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# The Study on Provincial-level Land Consolidation Zoning

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**Abstract** The principles and methods of regional land consolidation in Yunnan Province are expounded. On the basis of differences in topography, climate, soil, hydrology and other natural conditions and the characteristics of spatial layout of land use, agricultural zoning, cropping system and land consolidation measures, the land consolidation zoning indicator system composed of five indicators covering ecological environment, socio-economy, land use, land consolidation and land quality is established by using the GIS spatial analysis and mathematical analysis. Against this backdrop, the Yunnan Province is divided into five first-level land consolidation zones, including the middle-mountain lake basin plateau consolidation zone in central Yunnan, the middle and low mountain wide valley basin consolidation zone in southwest Yunnan, the karst middle and low mountains consolidation zone in southeast Yunnan, the high-mountain and highlands consolidation zone in northeast Yunnan, the middle-mountain and mountain plateau consolidation zone in northeast Yunnan.

**Key words** Yunnan Province, Land consolidation, Types, Zoning

Land consolidation is a campaign launched in accordance with the designed targets and purposes of economic and social development requirements as well as the overall planning of land use. It mainly applies the administrative, economic, legal and project approaches to comprehensively manage the land use so as to promote farmland protection and rational use of land, improve land efficiency and enhance production and living conditions and ecological environment. Due to the spatiality and naturality of land, there are differences in the natural, economic and social conditions among different zones, thus, the land use also has regional differences. In this sense, the land consolidation zoning will focus on the similarities and differences of conditions, land use methods, purposes and management measures of land use, to divide the land, which will be consolidated, into different zones based on the suitability of land resources and the current situation of land use, which will provide the basis for the technological design, construction and supervision of the land consolidation<sup>[1]</sup>.

## 1 The principles and methods of land consolidation zoning

**1.1 Land consolidation zoning principles** On the basis of previous studies, including six principles of land consolidation zoning in China put forward by Feng Zhiming<sup>[2]</sup> *et al.*, three principles of land use comprehensive zoning put forth by Zheng Weiyan<sup>[3]</sup> *et al.* and the six principles of land use comprehensive zoning proposed by Yang Zisheng<sup>[4]</sup> *et al.* and considering the natural and geographical conditions, the socio-economic development level, and utilization situation of water resources, the land consolidation zoning in Yunnan Province should focus on the following principles:

lowing principles:

(1) The principle of sustainable development. The purpose of land consolidation lies on increasing effective farmland, improving the quality of agricultural land, perfecting agricultural infrastructure construction, raising farmers' income and realizing the sustainable use of regional land resources.

(2) The principle of comprehensive benefits. The Land consolidation benefits are the unification of the social, economic and ecological benefits. Therefore, in the implementation of land consolidation zoning, the comprehensive and long-term concept should be established and the guidelines of "comprehensive planning, rational distribution, comprehensive development, supporting construction" should be strictly implemented, and the comprehensive benefits principle should be followed.

(3) Establish the principle of basic farmland protection and grain security. Land, especially arable land, is the basis of food production. Land resources have to undertake its basic functions to protect the food security of the people from all ethnic groups. According to the actual situation in Yunnan Province, under the premise of ensuring the protection of basic farmland indicators, the basic farmland should be partially adjusted and optimized according to the policy of "do not reduce the arable land area, improve the land quality and ensure stable overall layout".

(4) The principle of ecological protection. Land consolidation should adhere to the basic policy of unifying development and protection, so as to integrate development and protection organically.

(5) The principle of coordination. During land consolidation, the land use in different areas should be coordinated to the balance of the economic, social and ecological issues during land use and properly deal with the protection of resources and development.

(6) The principle of linking between the preceding and the following. Land consolidation zoning will divide the land according to the land use status and functional demands on the basis of carrying out the tasks required by the nation in terms of national west-

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ern ecological construction, prospering the land and stabilizing the border areas, overall planning of land use. On the one hand, the land zoning will be on a planning further refinement and depth, while subordinates land zoning is the further development of the plan designed by the government at the higher level, on the other hand, it will offer specific tasks and requirements on the planning of land consolidation at the lower level.

(7) The principle of adjusting measures to local conditions. Land consolidation zoning will be based on the land use conditions of Yunnan Province, and fully consider the major contradictions and problems in land use, follow the objective laws of economic, social and natural development, so as to launch the land consolidation zoning scientifically. The land consolidation zoning will express the economical society and land resources characteristics and land use strategic target and policies, which will be conducive to supporting the rational and orderly implementation of land consolidation work.

**1.2 Research methods** Land consolidation zoning mainly relies on the spatial layout of land consolidation planning, agricultural zoning and farming system characteristics as well as the topography, climate, soil, hydrology and other natural conditions. The zoning adopts GIS spatial analysis and mathematical analysis.

(1) GIS spatial analysis. Spatial analysis is one of the most common ways of extracting the spatial hidden information in geographic information system. Through superimposing the layers required by the related research analysis, it will generate a new data layer of the operation, which combines the properties of the origi-

nal multilayer elements.

(2) Mathematical analysis methods. Mathematical analysis method belongs to quantitative research. Different mathematical methods should be applied according to different problems. The method is able to quantify the problems. In this paper, factor analysis is adopted, on the one hand, by using factor analysis; the number of indicators of analysis can be reduced, which is convenient for clustering. On the other hand, by using cluster analysis, the similarities and differences among areas can be concluded and distinguished, which is conducive to zoning land use zones.

## 2 Land consolidation zoning in Yunnan Province

**2.1 Indicator system** The indicator system of indicators is the actual application and specific manifestation of zoning principle. In the paper, the land consolidation zoning indicator system, which is composed of 5 indicators (*i. e.* ecological environment indicators, socio-economic indicators, land use indicators, land consolidation indicators, land quality indicators) and 18 Meta indicators, on the basis of research requirements, possibly accessible information and the previous indicator system of comprehensive zoning of land use (Table 1).

### 2.2 The process and procedures of land consolidation zoning

**2.2.1 Data normalization processing.** Data normalization process is designed to eliminate the differences of each dimension in terms of units and orders-of-magnitude, so that the data will be transversely comparable.

**Table 1 Land consolidation zoning indicator system**

Indicator item	Code	Meta indicator	Source or calculation methodology
Ecological environment indicators	I <sub>1</sub>	Forest coverage rate( % )	The second national land survey data of Yunnan Province
Socio-economic indicators	I <sub>2</sub>	Urbanization level( % )	From 2010 statistical yearbook data
	I <sub>3</sub>	Per capita occupancy of grain( Kg/person)	From 2010 statistical yearbook data
	I <sub>4</sub>	GDP per capita( ×10 <sup>4</sup> yuan)	From 2010 statistical yearbook data
Land use indicators	I <sub>5</sub>	Net area of cultivated land( hm <sup>2</sup> )	The second national land survey data of Yunnan Province
	I <sub>6</sub>	Per capita area of cultivated land( hm <sup>2</sup> /person)	The second national land survey data of Yunnan Province
	I <sub>7</sub>	Land reclamation rate ( % )	The second national land survey data of Yunnan Province
	I <sub>8</sub>	The proportion of construction land( % )	The second national land survey data of Yunnan Province
	I <sub>9</sub>	The proportion of city and town industrial and mining land to that of the construction land( % )	The second national land survey data of Yunnan Province
Land consolidation indicators	I <sub>10</sub>	The potential of cultivated land increased by land consolidation( hm <sup>2</sup> )	The second national land survey data of Yunnan Province
	I <sub>11</sub>	The potential of cultivated land increased by land reclamation( hm <sup>2</sup> )	The second national land survey data of Yunnan Province
	I <sub>12</sub>	The potential of cultivated land increased by land development( hm <sup>2</sup> )	The second national land survey data of Yunnan Province
Land quality indicators	I <sub>13</sub>	>25°Land area ratio( % )	The second national land survey data of Yunnan Province
	I <sub>14</sub>	Water and soil loss area ratio of cultivated land( % )	Remote sensing survey of soil erosion in Yunnan Province
	I <sub>15</sub>	Average farmland soil erosion modulus( t/km <sup>2</sup> · a )	Remote sensing survey of soil erosion in Yunnan Province
	I <sub>16</sub>	≤6°Land area ratio( % )	The second national land survey data of Yunnan Province
	I <sub>17</sub>	Effective irrigation rate of farmland( % )	The second national land survey data of Yunnan Province
	I <sub>18</sub>	Terrace land change level( % )	The second national land survey data of Yunnan Province

**2.2.2 Factor analysis.** Factors affect the sustainable development are determined by using the SPSS statistical software.

Through using the correlation between the original indicators, the dimension of indicators is reduced, in order to achieve the purpose

of a small number of common factors instead of more original indicators, so as to conduct comprehensive analysis.

Matrix form is;  $X = BZ + E$

Wherein,  $X$  is the original variable vector,  $B$  is a common factor load coefficient matrix,  $Z$  is common factor vector,  $E$  is vector of residuals.

Based on the above analysis model, principal component analysis is adopted to extract the common factor; the cumulative contribution of each common factor means containing more than 87% of the original indicator information; the common factors or principal components is a reflection of the original indicator information; take the biquadrate maximum orthogonal rotation method for rotating, to ensure the respective components of the vectors of the common factor are independent of each other. The characteristic value and the contribution of each factor can be seen in Table 2 and Fig. 1.

**2.2.3 Common factor explanation.** Through factor analysis, the 18 original indicators are reduced into 6 common factors. The load of the 6 common factors in the 18 original indicators is different. Though rotating the common factors by using the maximum variance method, the influence degree of original indicators on common factors can be clearly indentified, thus, the original indicating meaning represented by each common factor can be distinguished. The correlation matrix of the common factors and original

**Table 3 The correlation matrix of common factors and original indicators**

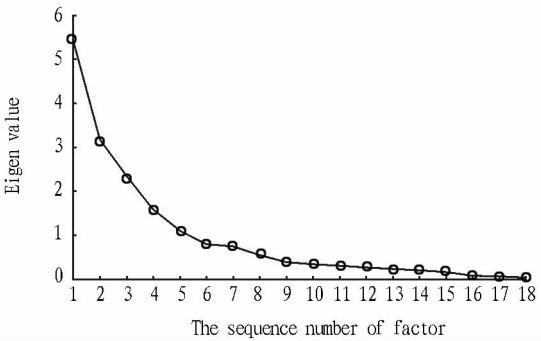
Original indicator	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Urbanization level(%)	0.881	-0.111	-0.113	0.020	0.121	-0.026
Per capita GDP (yuan/person)	0.816	0.136	-0.175	-0.087	0.306	-0.057
Per capita area of cultivated land(hm <sup>2</sup> /person)	-0.593	-0.067	0.322	0.221	0.242	0.459
The potential of cultivated land increased by land consolidation(hm <sup>2</sup> )	0.803	0.703	-0.292	0.020	0.116	-0.296
Per capita output of grain(kg)	-0.127	0.015	-0.042	-0.076	0.220	0.177
Water and soil loss area ratio of cultivated land(%)	-0.220	-0.108	0.886	0.032	-0.082	0.143
Average farmland soil erosion modulus(t/km <sup>2</sup> · a)	-0.184	-0.200	0.867	0.137	-0.166	-0.077
Effective irrigation rate of farmland(%)	0.060	-0.101	-0.769	0.353	0.241	-0.261
Terrace land change level(%)	-0.140	-0.556	-0.392	0.613	-0.066	-0.066
Forest coverage rate(%)	-0.203	-0.775	0.028	-0.011	0.251	-0.202
≤6°Land area ratio(%)	-0.004	0.721	-0.375	-0.075	0.473	0.021
>25°Land area ratio(%)	-0.152	0.130	0.379	0.094	-0.804	0.037
The potential of cultivated land increased by land reclamation(hm <sup>2</sup> )	0.812	0.123	0.072	0.913	-0.068	0.100
Net area of cultivated land(hectare)	-0.274	0.293	0.135	0.051	-0.057	0.829
Land reclamation rate of cultivated land(%)	-0.130	0.869	0.051	0.085	-0.163	0.317
The proportion of construction land(%)	0.287	0.392	-0.203	-0.071	0.077	-0.125
The potential of cultivated land increased by land development(hm <sup>2</sup> )	0.581	0.743	0.011	-0.195	0.101	-0.027
The proportion of city and town industrial and mining land to that of the construction land(%)	-0.159	-0.014	0.154	-0.004	-0.113	0.046

It can be seen from Table 3 that the first common factor has higher load in the proportion of urbanization level, per capita GDP, the potential of cultivated land increased by land consolidation, the potential of cultivated land increased by land reclamation, and it has the highest contribution rate of 19.752% in explaining the original variance, indicating that the economic development level of this area, the potential of land consolidation, land reclamation has a great impact on the zoning system. The second

indicators can be seen on Table 3.

**Table 2 Load sum of squares of rotating extraction factor**

Factor	Eigen value	Variance // %	Accumulative variance contribution // %
1	3.555	19.752	19.752
2	3.069	17.050	36.802
3	2.892	16.066	52.867
4	1.485	8.250	61.117
5	1.321	7.341	68.458
6	1.291	7.175	75.633
7	1.136	6.310	81.943
8	1.078	5.988	87.931



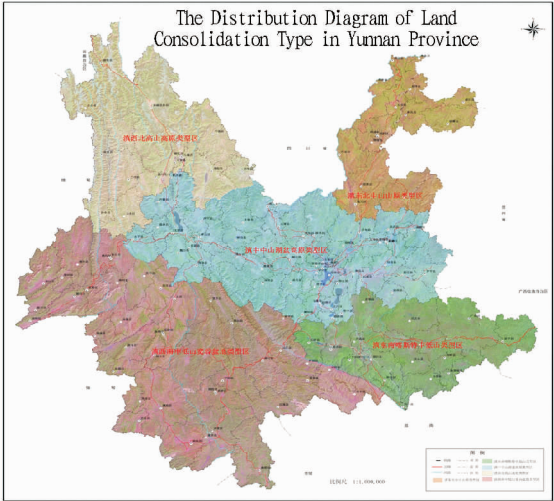
**Fig.1 Scree Plot of Factor Contribution**

common factor has high load in terms of land reclamation rate of cultivated land, the land development potential with the contribution rate of 17.050% ; the third common factor has high load in terms of the arable land area of soil erosion, soil erosion with the contribution rate of 16.066 % , the cumulative contribution rate of the first three common factors is more than 52.867% , indicating that the factors of land functional zoning in Yunnan Province mainly concentrated on the economic conditions of land use, the use

rate of farmland and soil erosion situation.

Against the above analysis, factors that affect the land functional zoning in Yunnan Province according to the degree of importance are as follows: land consolidation potential, land use degree and natural environment factors.

**2.3 The results of zoning** Through the above analysis, the land consolidation zoning in Yunnan Province can be divided into five types: the middle-mountain lake basin plateau consolidation zone in central Yunnan, the middle and low mountain wide valley basin consolidation zone in southwest Yunnan, the karst middle and low mountains consolidation zone in southeast Yunnan, the high-mountain and highlands consolidation zone in northeast Yunnan, the middle -mountain and mountain plateau consolidation zone in northeast Yunnan. On the basis of the five zoning, the essential land consolidation zones, land reclamation and land development are further planned. The specific division results can be seen on Table 4, 5, 6 and the land consolidation type can be seen on Fig. 2.



**Fig.2** Diagram of Land Consolidation Zoning Types in Yunnan Province

**Table 4** Divisions and potential grade division of land consolidation in Yunnan Province

The first-level zoning	Potential zone	County ( City, District )
The middle-mountain lake basin plateau consolidation zone in central Yunnan	The first-level potential zone	Wuhua, Guandu, Xishan, Chenggong, Jinning, Anning, Fumin, Yiliang, Chuxiong, Yao, Hongta, Tonghai, Yimen, Dali, Xiangyun Midu, Yongping
	The second-level potential zone	Panlong, Xundian, Malong, Luliang, Mouding, South, Dayao, Yongren, Wuding, Jiangchuan, Yangbi, Binchuan, Nanjian, Weishan
	The third-level potential zone	Songming, Luquan, Shuangbai, Yuanmou, Lufeng, Chengjiang, Huaning, Es-han, Xiping, Yuanjiang, Huaping
The middle and low mountain wide valley basin consolidation zone in southwest Yunnan	The first-level potential zone	Mojiang, Jinghong, Longyang, Tengchong, Changning, Luxi, Ruili, Yingjiang, Linxiang, Fengqing, Yun
	The second-level potential zone	Ningér, East King, Jinggu, Longling, Lianghe, Longchuan, Gengma
	The third-level potential zone	Zhenyuan, Menglian, Lancang, Shidian Yongde, Zhenkang ,Shuangjiang
The karst middle and low mountains consolidation zone in southeast Yunnan	The first-level potential zone	Gejiu, Wenshan, Mengzi ( major projects)
	The second-level potential zone	Yuanyang, Honghe, Yanshan, Maguan, Malipo (prospering land and stabilizing border areas) , Qiubei
The high-mountain and highlands consolidation zone in northeast Yunnan		Ninglang, Yulong, Shangri-la
The middle-mountain and mountain plateau consolidation zone in northeast Yunnan		Qiaojia, Suijiang, Yanjin, Daguan, Yiliang

**Table 5** Divisions and potential grade division of land reclamation in Yunnan Province

The first-level zoning	Potential zone	County ( City, District )
The middle-mountain lake basin plateau consolidation zone in central Yunnan	The first-level potential zone	Xishan, Jinning, Mouding, Lufeng, Xiping, Jianchuan, Luoping
	The second-level potential zone	Shizong, Fuyuan, Dayao, Yuanmou, Yimen, Heqing, Shilin
The middle and low mountain wide valley basin consolidation zone in southwest Yunnan		Mojiang, Jinghong
The karst middle and low mountains consolidation zone in southeast Yunnan		Gejiu, Kaiyuan, Yanshan, Funing
The high-mountain and highlands consolidation zone in northeast Yunnan		Lanping, WeiXi.
The middle-mountain and mountain plateau consolidation zone in northeast Yunnan		Dongchuan, Huize, Zhaoyang, Zhenxiong, Weixin

**Table 6** Divisions and potential grade division of land development in Yunnan Province

The first-level zoning	Potential zone	County ( City, District )
The middle-mountain lake basin plateau consolidation zone in central Yunnan	The first-level potential zone	Songming, Luquan, Xundian, Zhanyi, Shuangbai, Dayao, Lufeng, Xinping, Yuanjiang, Midu, Qilin, Eryuan
	The second-level potential zone	Yiliang, Mouding, Yongren, Wuding, Jiangchuan, Eshan, Xiangyun
	The third-level potential zone	Chuxiong, Yuanmou, Binchuan, Heqing, Yongsheng, Huaping, Yunlong, Xishan, Anning
The middle and low mountain wide valley basin consolidation zone in southwest Yunnan	The first-level potential zone	Simao, Ning'er, Mojiang, East King, Jinggu, Jiangcheng, Menglian, Linxiang, Yun, Shuangjiang, Gengma, Cangyuan, Luxi
	The second-level potential zone	Lancang, West Union, Menghai, Tengchong, Longchuan, Fengqing
	The third-level potential zone	Jinghong, Mengla, Longyang, Luxi, Yingjiang, Zhenyuan ,Yongde
The karst middle and low mountains consolidation zone in southeast Yunnan	The first-level potential zone	Jianshui, Mile, Yuanyang, Luchun, Hekou
	The second-level potential zone	Pingbian, Shiping, Honghe, Jinping, Yanshan, Guangnan, Funing, Xichou
The high-mountain and highlands consolidation zone in northeast Yunnan		Gongshan, Fugong, Lushui, Deqin, Old Town
The middle-mountain and mountain plateau consolidation zone in northeast Yunnan		Xuanwei, Ludian, Yongshan, Shuifu

3 Conclusions

Land consolidation zoning is the basic work of comprehensive land consolidation. On the basis of analyzing the existing zoning principle and according to the characteristics of Yunnan Province, seven zoning principles concerning sustainable development, comprehensive benefits, basic farmland protection, ecological protection, integration and coordination, connecting the proceeding and the following are put forward. By using the GIS spatial analysis, mathematical analysis and some other methods, the land consolidation zoning indicator system covering five indicators and 18 Meta indicators are established, so the Yunnan Province are divided into 5 first-level land consolidation zones. Namely, the middle-mountain lake basin plateau consolidation zone in central Yunnan, the middle and low mountain wide valley basin consolidation zone in southwest Yunnan, the karst middle and low mountains consolidation zone in southeast Yunnan, the high-mountain and highlands consolidation zone in northeast Yunnan, the middle -mountain and mountain plateau consolidation zone in northeast Yunnan. Against the backdrops, the essential zones of land consolidation, land rec-

lamation and land development are further divided. It is proven that such division is scientific, which complies with the characteristics of Yunnan Province and is conducive to the planning and implementation of comprehensive land consolidation in Yunnan Province.

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