93
Dadukou	3	Cultivated land – construction land – forest land	412.33
Ba'nan	2	Cultivated land – forest land	912.26
Nan'an	3	Cultivated land – construction land – forest land	333.96
Shapingba	3	Cultivated land – forest land – construction land	178.17
Jiangbei	3	Cultivated land – construction land – forest land	378.43
Yubei	2	Cultivated land – forest land	864.67
Beibei	2	Cultivated land – forest land	212.89
Changshou	2	Cultivated land – forest land	872.49
Fuling	2	Cultivated land – forest land	117.96
Wulong	2	Forest land – cultivated land	80.87
Fengdu	2	Cultivated land – forest land	51.44
Shizhu	2	Forest land – cultivated land	601.64
Zhongxian	2	Cultivated land – forest land	298.42
Wanzhou	2	Cultivated land – forest land	466.96
Kaixian	2	Cultivated land – forest land	219.67
Yunyang	2	Forest land – cultivated land	117.70
Fengjie	2	Forest land – cultivated land	408.91
Wuxi	1	Forest land	739.50
Wushan	2	Forest land – cultivated land	403.78
Badong	2	Forest land – cultivated land	573.90
Zigui	2	Forest land – cultivated land	286.31
Xingshan	1	Forest land	336.67
Yiling	1	Forest land	612.49

Table 4 Location index of land use in districts or counties of the Three-gorges Reservoir Region in 2010

District or County	Cultivated land	Forest land	Grass land	Waters	Construction land	Unused land
Jiangjin	1.2774	0.8564	0.3113	1.1661	0.9318	0.0000
Jiulongpo	1.3064	0.5057	0.0061	2.1733	8.0666	0.0000
Yuzhong	0.0684	0.0798	0.0000	6.9283	34.5922	0.0000
Dadukou	1.0195	0.2808	0.0000	5.1975	15.1334	0.0000
Ba'nan	1.4488	0.7385	0.1151	0.8775	1.3532	0.2458
Nan'an	1.1791	0.4598	0.0404	2.0750	11.3457	0.0000
Shapingba	1.0976	0.5762	0.0695	0.8657	11.2966	0.0000
Jiangbei	1.0909	0.3825	0.0515	6.0535	10.6039	0.0000
Yubei	1.5100	0.4379	1.1180	0.9521	4.4884	0.5951
Beibei	1.3380	0.7051	0.1953	1.0129	3.7053	0.6369
Changshou	1.6589	0.4887	0.1617	2.4111	1.6487	0.0000
Fuling	1.2115	0.7792	1.5038	1.3232	0.7146	0.1024
Wulong	1.0476	0.9516	1.6536	0.3533	0.3112	0.0000
Fengdu	1.1803	0.8659	1.2567	0.9390	0.3081	0.0000
Shizhu	0.7300	1.2300	1.4497	0.2563	0.2085	0.0000
Zhongxian	1.4041	0.6633	1.1029	1.9578	0.3057	0.0000
Wanzhou	1.2626	0.5616	3.1874	1.2543	0.6270	0.0000
Kaixian	1.3146	0.6978	2.0494	0.3947	0.3280	0.0000
Yunyang	0.9985	0.9560	1.5029	1.4818	0.2975	0.5663
Fengjie	0.8423	1.2095	0.4999	0.8527	0.4408	0.5215
Wuxi	0.5160	1.4401	1.0593	0.2751	0.1708	0.1904
Wushan	0.8426	1.2054	0.5142	0.9445	0.4040	0.3777

To be continued

Continued Table 4

District or County	Cultivated land	Forest land	Grass land	Waters	Construction land	Unused land
Badong	0.7958	1.2852	0.0106	0.7303	0.8005	4.2799
Zigui	0.8944	1.1506	0.0117	1.8035	1.0662	2.3497
Xingshan	0.3283	1.6150	0.2607	0.7482	0.8917	5.9616
Yiling	0.4621	1.4884	0.4600	0.7727	0.9072	4.7204

Table 5 Composite index of land use degree of the Three-gorges Reservoir Region and districts or counties

Area	Composite index of land use	Area	Composite index of land use
Reservoir Region	163.01	Fengdu	154.26
Jiangjin	151.84	Shizhu	171.75
Jiulongpo	166.72	Zhongxian	145.45
Yuzhong	274.95	Wanzhou	151.74
Dadukou	193.86	Kaixian	149.02
Ba'nan	146.07	Yunyang	161.44
Nan'an	179.08	Fengjie	167.91
Shapingba	182.18	Wuxi	180.11
Jiangbei	180.89	Wushan	167.80
Yubei	150.73	Badong	170.92
Beibei	155.75	Zigui	167.44
Changshou	138.45	Xingshan	189.68
Fuling	153.96	Yiling	184.33
Wulong	159.49		

Table 5 indicates that Yuzhong District has the highest land use degree, and Changshou District is lowest in land use degree; the land use degree of Dadukou, Xingshan, Yiling, Shapingba, Jiangbei, and Wuxi is about equal and relatively high; the land use degree of Yunyang, Wuling, Beibei, Fengdu, Fuling, Jiangjin, Wanzhou, Yubei, Kaixian, Ba'nan, Zhongxian and Changshou is lower than the average level of entire reservoir region.

5 Conclusions

In the entire Three-gorges Reservoir Region, forest land takes up a half, in some districts and counties, forest land covers more than 80%, indicating that the Reservoir Region has much mountain area and the forest resource is rich. There are significant differences in land use in districts and counties of the Three-gorges Reservoir Region. Land types diversity, combination types and location index are also varied. In Yuzhong District, except waters, other land use types are mainly construction land and the land use type is single; as to the diversity index, Xingshan County has the largest single land use type, mainly forest land. As to land use degree, Yuzhong District has the highest degree of land use, while Changshou District has the lowest composite index of land use.

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