Land Use Zoning in Three - Gorge Reservoir Region: A Case Study of Fengdu County in Chongqing Municipality

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Abstract Taking Fengdu County in Three - Gorge Reservoir region as an example, this paper applies the dynamic clustering analysis model, and divides land resource utilization of Fengdu County into three zones: Yangtze River valley economic zone, low mountains and hills agricultural zone, and low and middle agricultural, forestry and animal husbandry zone. It also analyzes current situation and existing problems in the land utilization of every zone, and finally puts forward corresponding recommendations.

Key words Three - Gorge Reservoir region, Fengdu County, Dynamic clustering analysis model, Land utilization zoning

The Three - Gorge Reservoir region is an important sensitive ecological economic zone in China and has high density of population, complex geology and landform, poor natural resources and land conditions, and small per capita area of cultivated farmland[1]. With land flooded due to water storage of the Three Gorges Dam, resettlement of inhabitants, relocation and construction of new city and industry and mining, there has been great changes in utilization structure and layout of land in the reservoir region[2]. Relevant researches have shown that functions of ecological system in Three - Gorge Reservoir region remain in the state of local improvement, but overall degradation or even deterioration, while land utilization / land coverage changes driven by human activities are the most direct reason for overall degradation of ecological system[3-4]. In this situation, scientific and reasonable development and utilization of land resources become extremely important in this region. Land use zoning is an integral part of overall plan for land use, major means of reasonable development and highly effective use of land resources, and also major basis for determining land use and taking appropriate measures[5].

Fengdu County of Chongqing Municipality lies in upper reaches of Yangtze River and central zone of Three - Gorge Reservoir region. It plays a significant role in maintaining ecological security of Three - Gorge Reservoir region and promoting social sustainable development of the Yangtze River valley. Its ecological environment and land use characteristics are representative in Three - Gorge Reservoir. Therefore, it is selected to divide land use zones from ecological, social and economic perspectives by dynamic clustering analysis model. Through analyzing land use characteristics and problems in each zone, I put forward countermeasures, in the hope of providing reference for land zoning at county level in Three - Gorge Reservoir region, promoting reasonable development and utilization of land in this region, and so as to realize coordinated and sustainable development of socio-economy, resource and environment,

1 General situation of Fengdu County

Situated at upper reaches of Yangtze River, the middle part of Chongqing Municipality and central zone of Three - Gorge Reservoir region, Fengdu County is 172 km from downtown of Chongqing. With an area of 2 904.07 km^2, Fengdu County governs 19 towns and 12 townships. In 2009, the GDP of this region was 6.570 76 billion yuan, 16.2% of the previous year. The added value of primary industry was 1.448 18 billion yuan, with growth rate of 5.9%, accounting for 22% of GDP, and the number of employed people in primary industry reached 166 000; the added value of secondary industry was 2.503 69 billion yuan, with growth rate of 29.9%, accounting for 38.1% of GDP, and the number of employed people in secondary industry was 37 000; the added value of tertiary industry reached 2.618 89 billion yuan, with growth rate of 7.7%, accounting for 39.9% of GDP, and the number of employed people in this industry was 69 000. The local financial revenue reached 565 million yuan.

2 Selection of land use zoning models

Land use zoning usually adopts clustering analysis method. This method is to determine closeness degree between things and divided things that have close characteristics into the same type. Compared with regression model, the dynamic clustering method is not one-sided; compared with fuzzy clustering and correlation analysis, the dynamic clustering can directly and obviously reflect zoning results[6-7]. Therefore, I adopt this model to conduct land resource use zoning.

3 Land use zoning of Fengdu County

3.1 Selection of samples and factors Considering organization and implementation of development strategy, to facilitate administrative management, here I take the most basic administrative unit "town (township)" as a unit, and divide Fengdu County into 31 sample units. Selection of indicators for land use zoning is

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based on characteristics of land use in Fengdu County. In each unit, 17 factors are taken as variable indicators according to social, economic and natural conditions.

Table 1 Indicator system for land use zoning

Indicator type	Specific indicator	Indicator No.	Unit
Ecological	Arable land at steep slope above 25 degrees	1	hm^2
	Forest area per capita	2	hm^2/person
	Forest coverage rate	3	%
	Water area index	4	%
	Percentage of geological disasters	5	%
	Average height above sea level	6	m
Social	Population density	7	person/km^2
	Urbanization rate	8	%
	Farm land per capita	9	hm^2/person
	Road network density	10	m/km^2
	Consumption of agricultural fertilizer	11	t
	Mineral resources	12	–
Economic	Output value of secondary and tertiary industry per capita	13	yuan/person
	Land utilization rate	14	%
	Per unit area yield of grain crops	15	t/hm^2
	Cultivated land occupied by construction	16	hm^2
	Per unit area yield of cash crops	17	t/hm^2

Notes: due to lack of specific data, mineral resources are divided into three types (abundant, intermediate and few or no) and denoted as 3, 2, and 1 respectively; the per unit area yield of rape seed is taken as the per unit area yield of cash crops; calculation of road network density is added with area of rural road; water area index does not contain reservoir.

3.2 Zoning result According to indicator value of samples and relevant data, I conduct calculation with the aid of DPS statistical analysis software. After such standardization, 4 numbers of categories are selected. Through several times of adjustment, dynamic clustering result is obtained, as listed in Table 2.

Table 2 Dynamic clustering result of Fengdu County

Township name	Initial category	Final category	Distance from condensation point	Township name	Initial category	Final category	Distance from condensation point
Shetan	2	2	0.63	Gaojia	3	2	0.94
Rensha	2	2	0.98	Xingyi	2	2	0.63
Baohe	1	1	0.18	Shuanglu	2	1	0.56
Xumingsi	1	1	0.36	Zhanpu	1	1	0.32
Dongjia	1	1	0.35	Mingshan	2	2	1.49
Longhe	4	4	0.00	Longkong	2	2	0.45
Chongxing	1	1	0.19	Jiangchi	1	1	0.26
Qinglong	1	1	0.29	Wuping	3	3	0.48
Shuanglongchang	1	1	0.23	Taipingba	1	3	1.10
Sanyuan	1	1	0.16	Dudu	2	3	0.85
Baoluan	2	3	0.34	Jilong	3	3	0.47
Sanhe	2	2	1.61	Lizi	2	1	0.34
Huwei	2	2	0.26	Sanjian	2	3	0.41
Shuren	1	2	0.40	Nantianhu	2	3	0.08
Shizhi	2	2	0.68	Sanba	2	3	0.46
Zhenjiang	1	1	0.79				

Samples are basically similar in clustering factors, but not totally the same. Besides, different samples have certain fluctuation due to land use indicators. Therefore, when determining final zone, following the principle of regional unity and convenient management, I properly adjust and improve the clustering result; include Zhenjiang Town into the second category, Longhe Town into the third category, bringing them to close to future development goal. Then, I divide Fengdu County into 3 land use zones. The zoning results and indicator values are listed in Table 3 and Table 4 separately.

4 Characteristics of land use zones and recommendations

4.1 Yangtze River valley economic zone This zone is mainly distributed along Yangtze River valley, suburban economic circle and commercial development zone along the bank of Yangtze River. Land use zoning indicators for this zone are mainly social and economic indicators. Population density, urbanization rate, con-

sumption of agricultural fertilizer, output value of secondary and tertiary industry per capita, land utilization rate, cultivated land occupied by construction, and percentage of geological disasters are dominant in these three zones. Only percentage of geological disasters belongs to ecological indicators, other 6 indicators are social and economic indicators by half. It shows that this zone plays a key role in social and economic functions of the whole county.

This zone has 11 towns in total. Sanhe Town and Mingshan Town are economic, political and cultural centers of this county. There is the national-level famous scenic spot, Fengdu Ghost Town and Snow Jade Cave. Besides, natural conditions of agricultural land are favorable, the population density is high, and the traffic is convenient. Thanks to county center, Feng – Shi road and Feng – Dian road, the surrounding Huwei, Rensha, Shetan and Zhenjiang towns have excellent social and economic conditions and high level agricultural land. Especially, Shetan Town is the northern economic center, transshipment base of materials, and a comprehensive town of agricultural tourism and processing industry. Gaojia, Xingyi, Shizhi, Longkong and Shuren towns, radiated by Fengdu County, Feng – Shi road, Yu – Feng, Feng – Zhong road and Gaojia Town dock, have developed land and water transportation, and favorable social and economic conditions.

Therefore, it indicates that this zone is the central zone of economic development of Fengdu County. Its economic development speed and opportunity are better than other economic zones. However, its geological disasters occur more frequent than other two zones. What's worse, its ecological environment not only concerns social and economic development of Fengdu County, but also influences the whole Three – Gorge Reservoir region. In this situation, it should stress economic development, protection of ecological environment and control of pollution. Therefore, it is recommended that the construction land should be concentrated on this zone. Furthermore, it should prevent blind expansion, strengthen intensive use of land, attach importance to construction of greenery space and forest shelter belt of Yangtze River, and improve traffic at the same time.

Table 3 Result of land use zoning of Fengdu County

Land use category	Land use zone	Name of town
1	Low mountains and hills agricultural zone	Baohe, Xumingsi, Dongjia, Chongxing, Qinglong, Shuanglongchang, Sanyuan, Shuanglu, Zhanpu, Jiangchi, and Lizi
2	Yangtze River valley economic zone	Shetan, Rensha, Sanhe, Huwei, Shuren, Shizhi, Gaojia, Xingyi, Mingshan, Longkong, and Zhenjiang
3	Low and middle agricultural, forestry and animal husbandry zone	Longhe, Baoluan, Wuping, Taipingba, Dudu, Jilong, Sanjian, Nantianhu, and Sanba

Table 4 Indicator values for zoning of Fengdu County

Indicators	Yangtze River valley economic zone	Low mountains and hills agricultural zone	Low and middle agricultural, forestry and animal husbandry zone
Per unit area yield of grain crops // t/hm^2	3.55	3.84	3.58
Per unit area yield of cash crops (rape seed) // t/hm^2	1.36	1.67	1.49
Cultivated land occupied by construction // hm^2	12.91	3.00	1.11
Percentage of geological disasters // %	5.15	1.65	2.80
Consumption of agricultural fertilizer // t	4 210.79	1 880.82	2 413.82
Farm land per capita // hm^2/person	0.09	0.11	0.15
Forest area per capita // hm^2/person	1.12	1.90	6.60
Arable land at steep slope above 25 degrees // hm^2	122.45	78.64	161.89
Land utilization rate // %	94.43	94.30	91.86
Forest coverage rate // %	27.85	36.09	62.06
Water area index // %	1.24	1.44	1.36
Mineral resources	1.82	2.09	2.89
Population density // person/ km^2	480.41	298.75	148.84
Output value of secondary and tertiary industry per capita // yuan/person	1 012.08	705.09	609.48
Road network density // m/km^2	0.35	0.34	0.38
Urbanization rate // %	14.53	6.85	5.12
Average height above sea level // m	293.66	411.46	622.92

4.2 Low mountains and hills agricultural zone This zone is mainly low mountains and hills. Among the 17 indicators, only water area index, per unit area yield of grain crops and per unit area yield of cash crops are higher in the three zones, showing that only economy takes the superior position in the whole county.

In this zone, there are 11 towns, among which Sanyuan Town is characterized by its characteristic and sightseeing agriculture. Baohe and Shuanglongchang townships also develop characteristic agriculture, and have excellent natural quality of agricultural land, but have poor traffic condition due to far from the county. Dongjia, Xumingsi, Chongxing and Qinglong towns mainly develop agriculture and county border economy. The southern Jiangchi Town is the farthest from Fengdu County. Greatly influenced by the southern Shizhu County, Jiangchi Town is single in economic

development. Shuanglu Town and Zhanpu Town are close to Sanhe Town, and along the bank of Yangtze River. However, because Sanhe Town is a new town, its radiation function is not brought into full play, in addition to poor traffic, Shuanglu Town and Zhanpu Town develop relatively slowly compared with other towns, and the economy is still mainly agriculture. Therefore, the demand of construction land in these two towns will be higher than other towns, and they will advance towards the development trend of Yangtze River valley economic zone. Lizi Town is situated in the southern part, but most part is low hills and mountains. Agricultural land is mainly cultivated land; construction land is larger compared with other towns; agricultural economy is better. Nevertheless, it is far from Fengdu County, economic development is single and traffic is inconvenient.

This zone will be the major zone of characteristic and sightseeing agriculture of Fengdu County. In the aspect of land use, it is recommended to strengthen protection of capital farmland, consolidate its position as main producing region of grain, and reinforce construction of towns and increase traffic construction, to provide transportation service for cash crops of this zone.

4.3 Low and middle agricultural, forestry and animal husbandry zone This zone is a mountainous agricultural zone with poor production conditions. The altitude of this zone is generally above 1 000 m. Slight cold, much fog and high humidity are characteristics of this zone. Forest land is the major land use type. Among the zoning indicators, arable land at steep slope above 25 degrees, forest land per capita, forest coverage rate, average height above sea level, road network density and mineral resources are dominant in these three zones. Four indicators are ecological and other three are social indicators. It indicates that this zone plays a key role in social and ecological functions of the whole county.

This zone has 9 towns: Longhe Town belongs to southern agricultural, forestry and animal husbandry economic zone; its neighbor Wuping Town also mainly develops agriculture, forestry and animal husbandry; however, due to low and middle mountainous area, natural conditions are worse, traffic condition is also worse (only one trunk road passes through them); Nantianhu Town mainly develops tourism and characteristic agriculture; Sanjian Township and Sanba Township mainly develop agriculture, are close to Fengdu County, so the natural conditions are better, but the terrain is uneven. Taipingba, Jilong and Dudu townships and Qiyaoshan Forest Farm and Sanfu Forest Farm are at the edge of southern region, and in the low and middle mountainous yellow soil region, the traffic condition and natural condition of agricultural land are poor. Baoluan Town mainly develops building materials, ecological sightseeing, tourism and recreation. The agricultural land use is at the moderate level. However, due to large area of forest land and small proportion of land for town construction, the industrial and commercial development is slow. Thus, it is classified as southern middle mountainous agricultural, forestry and animal husbandry economic zone. In summary, this zone is farthest from Fengdu County and has poor traffic and cultivation conditions. This zone has Sanfu and Qiyaoshan state-owned forest farms, so the overall ecological environment is good, and the possibility and degree of industrial and agricultural pollution are smaller than other two economic zones. However, there is also prominent problem of cultivation on steep slopes. Thus, it is suggested to continue implementing the policy of conceding the land to forestry.

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