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The evaluation of the sustainability of land consolidation and remediation in Funing County

H.G. Zheng[1,2*], F.R. Qiao[1], Y.Q. Li[3] , J.S. Zhang[1,2],L.J. Liao[1,2], D.J. Wang[4],J.X. Yu[1,2],

[1]*Water Resources and Building, Yunnan Agricultural University, Kunming* 650201, *China*
[2]*Engineering Research Center of Science and Technology of Land and Resources, Yunnan Agricultural University, Kunming* 650201, *China*
[3]*Yunnan Agricultural University Library, Kunming* 650201, *China*
[4]*College of Resources and Environment, Yunnan Agricultural University, Kunming* 650201, *China*

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Land consolidation and reclamation is an important measure to increase the quantity and quality of arable land. Because the land consolidation and remediation covers a long construction period, the sustainability of the project has become the subject of controversy and suspicion. Combining the characteristics and the theory of sustainable land consolidation and rehabilitation management by building a sustainable evaluation system, the implementation and sustainability of land remediation effect was evaluated. In this paper, the Land consolidation and rehabilitation project of Ban Lun town, Mu yang town, Gui chao town, Li da town, Hua jia town in Funing County as an example, on the basis of investigation and study on the use of Delphi method, Analytic Hierarchy Process (AHP), index summation method other methods, by 18 index. The results show that the effect of the implementation of Funing County land remediation and sustainability is good.

Keywords: land consolidation and rehabilitation; sustainability; evaluation

INTRODUCTION

At present, China is facing a severe shortage of land resources, and land consolidation and remediation is an important measure to increase the amount of arable land, improve the quality of cultivated land and maintain the dynamic balance of farmland. In 1999, the promulgation of *The Law of Land Administration of the People's Republic of China* ushered the prelude of large-scale land consolidation and remediation. Through more than ten years of development, land consolidation and remediation have made a series of achievements, developed and consolidated a lot of land, increased the effective agricultural acreage, and made a positive contribution to the dynamic equilibrium of total cultivated land area as well as macro strategies of food security. The launch of land consolidation and remediation alleviated the tense situation of arable land to some extent, but it outweighted the economic value and functions of land over the ecological functions of land, with relatively weak awareness of ecological environment protection. For instance, it still lays too much emphasis on the increase of quantity regarding the benefit evaluation index system of measuring the land consolidation and remediation project, with the lack of mandatory indexes that measure quality, environment and other aspects. Besides, land consolidation and remediation has broad construction contents, long duration, difficult supervision of construction quality and other characteristics, the project effect and post-implementation sustainability have received controversy and suspicion[1-8]. In November 2009, *"Land Consolidation Project for Border Development" Farmland Consolidation and Remediation Key Project in the Western Ecological Construction Region Yunnan Province* declared by Yunnan was approved by the joint review of the Ministry of Land and Resources and Ministry of Finance, and was commenced in 2010. This key project involves 210,000 hectares of land consolidation and remediation in 25 border counties (cities) of the border areas in Yunnan Province, with a construction period of 5 years and a total project budget of 8.62 billion yuan. Being one of the 25 border counties, Funing County is located in the southwest fragile ecological environment, with large differences in vertical elevation, complex topography and landforms, diverse land use patterns, frequent natural disasters and numerous ethnic minorities, hence it has strong representativeness in the evaluation of the effect and sustainability of land consolidation and remediation.

In this paper, the land consolidation and rehabilitation project of Banlun Town, Muyang

* To whom all correspondence should be sent:
E-mail: ynhg61@126.com

Town, Guichao Town, Lida Town, Huajia Town in Funing County was taken as an example to analyze and study the project sustainability after land consolidation and remediation, the results can provide a certain reference for similar studies and land administrative departments.

Overview of the Study Area

Located in southeastern Yunnan Province and the east of Wenshan Zhuang and Miao Autonomous Prefecture, Funing County is the channel connecting Southeast Asia and Yunnan. Its geographical coordinates are about east longitude 105°13′-106°12′ and north latitude 23°11′-24°09′, with the Tropic of Cancer crossing the south border. The county has an altitude of 684m, with the highest and lowest altitudes of 1,851.8m and 142m, respectively. Land area covers 5,352 km2, wherein mountainous and semi-mountainous areas cover 5,067.84km2, accounting for 96% of the total county area, the county has 69,300 hectares of arable land and is very rich in water resources, with an average annual rainfall of 1,103mm. Funing County is located in the low latitude hot region, with vast mountainous areas and undulating terrains, forming a monsoon climate that are mainly southern sub-tropical and tropical with distinct dry and wet seasons. Funing is a multi-ethnic settlement, the territory is inhabited by six ethnic groups--Zhuang, Han, Miao, Yao, Yi, Gelao, and the county has a total of 95,000 households and 418,300 people.

METHODS

Construction of evaluation index system

In this paper, the screening of evaluation index is mainly based on the existing benefit evaluation index of land department, while referring to the relevant existing evaluation index of the financial department and the relevant departments, combined with the evaluation characteristics, evaluation contents and purpose, research results at home and abroad[5-8]. The sustainability of land consolidation and remediation evaluation is divided into: comprehensive index, evaluation factors and evaluation index, evaluation factors are divided into cultivated land utilization factor, economic factors, social factors and ecological factors, including 18 evaluation indexes.

Determination of evaluation index weight

In this paper, Delphi method is adopted to determine the evaluation index weight. It generally takes several rounds of expert scoring, and the experts modify their views according to the weight mean values and variances gained in the previous round, thus achieving closer mean values and smaller variances until meeting the requirement. Specific requirements of the experts in scoring process are:

a) Experts carry out independent scoring based on their own theoretical knowledge and practical work experience, and no discussions among each other; b) the sum of selection factor weights is 1.00, otherwise invalid; c) the final classification factors and the determination of their weights must meet certain mathematical statistics requirements, otherwise the next round of scoring must be conducted. On the basis of preliminary indexes selection and project evaluation needs of “land consolidation project for border development” farmland consolidation and remediation key project in the western ecological construction region Yunnan Province, the research group invited 22 experts who are familiar with Yunnan land consolidation and remediation and agricultural production, and made final determination of evaluation index weights by using Delphi method to carry out several rounds of expert consultation and weight scoring until the expert opinions are close to each other. Refer to the evaluation index system of sustainable land consolidation and rehabilitation and evaluation index weight in Tab.1.

Classification of the sustainability of land consolidation and remediation

In this paper, comprehensive index of the sustainability of land consolidation and remediation is adopted to measure the sustainable level of land consolidation and remediation, the comprehensive index of the sustainability of land consolidation and remediation can be calculated by using index sum method, calculation formula is as follows:

$$SLC=\sum_{i=1}^{n} W_i C_i$$

Where, W_i is the comprehensive index of weights, C_i is the index’s score, n is the total number of indexes.

Table 1. Evaluation index system of sustainable land consolidation and rehabilitation and evaluation index weight table

composite Index	evaluation Factors	relative weights	evaluation index and weight		
			evaluation index	relative weight	comprehensive weight
Comprehensive index of sustainable land consolidation and rehabilitation	Cultivated land utilization factor	0.24	irrigation guarantee rate C1	0.21	0.05
			irrigation and drainage ditches density C2	0.17	0.04
			road density in the field C3	0.13	0.03
			cultivated land quality level C4	0.25	0.06
	economic factors	0.27	raise the level of grain output C5	0.25	0.06
			area ratio of cultivated land C6	0.29	0.08
			the increasing rate of income per mu C7	0.22	0.06
			mu cost reduction rate C8	0.19	0.05
			production improvement factor C9	0.19	0.05
	social factors	0.29	per capita GDP growth rate C10	0.11	0.03
			per capita annual net income increased C11	0.34	0.10
			poor people out of poverty rate C12	0.28	0.08
			public satisfaction rate C13	0.17	0.05
	ecological factor	0.20	the rate of increase in agricultural productivity C14	0.21	0.06
			land reclamation rate increment C15	0.15	0.03
			drought and flood disaster reduction rate C16	0.3	0.06
			green vegetation cover increment C17	0.2	0.04
			soil and water loss control rate C18	0.35	0.07

Table 2. Funing County land consolidation and rehabilitation sustainability post evaluation the calculation data

evaluation index	No1	No2	No3	No4	No5	No1	No2	No3	No4	No5	No1	No2	No3	No4	No5
	consolidation before					consolidation after					amount of change				
irrigation guarantee rate	78	70	75	73	64	80	75	80	85	75	2	5	5	12	11
irrigation and drainage ditches density	0.09	0.02	0.01	0.02	0.07	0.1	0.0	0.0	0.08	0.13	0.07	0.03	0.03	0.06	0.05
road density in the field	0.06	0.04	0.02	0.03	0.02	0.1	0.0	0.0	0.07	0.08	0.05	0.03	0.03	0.04	0.05
cultivated land quality level	3	3	4	3	3	4	5	6	5	4	1	2	2	2	1
the level of grain output	0.45	0.68	0.91	0.55	0.61	0.7	1.0	1.2	0.86	0.90	0.3	0.39	0.37	0.30	0.28
area ratio of cultivated land	78.6	74.1	75.4	79.1	80.3	92.	77.	81.	85.4	94.3	13.7	3.2	6.2	6.27	13.9
income per mu	692	979	673	785	518	809	104	805	931	703	117	66	132	146	185
the cost per mu	375	587	403	479	411	425	654	473	567	458	50	67	70	88	47
production improvement factor	0.47	0.79	0.80	0.53	0.50	1.0	1.2	1.1	0.80	0.95	0.55	0.46	0.33	0.26	0.45
GDP per capita GDP	687	564	495	712	788	978	845	769	102	100	2911	280	274	308	215
per capita annual net income	152	126	106	165	186	408	365	386	419	395	256	238	280	254	208
poor people out of poverty rate	3.42	0.86	2.06	4.82	1.25	15	13.	9.2	18.0	9.09	11.5	12.9	7.22	13.2	7.84
public satisfaction rate	66	58	54	42	40	82	84	86	85	82	16	26	32	43	42
agricultural labor productivity	36	12	33	24	35	75	70	82	66	78	39	58	49	42	43
land reclamation rate	81.0	74.1	75.4	86.7	79.7	84.	77.	81.	89.4	81.7	3.22	3.2	6.2	2.69	2.02
drought and flood rate	56.7	62.4	56.4	73.5	49.7	19.	20.	18.	21.6	19.5	-	-	-	-	-
green vegetation cover	82.5	75.2	76.3	87.4	80.9	85.	78.	82.	89.9	82.6	2.59	2.99	5.98	2.51	1.66
soil and water loss control rate	8.01	10.79	8.81	2.47	69	26.	36.	64.	44.5	37.9	18.5	25.9	55.0	32.1	30.2

Note: No1 instead Ban Lun town, No2 instead Mu Yang town, No3 instead Gui Chao town, No4 instead Li Da town, No5 instead Hua Jia town.

Table 3. Funing County land consolidation and rehabilitation sustainability post evaluation index scores Standard

score

evaluation index	0～40	40～70	70～85	85～100
irrigation guarantee rate	＜40	40～70	70～80	85～100
irrigation and drainage ditches	＜0.05	0.05～0.1	0.1～0.15	0.15～0.3
road density in the field	＜0.05	0.05～0.75	0.75～0.1	0.1～0.2
cultivated land quality level	＜3	3～5	6～10	10～16
the level of grain output	＜0.5	0.5～1	1～1.5	＞1.5
area ratio of cultivated land	＜50	50～70	70～90	90～100
income per mu	＜600	600～800	800～1000	＞1000
the cost per mu	＞600	600～400	400～300	＜300
production improvement factor	＜0.5	0.5～1	1～1.5	＞1.5
GDP per capita GDP	＜5000	5000～8000	8000～10000	＞10000
per capita annual net income	＜2000	2000～4000	4000～8000	＞8000
poor people out of poverty rate	＜10	10～30	30～50	50～100
public satisfaction rate	＜40	40～70	70～80	85～100
agricultural labor productivity	＜40	40～70	70～80	85～100
land reclamation rate	＜40	40～70	70～80	85～100
drought and flood rate	＞50	50～40	40～20	＜20
green vegetation cover	＜40	40～70	70～80	85～100
soil and water loss control rate	＜20	20～50	50～80	80～100

Upon calculating the comprehensive index of the sustainability of land consolidation and remediation, classify the sustainability level of land consolidation and remediation on this basis. This paper divides the sustainability of land consolidation and remediation into four levels based on comparative analysis, expert consultation, reference to relevant literature[9-16], specifically: SLC value is not sustainable between 0-35; SLC value is barely sustainable between 35-70; SLC value is moderately sustainable between 70-85; SLC value is highly sustainable between 85-100.

Finishing of data acquisition

To ensure the comprehensiveness, representativeness and scientific rationality of the study results, method of correspondence survey, literature search, questionnaire, field observation and interview combined together for data acquisition.

Collate data of the five project areas collected via the above methods, calculate the comprehensive index of the sustainability of land consolidation and remediation based on the sustainability of land consolidation and remediation evaluation index system, evaluation index weight, standard for evaluation, etc., and classify and evaluate the sustainability of land consolidation and remediation in Funing County as per the classification standard of the sustainability of land consolidation and remediation. Specific evaluation process is shown in Tab. 2-3.

RESULTS AND DISCUSSION

A comprehensive evaluation analysis of the sustainability of land consolidation and

remediation project in the 5 project areas in Funing County has been carried out, the results are shown in Tab. 4:

(1) After land consolidation and remediation, the infrastructure of the five project areas in Funing County have been perfected, a certain improvement have been made in the quality of cultivated land, sustainability of arable land has been enhanced, and the comprehensive indexes value of sustainability by the increased from 12.22, 11.24, 12.14, 10.76 and 11.24 before consolidation and remediation to 17.85, 16.84, 17.33, 17.92 and 16.88 after consolidation and remediation.

(2) After land consolidation and remediation, rural income of the five project areas in Funing County and social stability both increased, social, economic and ecological benefits increase significantly, as for the comprehensive index values of sustainability, socially sustainable comprehensive indexes increased from 10.85, 6.86, 8.27, 8.48 and 9.18 before consolidation and remediation to 19.91, 18.5, 19.01, 20.37 and 18.94 after consolidation and remediation; economically sustainable comprehensive indexes increased from 17.04, 16.9, 16.9, 17.16 and 15.84 before consolidation and remediation to 20.8, 20.47, 20.28, 20.94 and 20.7 after consolidation and remediation; ecologically sustainable indexes increased from 8.43, 7.48, 8.21, 8.33 and 8.43 before consolidation and remediation to 14.47, 14.39, 16.29, 15.38 and 14.81 after

consolidation and remediation;

(3) After land consolidation and remediation, the comprehensive index values of sustainability of Banlun Town, Muyang Town, Guichao Town, Lida Town, Huajia Town in Funing County before land consolidation and remediation were 48.53, 42.47, 44.51, 44.72 and 44.68, respectively, and became 73.04, 70.21, 72.90, 74.62 and 71.33 after land consolidation and remediation, with increments of 24.51, 27.73, 27.38, 29.90 and 26.65, and the classification of the sustainability of land consolidation and remediation of the five project areas is promoted to moderately sustainable from barely sustainable.

CONCLUSION

Through a comprehensive evaluation analysis of the sustainability of land consolidation and remediation project in the five project areas in Funing County, the main conclusions are as follows:

(1) After land consolidation and remediation, rural income of the five project areas in Funing County and social stability both increased, social, economic and ecological benefits increase significantly. After land consolidation and remediation, the intensity of the sustainability of land consolidation and remediation of the five project areas is promoted to moderately sustainable from barely sustainable. The results show that the effect and sustainability of land consolidation and remediation in Funing County are favorable.

Table 4. Funing County land consolidation and rehabilitation sustainability post evaluation index comprehensive index

evaluation index	No.1	No.2	No.3	No.4	No.5	No.1	No.2	No.3	No.4	No.5
	SLC consolidation before SLC					SLC consolidation after				
irrigation guarantee rate C1	4.08	3.36	3.84	3.60	3.12	4.32	3.84	4.32	4.80	3.84
irrigation and drainage ditches density C2	2.81	1.30	0.86	1.51	2.16	3.67	2.59	1.73	3.02	3.02
road density in the field C3	1.25	1.25	0.94	0.94	0.94	2.81	1.87	1.87	2.18	2.34
cultivated land quality level C4	2.21	2.21	2.76	2.21	2.21	3.31	3.86	4.42	3.86	3.31
raise the level of grain output C5	1.87	3.12	3.74	2.50	2.81	3.74	4.68	4.99	4.06	4.37
subtotal	12.22	11.24	12.14	10.76	11.24	17.85	16.84	17.33	17.92	16.88
area ratio of cultivated land C6	5.83	5.47	5.47	5.83	5.83	6.20	5.83	5.83	6.20	6.56
the increasing rate of income per mu C7	3.42	4.66	3.42	4.04	2.17	4.35	5.28	4.35	4.97	3.73
mu cost reduction rate C8	3.85	2.05	3.59	3.08	3.59	4.10	3.08	3.85	3.59	4.10
production improvement factor C9	2.16	3.24	3.24	2.43	2.16	3.78	4.05	4.32	3.51	3.78
per capita GDP growth rate C10	1.78	1.49	1.19	1.78	2.08	2.38	2.23	1.93	2.67	2.52
subtotal	17.04	16.90	16.90	17.16	15.84	20.80	20.47	20.28	20.94	20.70
per capita annual net income increased C11	2.70	2.25	1.80	2.70	3.60	6.74	5.39	5.84	6.74	6.29
poor people out of poverty rate C12	2.52	0.84	1.68	2.10	1.26	4.21	4.21	3.36	5.05	3.36
public satisfaction rate C13	3.39	3.13	2.87	2.09	2.09	4.18	4.44	4.70	4.44	4.18
the rate of increase in agricultural productivity C14	2.23	0.64	1.91	1.60	2.23	4.79	4.47	5.10	4.15	5.10
subtotal	10.85	6.86	8.27	8.48	9.18	19.91	18.50	19.01	20.37	18.94
land reclamation rate increment C15	2.40	2.10	2.25	2.55	2.40	2.55	2.40	2.40	2.70	2.40
drought and flood disaster reduction rate C16	2.32	1.74	2.32	1.16	2.32	4.64	4.64	4.93	4.35	4.64
green vegetation cover increment C17	3.36	2.94	2.94	3.57	3.36	3.78	3.15	3.36	3.78	3.57
soil and water loss control rate C18	0.35	0.70	0.70	1.05	0.35	3.50	4.20	5.60	4.55	4.20
subtotal	8.43	7.48	8.21	8.33	8.43	14.47	14.39	16.29	15.38	14.81
total	48.53	42.47	45.52	44.72	44.68	73.04	70.21	72.90	74.62	71.33

Note: No.1 instead Ban Lun town, No.2 instead Mu Yang town, No.3 instead Gui Chao town, No.4 instead Li Da town, No.5 instead Hua Jia town.

(2) The study gives a comprehensive analysis of the various factors that affect the sustainability of land consolidation and remediation, but the screening index of Delphi method has a certain degree of subjectivity, the 18 indexes selected in the evaluation index system and their weights have certain limitations.

(3) In future studies, multiple regions in Yunnan

Province can be selected as the study object, finding the similarities and differences between districts through a comparative analysis, and building a project evaluation index system that can be applied to the sustainability of land consolidation and remediation in Yunnan Province and even a wider range, providing reference to the sustainability of land consolidation and remediation project evaluation in Yunnan Province and even the country.

REFERENCES

1. Y. Jianxin, W. Wei, L. Xiaohong, P. Yun, L. Lijun, Z. Yongli, T*ransactions of the Chinese Society of Agricultural Engineering*, **29**(10), 234 (2013).
2. B. Zhenxing, W. Bing, Y. Miao , D.Xiuru, S. Fujun, H. Chunlan, Q. Fengkun, *Transactions of the Chinese Society of Agricultural Engineering*, **24**(2), 95 (2008).
3. Y. Xiaoyan, Z. Deju, Y. Wenju, C. Feng, *Transactions of the Chinese Society of Agricultural Engineering*, **21**(9), 67 (2005).
4. Y. Liping, S. Xiazhen W. Cifang, *Journal of Agricultural Mechanization Research*, **12**(12), 48 (2006).
5. Y. Yang, H. Chunyang, L. Xiaobing, *Journal of Beijing Forestry University*, **32**(3), 33 (2010).
6. S. Nan, Evaluation of Sustainable Development of Forestry in Shaanxi County Region. North West Agriculture and Forestry University, 2012.
7. L. Wenli, Comprehensive Benefit Evaluation of Land Consolidation, Yunnan Agricultural University, 2012.
8. Z. Junfeng, H. Sheng, L. Youzhao, M. Zhan, *Resources and Environment in the Yangtza Basin*, **02**, 153 (2014).
9. Y. Jing, G. Minhua, C. Lijun, *Chinese Agricultural Science Bulletin*, **14**, 211 (2014).
10. Z. Zhengfeng, *Transactions of the Chinese Society of Agricultural Engineering*, **28**(7), 1 (2012).
11. Q. Pengfei, W. Wenke, D.Lei, W. Guangchao, C. Li, *China Sciencepaper*, **10**(3), 348 (2015).
12. X. Kang, J. Xiaobin, W. Dingguo, Z. Yinkang, *Transactions of the Chinese Society of Agricultural Engineering*, **31**(7), 247 (2015).
13. L. Shuyi, Y. Qingyuan, H. Chunyan, W. Xue, H. Pei, *Chinese Agricultural Science Bulletin*, **29**(26), 54 (2013).
14. W. Junmin, H. Baoqing, *Resources Science*, **35**(7), 1407 (2013).
15. H. Huiling, W. Cifang, Z. Shouzhong, *Transactions of the Chinese Society of Agricultural Engineering*, **28**(6), 240 (2012).
16. Y. Jun, W. Zhanqi, J. Gui, C. Bingyin, H. Xianhui, *Resources and Environment in the Yangtze Basin*, **22**(8), 1036 (2013).