J. Mt. Sci. (2011) 8: 551–563
DOI: 10.1007/s11629-011-2008-8

Spatial-temporal Pattern and Differences of Land Use Changes in the Three Gorges Reservoir Area of China during 1975-2005

CAO Yingui[1]*, ZHOU Wei[1], WANG Jing[1,2], YUAN Chun[1]

1 School of Land Science and Technology, China University of Geosciences, Beijing 100083, China

2 Land Key Laboratory, China Land Survey and Plan Institute, Beijing 100035, China

** Corresponding author, e-mail: caoyingui1982@126.com*

Abstract: Regional land use changes are an important part of global changes. The research on land use changes in the Three Gorges Reservoir Area of China attracts a lot of attention owing to the Three Gorges Dam building. The Three Gorges Reservoir Area becomes one of the important research areas. This study analyzed the transforming processes and traits of each land use type and the regional differences of land use changes during the past 30 years, summarized the distribution of different land use types in different buffer zones and regresses the equation areas and different buffer distances based on buffer analyses and regression analyses, and then analyzed the transforming rules in different buffer distances, got the optimal influence distances. The research results indicate that, (1) cultivated land lies at the northwest of the reservoir and was decreasing, however, the construction land was increasing, especially the urban construction land, a large number of land was flooded because of the reservoir water level rise; (2) urban area was sprawling quickly in developed and neighboring areas, and a great deal of cultivated land and a considerable amount of grassland were occupied; in the earlier time, rural settlements occupied lots of cultivated land and a sum of forestry land in the later time; (3) the optimum influenced distances for cultivated land and forestry land were 10-35 km, and for urban and rural settlements were in 5-20 km. Overall, this research can reflect the spatial-temporal characteristics of land use changes during the 30 years, and it is helpful for urban planning and land use planning in the reservoir area.

Received: 11 November 2010
Accepted: 8 May 2011

Keywords: Land use; Spatial-temporal changes; Differences; Three Gorges Reservoir Area

Introduction

Land use changes analysis is an important approach to deeply understand the complexity of land use changes, and is also the primary method to investigate the extent and future trend of land use changes. Only through fixed and quantitative research on the changes of different land use types from the microcosmic view, can the dynamic change process of different land use types be deeply and exactly understood (Pontius 2004; Anne 2006; Zhang 2008). Land use changes include quantitative change and spatial transformation. The former means the area increase and decrease after offsetting the transformation in and out. The latter means land use types transformation in space and position (Damian 2008).

The urban development of the Three Gorges Reservoir Area of China met an uncommonly historical opportunity because of the world-famous Three Gorges Project and the practice of western development strategy. But restrictions of factors in history, nature and reality lead to the delay of urban construction, unreasonable urban spatial layout, serious Three Dimensional Rural Issues (the issue of agriculture, the issue of countryside and the issue of farmers and their interactions),

tense relationship between population and resources. In the early ninety of last century, flooded land per capita decreased to 0.05 - 0.06 hm² (Wang 2007; Wang and Zhu 2000). The shape of each urban in the Three Gorges Reservoir evolves from a state of concentrate and compact lumpish into concentrate and compact strip. In addition, some researchers analyze problems in urban development and propose urban development modes in reservoir area from the aspect of resources distribution and limitation (Hu et al. 2006; Guo 2004; Xiao and Wang 2000). As to the ecological fragile area, construction occupying a great deal of farmland, forestry land and grassland has a serious impact on food production and ecological environment protection in reservoir area. In 2009, the immigrants in Chongqing Urban Area had less than 0.039 hm² cultivated land per capita. There exists a serious conflict between large population and insufficient arable land (Yu and Si 2009). From 1994 to 2004, cultivated land areas and cultivated land areas per capita in the reservoir area showed decreasing trends, which were closely related to urban expansion (Cao et al. 2006). During 1995 to 2000, inhabitant land and industry-mining land increased 1,2203.54 hm², cultivated land was the main source of its increase. Forestry land transformed into inhabitant land and industry-mining land occupied 4.86% of total forestry land transformation (Cao et al. 2001). During 1986 to 2000, constructive land increased continually and the increasing ratio after 1995 was three times than that before 1995. During the ten years before 1995, constructive land expansion occupied 6367 hm² land. The constructive land expansion concentrated basically around the urban, which aimed at meeting the regional economic development demand (Fan and Jiang 2002).

This research uses 30 years' data to analyze the land use changes and the differences between the administrational area and the river buffer area for providing reference to the Three Gorges Reservoir Area's land use planning and urban planning.

1 Research Area and Data

The Three Gorges Reservoir Area lies in E 106°16' - 111°28' and N 28°56' - 31°44' which contains Yichang Urban Area, Yichang County, Xingshan County, Zigui County and Badong County of Hubei Province, and Wushan County, Wuxi County, Fengjie County, Chongqing Urban Area, Yunyang County, Kai County, Wanzhou District, Zhong County, Fengdu County, Fuling City, WuLong County, Changshou County, Jiangbei County, Ba'nan District and Jiangjin City of Chongqing Municipality in China (Figure 1). It covers an area of 58 thousand km² and has a population of 1, 6736.30 thousand in 2005. The Three Gorges Reservoir Area mainly consists of mountainous region, accounting for 74% of the total areas, while hill areas make up of 22% of the total and plain or dam areas account for only 4% of the total areas.

This research utilizes the remote sensing images of five periods, i.e. MSS images in 1975, TM images in 1987, 1995, 2000 and 2005. Radiation and geometry to remote sensing images are corrected using Kra-sovsky ellipsoid, Transverse

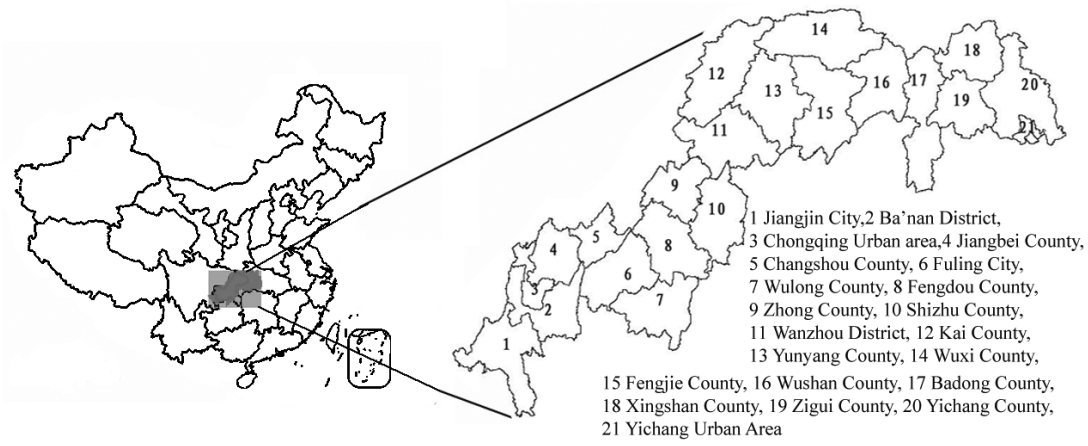

Figure 1 Location of Three Gorges Reservoir Area of China

Mercator projector, and then implements mosaic and groom work. Land use maps in 1975, 1987, 1995, 2000 and 2005 are acquired by human-computer interpretation in the ERDAS 8.6 environment according to National Remote Sensing to Monitor Land Use / Cover Classification System.

2 Analyses and Results

2.1 Spatial distribution of land use types

Cultivated land in the Three Gorges Reservoir Area mainly lay to the north-west of the Yangtze River, while forestry land and grassland were distributed over the south-west of Yangtze River. In terms of administrative division, cultivated land mainly spread over the upper reaches, including Jiangjin City, Ba'nan District, Jiangbei County, Changshou County, Fengdu County, Zhong County of Chongqing Municipality, and a large area of cultivated land was distributed over the center of Wanzhou District. Gradient cultivated land mainly distributed in Kai County and Wuxi County, and there was also odd distribution in Fuling City and Wulong County. Forestry land was distributed over the lower reaches of the Three Gorges Reservoir area, which was in Yichang County, Xingshan County, Zigui County, Badong County. Grass land mainly spread over Fuling City, Fengdu County, Yunyang County, Fengjie County (Figure 2). By comparison of land use map in 2005 with 1975, the figures showed that the scale of urban construction land expanded, especially in Chongqing Urban Area, Yichang Urban Area, Wanzhou District and counties around Chongqing Urban Area, and the areas of rivers and waters expanded (Figure 2 and Figure 3).

2.2 Land use changes

2.2.1 Land use changes in quantity

The area of cultivated land in the Three Gorges Reservoir Area was decreasing yearly from 1975 to 2005. From 1975 to 2000, cultivated land had a steady decrease with the total land area of 3911.35 hm². The annual decrease was 157.26 hm² from 1975 to 1987, 190.36 hm² from 1987 to 1995, 100.26 hm² from 1995 to 2000, 1621.4 hm² from 2000 to 2005. The area of cultivated slope land changed little from 1975 to 2005 while the area of forestry land was decreasing all along with the total area from 1975 to 2005 up to 1,3883.03 hm². Grass land was mainly distributed over the high altitude mountain areas, which was decreasing all along in each study period from 1975 to 2005.

During the whole study period, the area of grassland decreased by 2328.97 hm² with annual decrease of 77.63 hm² due to the construction. The water level increased obviously and the water area kept increasing in the Three Gorges Reservoir Area. From 1995 to 2000, water area increased by 571.29 hm². From 1995 to 2000, the area of rivers increased by 141.01 hm², the area of other waters decreased by 532.59 hm². From 2000 to 2005, the area of rivers showed dramatic increase by 7984.23

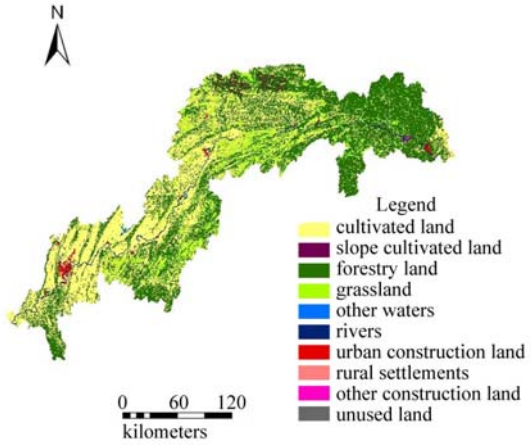

Figure 2 Land use map of Three Gorges Reservoir Area in 2005

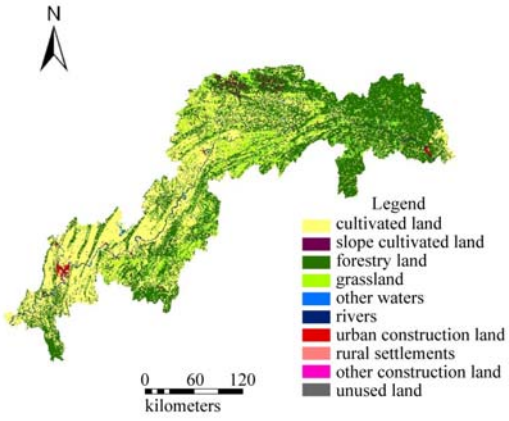

Figure 3 Land use map of Three Gorges Reservoir Area in 1975

hm^2 due to the rising of water level, while other water areas showed a relevant decrease of 436.83 hm^2.

Land use for various construction purposes was increasing, which led to the total increase in land use by 1, 9617.35 hm^2 from 1975 to 2005, with annual increase of 653.91 hm^2. The total land area used for urban construction increased by 1, 3612.22 hm^2 from 1975 to 2005, from 2, 3980.06 hm^2 in 1975, to 3, 7592.28 hm^2 in 2005, which accounted for 69.39% of the total increase in construction land. That is to say, it was the increase of urban construction land that led to the increase of construction land. A dramatic increase can be seen from 2000 to 2005. In this period, urban construction land accounted for 50.29% of the increase of construction land, with accumulative area up to 6846.06 hm^2..From 1975 to 2005, land use for rural settlements and other constructions showed small increase. The former increased by 2706.93 hm^2, with the annual increase of 90.23 hm^2, and the latter increased by 3298.20 hm^2, with the annual increase of 109.94 hm^2.

2.2.2 Spatial land use transformation

Data on land use changes can be obtained by using ArcGis 9.2 software, overlaying land use maps of different periods, extracting changing patches of each land use type and getting transferring information about each land use type for each study period. The research paid importance to analyze the numbers of transferred patches, transformed area and their proportions (Table 1).

Table 1 Land use transformation matrix at different periods in Three Gorges Reservoir Area

Land use type transformation	1975-1987			1987-1995		
	Transformation number of patches (#)	Transformation area (hm^2)	Ratio (%)	Transformation number of patches (#)	Transformation area (hm^2)	Ratio (%)
1→7	26	2032.58	0.094	24	1492.22	0.069
1→8	22	841.69	0.039	20	467.19	0.022
1→9	13	623.00	0.029	7	490.00	0.023
3→5	1	160.00	0.006			
3→6						
3→7	6	310.46	0.011	8	222.27	0.008
3→8	5	49.18	0.002	10	204.13	0.007
3→9	14	383.91	0.014	39	3260.73	0.119
4→5				1	94.00	0.013
4→6	1	200.00	0.027			
4→7	1	15.00	0.002	2	29.95	0.004
4→8	2	24.16	0.003	10	106.16	0.014
4→9	4	116.82	0.016	2	52.00	0.007
5→4						
5→6						
5→8				1	15.00	0.068
6→4						
6→8						
6→9						
7→6						
7→9						
8→6						
8→10						
9→1						
9→4	2	28.52	0.539	23	306.55	5.236
9→6						
9→7						
10→8						

-Continued-

Land use type transformation	1995-2000			2000-2005		
	Transformation number of patches (#)	Transformation area (hm²)	Ratio (%)	Transformation number of patches (#)	Transformation area (hm²)	Ratio (%)
1→7	22	454.63	0.021	52	6004.77	0.277
1→8	11	303.89	0.014	27	734.43	0.034
1→9	3	611.09	0.028	7	321.85	0.015
3→5						
3→6	1	6.05	0.000	12	2837.00	0.104
3→7	37	2383.40	0.087	9	954.71	0.035
3→8	87	3899.70	0.143	22	906.79	0.033
3→9	115	4604.13	0.170	24	487.60	0.018
4→5	3	70.01	0.010	1	5.81	0.001
4→6				10	727.19	0.099
4→7	8	194.18	0.027	8	342.00	0.047
4→8	21	993.47	0.136	17	484.67	0.066
4→9	8	579.79	0.079	9	572.00	0.078
5→4	1	5.88	0.027	1	87.00	0.412
5→6				5	3074.00	14.554
5→8	1	45.37	0.205			
6→4				1	66.00	0.109
6→8				1	180.00	0.298
6→9	2	97.91	0.163			
7→6				1	31.00	0.101
7→9				1	8.08	0.026
8→6				15	2776.40	20.444
8→10	1	13.00	1.310			
9→1				1	22.00	0.267
9→4	12	548.16	6.881	44	1171.85	14.236
9→6	1	27.61	0.347			
9→7	1	24.18	0.304	1	8.08	0.098
10→8				1	73.87	7.360

Note: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 stand for cultivated land, slope cultivated land, forestry land, grassland, other waters, rivers, urban construction land, rural settlements, other construction land, unused land.

It can be seen from each study period that cultivated land, forestry land, grassland were in large amount transformed to other land use types, such as urban construction land, rural settlements and other construction land. Cultivated land was transferred most during 1975 to 1987, which was primarily occupied by urban construction land expansion with occupied area up to 0.094% of the total cultivated land area of 1975 and the average patch area being 78.18 hm². Then rural settlements also occupied lots of cultivated land.

The forestry land was transferred most during 1987 to 1995, especially transformed to other construction land. The transformed area added up to 3260.73 hm², which was 0.119% of the total areas of forestry land in 1987. The annual transformed area was 407.59 hm², and the numbers of transferred patches were 39 with the average patch area being 83.61 hm². In the process of grassland being transformed to urban construction land, rural settlements and other construction land, there appeared other construction land transformed to grassland, which was up to 306.55 hm².

During 1995 to 2000, the area of forestry land transformed to construction land was the largest, the area of the grassland and cultivated land transformed to construction land were the next. In this period, the area and patch numbers of forestry land transformed to other construction land were

the largest, which were 4604.13 hm² and 115 respectively. The average patch area was 40.04 hm². Other construction land went on being transformed to grassland and the transferred area and average patch area kept increasing.

From 2000 to 2005, transformation of land use types was more frequent. The transferred area was up to 82.14% of the total transferred area during 1975 to 2005. The area of cultivated land quickly decreased because of urban expansion. The area of cultivated land transformed to urban construction land was up to 6004.77 hm², and the average patch area was 115.48 hm². Then construction-related land occupation and water flooding resulted in dramatic decrease in forestry land area. Other construction land took on flooding largely.

Overall, transformation of land use type in the Three Gorges Reservoir Area showed the following traits, firstly, as time passed, human activities were having a greater impact on the transformation of land use types, especially, urban expansion had occupied a great deal of cultivated land, forestry land and grassland; secondly, as to the mountain region, that the cultivated land, forestry land and grassland were occupied by construction land would have a great impact on its ecological environment; thirdly, due to the influence of mountain terrain and the restriction of cultivated land protection, construction land relied more on forestry land and grass land; fourthly the submerged areas kept expanding with the water level rising; lastly, that part of other construction land was being transformed to grass land indicated this area was implementing ecological restoration and reform.

2.2.3 Regional differences of land use changes

At present, when studying regional differences of land use changes, what is widely used are comparative analysis of different spatial land use pattern change as well as differentiation traits of land use type changes (Wang 2006). Basically, many studies focus on the whole reservoir. This study based on the integral study, continue to analyze differences of land use changes in each county, and furtherly analyzes the traits of land use changes quantitatively. In this study, cultivated land, forestry land and grassland were generally referred to as agricultural land. The analyses of regional difference of land use changes were based on five aspects, i.e., agricultural land occupied by urban expansion, agricultural land occupied by rural settlements, agricultural land occupied by other construction land, inverse change of construction land and land use changes in the submerged area, respectively.

(1) Agricultural land occupied by urban expansion

Among the study period, the agricultural land occupied by urban expansion was the largest from 2000 to 2005, especially in the Ba'nan District, Jiangbei County and Chongqing Urban Area of the Chongqing Municipality, with an annual occupied area being 195.06 hm², 774.06 hm² and 712.19 hm² respectively (Figure 4). The annual occupation proportions of cultivated land, forestry land, grassland were 83.07%, 15.76%, 2.17% respectively in the Ba'nan District, 94.21%, 5.79%, 0% respectively in the Jiangbei County, and 89.43%, 1.46%, 9.12% respectively in the Chongqing Urban Area. Annual agricultural land occupied by urban expansion in Kai County and Yichang Urban Area were 98.99 hm², 45.73 hm² respectively.

Urban expansion mainly occupied forestry land in Kai County. The annual occupation proportion of cultivated land and forestry land in Yichang Urban Area were 93.78%, 6.22% respectively. Counties (or cities) where urban expansion occupied less agricultural land were Fengdu, City, Jiangjing, Wushan, Yichang and Yunyang, and the tatal area was less than 25.01 hm², from 2000 to 2005, no agricultural land was occupied in Badong, Changshou, Shizhu, Wuxi, Xingshan, Zhong, and Zigui counties, and the Wanzhou District.

During the other three study periods, the annual urban expansion occupying agricultural land was less than 100 hm². No agricultural land was occupied in Badong, Kai, Wuxi, Xingshan counties and the Yichang Urban Area from 1995 to 2000. The occupied agricultural land was mainly forestry land, with a small quantity of cultivated land and grassland. Urban expansion occupying agricultural land only occurred in a few counties from 1975 to 1987 and 1987 to 1995, mainly in the Ba'nan District, Changshou and Jiangbei counties, Yichang and Chongqing urban areas.

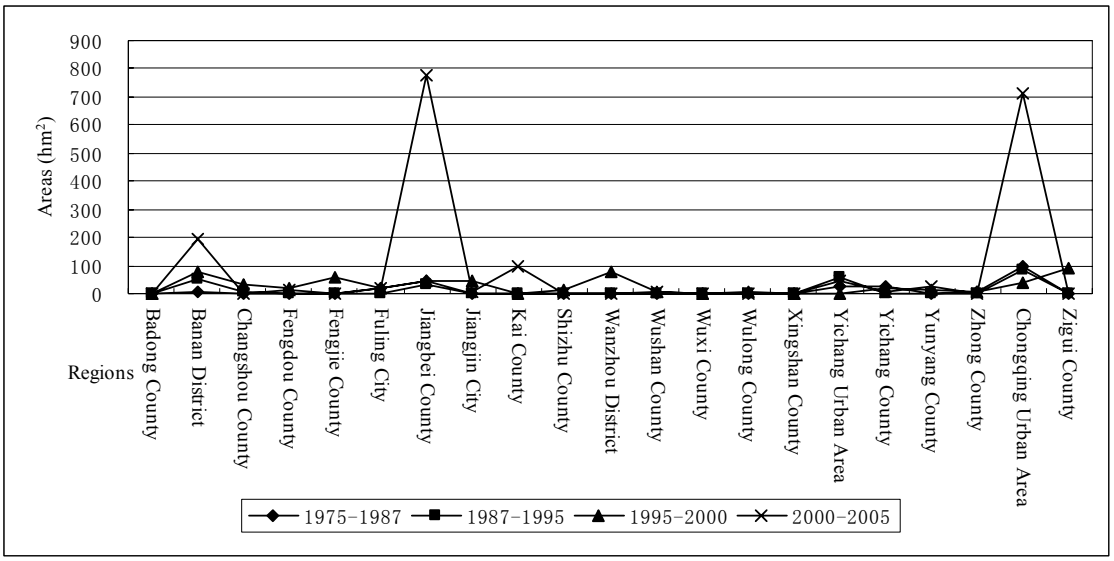

Figure 4 Areas of urban sprawling occupying agriculture land at different periods

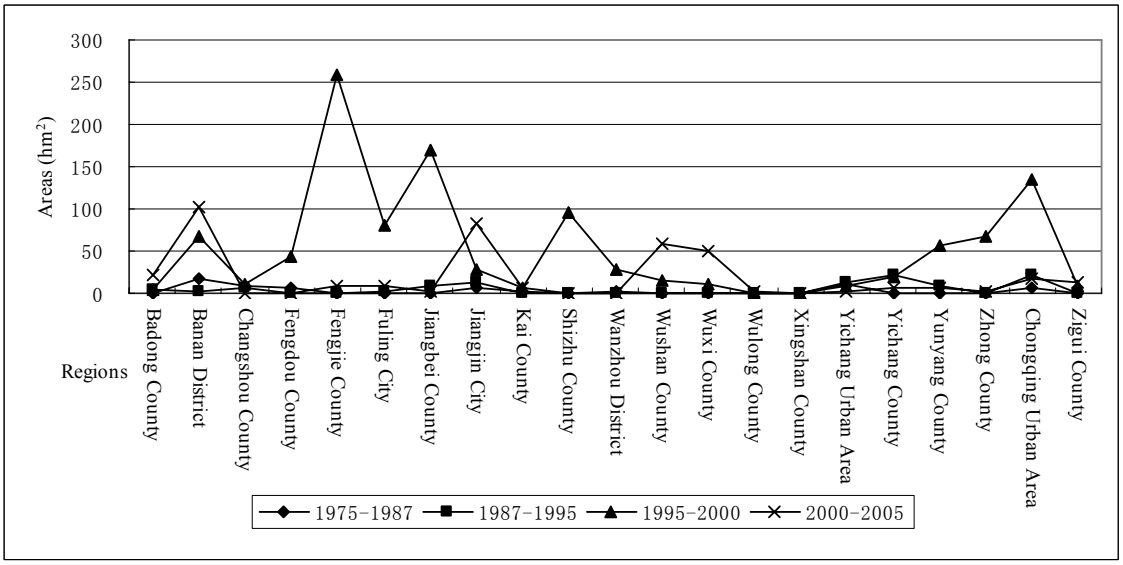

Figure 5 Areas of rural settlements occupying agriculture land at different periods

In a whole, urban expansion occupied little agricultural land at the beginning, but then occupied increasing area in the later period with the rapid economy development for the construction of the Three Gorges Project together with the new urban construction. Among the occupied agricultural land, the proportions of cultivated land and forestry land were relatively higher, but their proportions were not the same in different periods. In more developed regions the urban area expanded rapidly, which occupied a great deal of agricultural land and caused agricultural land decrease in the surrounding counties. In the remote mountainous regions, urban area expanded slowly, where basically it's the renovation of the old towns.

(2) Agricultural land occupied by rural settlements

From 1995 to 2000, annual change of agriculture land occupied by rural settlements was obvious among different regions, with the peak value in Ba'nan District, Fengjie County, Jiangbei County, Shizhu County and Chongqing Urban Area and the annual occupied area being 66.90, 257.80, 168.49, 96.37 and 134.78 hm² respectively (Figure 5). Rural settlements occupied mainly forestry land, with the occupation proportion of 41.90%, 99.30%,

68.66%, 32.68% and 61.52% respectively in these five regions. During this period, rural settlements which occupied only forestry land was in Badong County, Changshou County, Fengdu County, Jiangjin City, Kai County, Wanzhou District, Yichang Urban Area, Zhong County and Zigui County with the annual occupation area of 4.74 hm^2, 11.67 hm^2, 43.25 hm^2, 28.02 hm^2, 6.48 hm^2, 27.31 hm^2, 8.68 hm^2, 66.90 hm^2 and 7.62 hm^2 respectively.

From 2000 to 2005, agricultural land annually occupied by rural settlements was relatively larger in Ba'nan District, Jiangjin City and Wushan County with the area being 102.96 hm^2, 83.19 hm^2 and 58.62 hm^2 respectively. Rural settlements in the Ba'nan District mainly occupied cultivated land with a proportion of 69.61%, in the Jiangjin City mainly forestry land with a proportion of 85.37%, in the Wushan County mainly grassland with a proportion of 92.15%. From 1987 to 1995, Yichang County and Chongqing Urban Area occupied more agricultural land with areas of 22.34 hm^2 and 21.25 hm^2 respectively. Yichang County occupied mainly forestry land with the proportion of 58.01%, Chongqing Urban Area occupied mainly cultivated land with the proportion of 95.63%. And during this period, Changshou and Yunyang counties occupied only cultivated land.

From 1975 to 1987, rural settlements occupied a large amount of cultivated land, where the occupation was only cultivated land was in Ba'nan and Wanzhou districts, Jiangjin City, and Changshou, Fengdu, Kai, and Yichang counties. During the period, agricultural land annually occupied by rural settlements was relatively smaller, with the largest occupation in Ba'nan District which was 17.93 hm^2.

Throughout the whole study period, rural settlements occupied increasing more agriculture land before 2000, then had a decrease after 2000. In the early period, agricultural land occupied by rural settlements was mainly cultivated land and then gradually forestry land because of the protection policy for cultivated land. The counties where rural settlements occupied relatively larger agricultural land were distributed mainly in the rapid developed regions, such as the Ba'nan District, Jiangbei County, Jiangjin City, Yichang Urban Area and Chongqing Urban Area.

(3) Agricultural land occupied by other construction land

Other construction land refers to land for factories, mining areas, oil fields, transporting roads and so on, that is apart from urban construction land and rural settlements.

From 1995 to 2000, the agricultural land area annually occupied by other construction land was larger in Fuling City, Yichang and Yuyang counties, and the Chongqing Urban Area, with the areas of 172.48 hm^2, 109.59 hm^2, 140.25 hm^2, 187.80 hm^2, 109.19 hm^2 respectively. 59.79% of the other construction land in the Fuling City was from cultivated land, and it was mainly from forestry

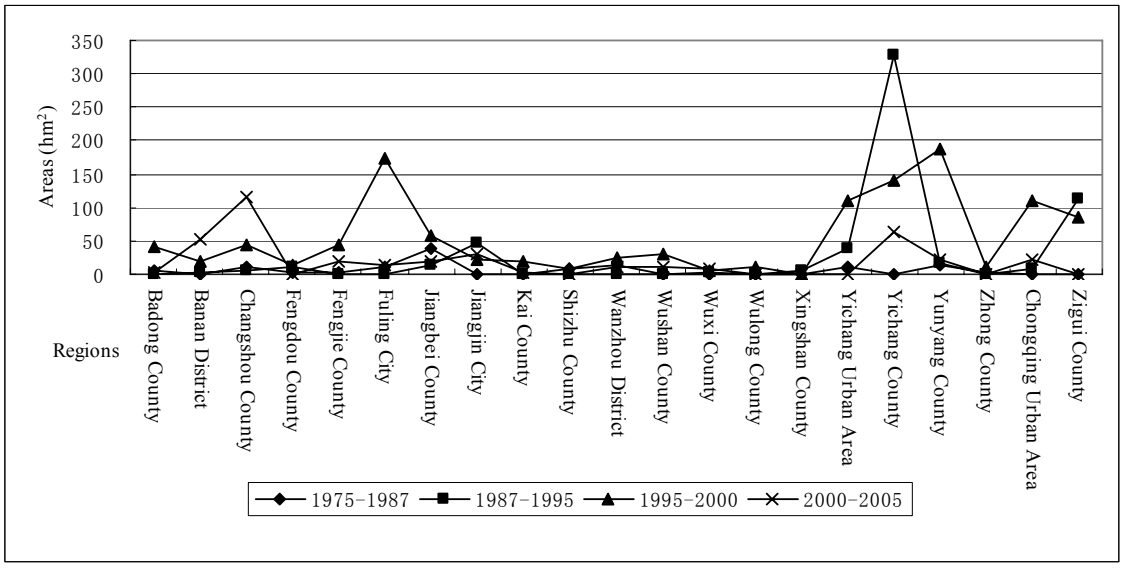

Figure 6 Areas of other construction land occupying agriculture land at different periods

land in the other four regions with the proportion of 99.32%, 78.66%, 97.04%, 100.00%, respectively (Figure 6).

From 2000 to 2005, the agricultural land area annually occupied by other construction land in Changshou County was the largest, which was up to 114.41 hm² with 97.62% of the occupied land being from grassland. In other regions, other construction land mainly occupied forestry land. Regions which occupied larger proportion of cultivated land, were basically developed regions, such as Ba'nan District, Jiangjin City, Yichang County and Chongqing Urban Area.

From 1987 to 1995, the annual area of other construction land occupying agriculture land in Yichang County reached to a peak value of 327.00 hm², mainly occupied forestry land at a proportion of 97.04%. From 1975 to 1987, the annual area of other construction land occupying agriculture land was small, among which Jiangbei County occupied the largest, but only 38.13 hm², mainly cultivated land, accounting for 90.68%. Occupied cultivated land was in larger proportion in regions such as Changshou County, Fuling City, Jiangbei County, Wanzhou District, Zhong County, with the proportion of 87.50%, 56.59%, 90.68%, 100%, 100% respectively. Generally speaking, where other construction land increased rapidly were Chongqing Urban Area and Yichang Urban Area, and counties near these two areas. Land for other construction had little increase in the middle reservoir area including Kai County, Shizhu County, Wulong County, where the industry development was slow. Occupied cultivated land was in relatively smaller area after 1995, while forestry land turned out to be the mainly occupied land type.

(4) Inverse change of construction land

Transformation from agricultural land into construction land is called change while transformation from construction land into agricultural land is called inverse change. In analysis, the inverse change of construction land mainly refers to the transformation of other construction land into grassland.

From 1975 to 1987, other construction land was rarely transformed into grassland except in Kai County and Zhong County with the annual transformed area of only 0.71 hm² and 1.66 hm² respectively.

From 1987 to 1995, the annual transformed area increased. Transformation area of the Jiangjin City was the largest, however, it was only 9.46 hm².

From 1995 to 2000, the annual transformed area increased obviously in Fengdu, Jiangbei and Kai counties, where the annual transformed areas were 52.35 hm², 17.77 hm², 20.27 hm², respectively.

From 2000 to 2005, inverse change was relatively more frequent. The peak values were in Fengjie County, Jiangjin City, Wanzhou District, Wuxi County and Yunyang County where the transformed areas were 8.70 hm², 60.19 hm², 50.69 hm², 36.43 hm² and 18.81 hm², respectively (Figure 7).

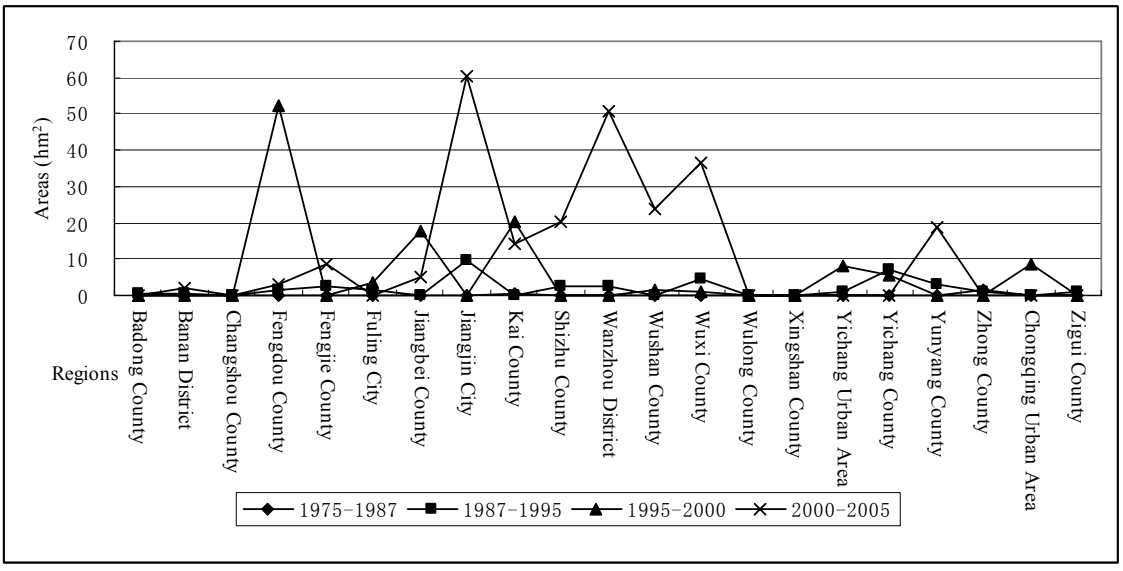

Figure 7 Areas of other construction land transformed into grassland land at different periods

(5) Land use changes in the submerged area

Flooded area was increasing in the Three Gorges Reservoir Area with water level rise. After 2000, a large area of forestry land in Badong County and Zigui County was flooded, with an amount of 279.48 hm² and 2359.08 hm² respectively. Grassland flooded in Badong County, Fengjie County, Wushan County, Yunyang County and Zigui County was 40.05 hm², 563.35 hm², 94.26 hm², 24.54 hm² and 39.99 hm², respectively. Urban area of Yunyang County was flooded with an area of 30.89 hm². Rural settlements were flooded in Zigui County, whose flooded area was 2776.40 hm². As the water level continued rising, there would be more land to be flooded by the rivers in the Three Gorges Reservoir Area.

2.3 Buffer analyses

2.3.1 Buffer division

Taking the main stream of the Yangtze River in the Three Gorges Reservoir Area as the center line of buffer area, according to the distance from the main land use types to the river we set up buffers with buffer area radius of 5 km, 20 km, 35 km, 50 km, 65 km, 80 km and 95 km, and overlay the buffers and land use maps to extract the area of each land use type in each buffer.

2.3.2 Distribution traits of each land use type in each buffer

This study mainly analyzed distribution traits of different land use types in different buffers in 2005. It overlaid the buffer map and land use maps to extract the area of each land use type in each buffer. The change traits of cultivated land, forestry land, urban and rural settlements in different buffers are shown in Figure 8. Change traits of cultivated land and forestry land were relatively the same in different buffers, showing a trend of increase first and then followed by a decrease. In the 5 km buffer zone, the area of cultivated land was larger than that of forestry land, the cultivated land being 41, 7592.62 hm² and forestry land 22, 7005.62 hm². In the 20 km buffer zone, the area of cultivated land and forestry land reached the peak value at the same time, with cultivated land of 968335.17 hm² and forestry land of 94,5888.13 hm². Outside the 20 km buffer zone, cultivated land and forestry land decreased rapidly. Forestry land decreased in line with the decrease of buffer radius. At 50 km an inflexion came out in cultivated land, then it decreased slowly when it reached 95 km with the area of cultivated land up to 2979.63 hm² and forestry land up to 2, 0027.87 hm². According to the analyses, the regress relation between the area of cultivated land in different buffers and the buffer radius was as the equation, $A=-8659.3D+780419.00$ ($R^2=0.6226$).Change traits of the urban area were similar to those of the rural settlements, which decreased overall. Rural

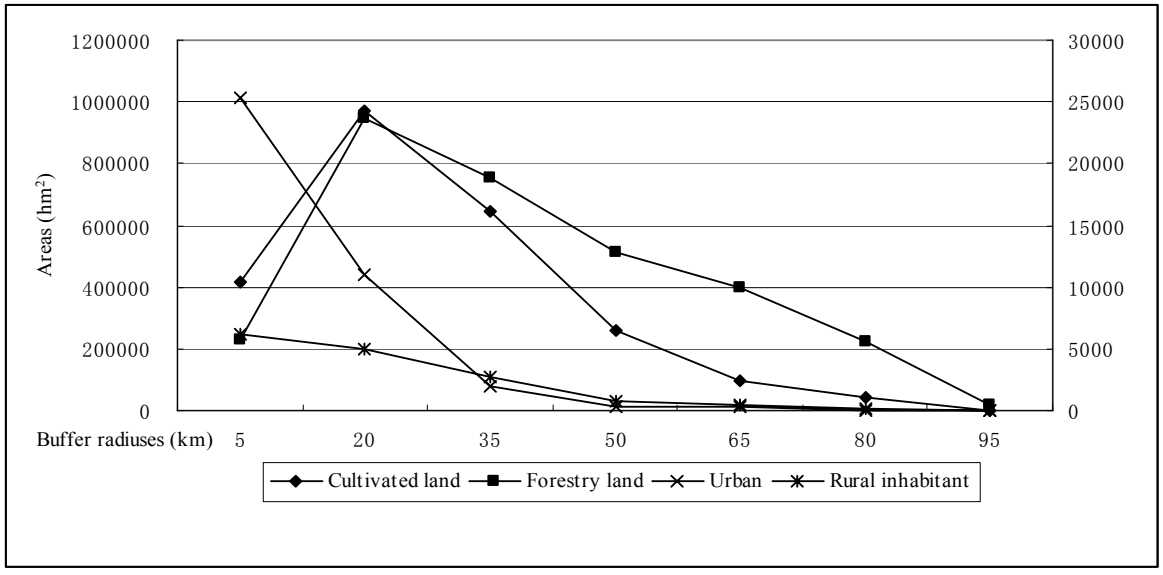

Figure 8 Distribution in buffer of different land use types

settlements decreased at a relatively lower rate with the decrease of radius, indicating that rural settlements were distributed in every buffer radius zone, and mainly distributed in areas at the radius of 5 km, 20 km and 35 km, which were in coincidence with the distribution of urban area, which indicated that rural settlements were distributed mainly around Urban Areas with high intensity. Urban Areas were distributed at the radius of 5 km and 20 km, and began to decrease gradually, with no distribution of Urban Areas above 65 km. Where the intensity of Urban Areas was high was at the radius of 5 km around the river, which proved that river's influence on urban expansion was significant. The Urban Area was 25264.80 hm². According to the analyses, the regression relation between the area of urban in different buffers and the buffer radiuses was as the equation, $A=-9020.40\ln D+37978.00$ ($R^2=0.9325$, $D\leq 65$ km), the regression relation between the area of rural settlements in different buffers and the buffer radiuses was as the equation, $A=-2367.80\ln D+10679.00$ ($R^2=0.9170$, $D\leq 80$ km). Overall, the river had great impact on urban and rural settlements distribution, which influenced the urban and rural settlements to distribute along the river because production and live need water, as a result, in the process of town planning, it is necessary to focus on the river influence on urban and rural settlements and make a rational distribution by selecting the right distance from the river.

2.3.3 Urban expansion in buffer zone

We extracted transformation area of different land use types in different buffer zones by overlying each land use change maps and buffer zones (Baskent and Kadiogullari 2007; Porter-Bolland et al. 2007). The analyses focused on urban expansion in the buffer zones. The most dramatic expansion of urban areas was at the 5 km buffer zone, the urban expansion was the least from 1995 to 2000, while it was the most dramatic from 2000 to 2005. The main land occupation type was cultivated land in all period except from 1995 to 2000 during which the main occupation type was forestry land. At the 20 km buffer zone, the area of urban expansion during 2000 to 2005 was the largest among all period and the cultivated land accounted for 91.41% of the total occupied land. All occupied land during 1975 to 1987 was cultivated land. Outside of the 35 km buffer zones, urban expansion scale was relatively smaller. Urban expansion existed from 5 to 65 km buffer zones during 1995 to 2005.

2.3.4 Increase in rural settlements in the buffer zone

With the advancement of the Three Gorges resettlement work, rural settlements are increasing continually. Judged from the buffer radius, rural settlements increased mostly at 5 km buffer zone, the increased area was 540.04 hm² from 1975 to 1987, with average annual increase of 45.00 hm², mainly transformed from cultivated land by 87.68%. From 1987 to 1995, the average annual increase of rural settlements was 52.57 hm², with a decrease in occupation ratio of cultivated land and an increase in occupation ratio of forestry land and grassland. From 1995 to 2000, the average annual increase of rural settlements was 664.33 hm², with higher forestry land occupation ratio and less cultivated land and grassland occupation ratio. From 2000 to 2005, the average annual increase of rural settlements was 139.72 hm², with increase speed lowered compared with the previous period , mainly occupying forestry land. The change traits of rural settlements at 20 km buffer zone were basically the same as that at 5 km buffer zone. The new rural settlements were decreasing at 35 km, 50 km and 65 km buffer zones. Judged from the periods, the rural settlements increased the most from 1995 to 2000. Judged from the distribution buffer zones, the rural settlements increase were the largest at 5 km and 20 km buffer zones, mainly increased from cultivated land, forestry land and grassland. Before 1995 rural settlements occupied mainly cultivated land, while after 1995 the occupation proportions of forestry land and grassland kept increased.

3 Conclusions

(1) Based on the data of land use in 1975, 1987, 1995, 2000, 2005, this paper has analyzed the spatial distribution of different land use types and quantitative change of each land use type. According to the transformation matrix, this paper analyzes the transferring process of each land use

type in each period, especially spatial distribution differences of some land use type, then analyses the distribution traits and change regulation of each land use type in buffer zones, especially the traits of urban expansion and rural settlements increase. Two thoughts are reflected in the study, one is the connection changes of temporal and spatial, which is used to study on whole land use change traits of the Three Gorges Reservoir Area and change traits in each county and in each period, and to analyze the spatial differences of land use changes; the other is the connection of land use changes in each county and in buffer zones. Overall, with a relatively long period and from different angles, this paper can have a good reflection on land use changes during 30 years.

(2) Seen from spatial distribution of land use types, cultivated land in the Three Gorges Reservoir Area is mainly distributed in the north-west of the Yangtze River, forestry land and grassland are mainly distributed in the south-west of the Yangtze River. With the economic development of the reservoir area, the scale of urban construction land keeps expanding, especially in the Chongqing Urban Area, Yichang Urban Area, Wanzhou Urban Area. With the radiation influence of developed regions, the urban construction land area surrounding the Chongqing Urban Area is increasing. In addition, the water area is increasing because of water reserve.

(3) By generalizing the quantitative traits and the transformation traits of the land use in the Three Gorges Reservoir Area, land use changes in the reservoir area shows the following characteristics, firstly, as time went by, human activities has a great impact on land use transformation, especially on the occupation of cultivated land, forestry land and grassland by urban expanding. Secondly, as for the mountainous regions, construction occupied lots of cultivated land, forestry land and grassland, which exerts great impact on ecological environment protection. Thirdly, because of the influences of mountain and cultivated land protection, constructive land relies more and more on forestry land and grassland. Fourthly, due to the water level rise recently, the flooded area is gradually expanding in the reservoir area. Fifthly, the transformation of other construction land into grassland indicated that other construction land is on the way of ecological restoration and improvement.

(4) After analyzing the differences of land use changes in each county, this paper focuses on change traits and differences on urban, rural settlements and other construction land, and analyzes the inverse change traits of construction land and land use changes in flooded regions. Overall, in the early period urban expansion occupied a small amount of agricultural land. With the initiation of the Three Gorges Project, economy in the reservoir area developed rapidly, together with the reserving water, new town construction increased the agricultural land occupation in the later period. The cultivated land and forestry land are largely in the occupied agricultural land, with different proportion in each period. Urban areas expanded rapidly in developed regions with more agricultural land occupied. In remote mountainous regions the urban area expanded slowly, basically by the way of renovating the old Urban Area. Agricultural land occupied by the rural settlements was mainly cultivated land in the early period and then it gradually turns to forestry land, which results from cultivated land protection policy. Seen from the change of other construction land, the hot time of increase was around 2000, and other construction land increased dramatically in the Chongqing Urban Area, Yichang Urban Area and their surrounding regions. In the middle reaches of reservoir area, other construction land increased a little. The inverse change of constructive land reflects that ecological environment in the reservoir area was being improved and the extent of land use was lowered, thus it would be beneficial for the sustainable land use in the reservoir area.

(5) In the reservoir area, the river has impacts on the land use. Rivers have radiating influences on land use types. The best radiation distance of cultivated land and forestry land is between 10 km to 35 km buffer zones. Rivers have great influence on the distribution of urban and rural settlements, which are the water resource of living and production. So in the process of urban and rural planning, it is necessary to consider the influence of rivers on the urban and rural settlements position. Urban expansion and rural settlements increase are mainly at buffer zones of 5 km and 20 km. As for the Three Gorges Reservoir Area, it is necessary to strengthen land management, and control urban expansion and rural settlements

increase at random by strictly abiding by land use planning and urban planning.

(6) As for mountainous regions, the most important is intensive land use due to the limited cultivated land and the fragil ecological environment in the reservoir area. Intensive land use is an important guarantee to realize sustainable land use by relying on strengthening cultivated land protection, ecological environment construction and improving intensive extent of constructive land. This paper analyzes the land use change process in the reservoir area, and the effect of land use changes. Land use change will become a hot topic in the Three Gorges Reservoir Area because it is greatly related to the sustainable development of this area.

Acknowledgements

This paper was supported by the National Science and Technology Support Project (Grant No. 2006BAB15B03). I would like to thank professor ZHENG Xinqi and associate professor KANG Zhizhong for their instruction and advice.

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