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Evaluation of Comprehensive Benefits of Land Consolidation Based on AHP and FUZZY

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Abstract Based on the modern comprehensive evaluation method, in accordance with the scientific, objective and systematic principles, we select four factors (economic, social, ecological and landscape benefits), to establish the evaluation indicator system of comprehensive benefits of rural land consolidation. Then using the theory of fuzzy mathematics (FUZZY) and fuzzy relationship synthesis theory, we establish the fuzzy evaluation model of comprehensive benefits of land consolidation; using analytic hierarchy process (AHP), we determine the weight of each indicator, and conduct fuzzy comprehensive evaluation from various levels. By the weighted average synthesis algorithm, we calculate the evaluation indicators and finally summarize the overall evaluation results for comprehensive evaluation. Taking the case of land consolidation project in Shangyao Town, Datong District, Huainan City in Anhui Province, we calculate the case data based on Matlab software, and the calculation results and evaluation level are consistent with the project acceptance results, verifying the feasibility of this evaluation method.

Key words Land consolidation, Comprehensive benefits, Analytic hierarchy process (AHP), Fuzzy comprehensive evaluation method

Benefit evaluation of land consolidation is an important part of land consolidation theory and practice. Rafael Crecente et al, through comparison and analysis of land consolidated area and non consolidated area, found out the mutual relationship between land consolidation and rural development[1]. JC. Coelho believed that every time of land consolidation will not only change natural, biological and structural environment, but also change social and economic environment of human beings[2]. Since entering the 21st century, domestic scholars have conducted numerous researches on land consolidation benefits and evaluation method, and have made certain achievements[3-6]. Considering particularity of land consolidation projects, we combined the analytic hierarchy process (AHP) and fuzzy comprehensive evaluation method[7-8] with specific cases, and evaluated comprehensive benefits of land consolidation, to provide reference for extending theoretic system of land consolidation benefit and benefit evaluation methods.

1 The evaluation indicator system of comprehensive benefits of land consolidation

There are many factors influencing comprehensive benefits of land consolidation. Here, we selected four factors: economic, social, land and landscape benefits. On the basis of industry analysis (current situation drawing and topographic map of the project area, hydrogeological, soil, climatic and biological resources), expert inspection data on land resource management and on-site investigation, on the representative, independent, systematic, quantitative and qualitative principles, and based on AHP theory, we established three layers (target layer, criteria layer and indicator layer). The detailed indicator system is shown in Fig. 1

1.1 Economic benefits The economic benefit is an important factor influencing comprehensive benefits of land consolidation[9]. It is manifested as increase or not in the yield of the project area, reduction or not of the product cost, and effective increase in cultivated area or not and increase or not in the irrigation ability of cultivated land. We selected $C_{11} - C_{16}$ as major indicators of economic benefits, C_{17} in social benefits and C_{18} in ecological benefits as cross indicators to calculate economic benefits together.

1.2 Social benefits Social benefit refers to the influence of land consolidation on people's living and social effect. We selected $C_{22} \sim C_{25}$ as major indicators of social benefits, C_{21} in economic benefits and C_{26} in landscape benefits as cross indicators to calculate social benefits together.

1.3 Landscape benefits Landscape benefit refers to building farmland landscape system with harmonious space, stable ecology and ideal social economic benefits on the principle of combining landscape ecology and land consolidation[10-12]. Landscape is designed according to requirements of ecological system, to ensure biological diversity, raise land utilization ratio and improve quality of cultivated land, improve ecological environment, including patch regularity, landscape type change, vegetation coverage, and uniform distribution of landscape. We selected $C_{31} - C_{35}$ as major indicators of landscape benefits, and took C_{36} in ecological benefits as cross indicator to evaluate landscape benefits.

1.4 Ecological benefits Ecological benefit refers to direct and indirect influence of land consolidation on water resource, water environment, soil, vegetation and ecological process in the project area. The selected indicators should reflect difference of land quality and strong or weak of ecological functions. We selected C_{41}

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$-C_{45}$ as major indicators of ecological benefits, and took C_{46} in landscape benefits as cross indicator to evaluate ecological benefits.

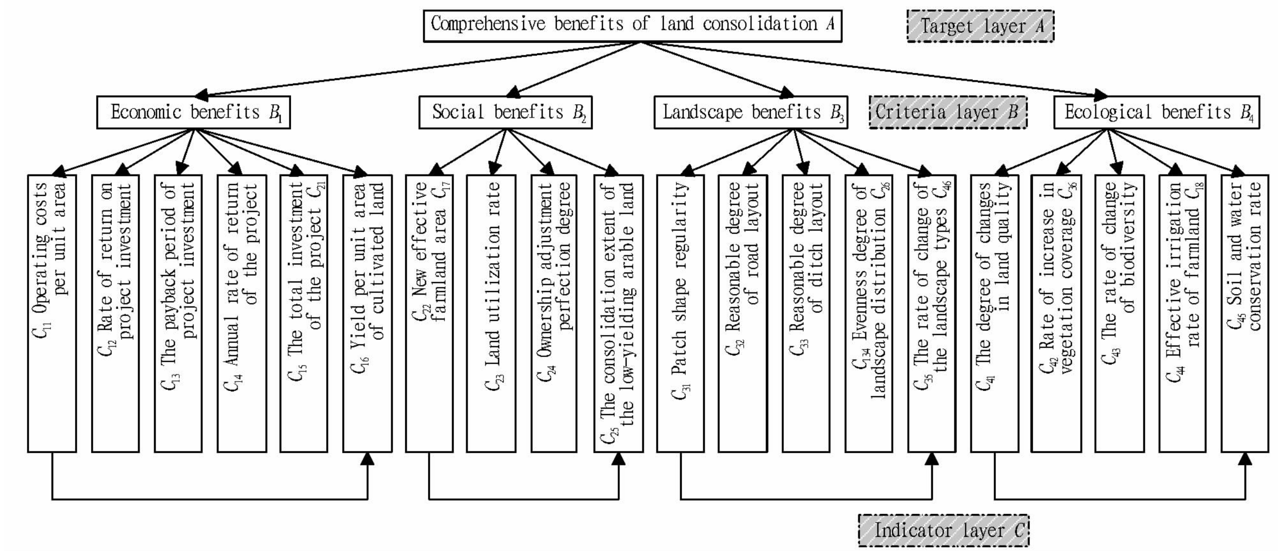

Fig. 1 The evaluation indicator system of comprehensive benefits of land consolidation

2 Fuzzy comprehensive evaluation model of comprehensive benefits

The designed comprehensive evaluation indicator system of land consolidation in Fig. 1 is a two level three layer indicator system. Most of these indicators are fuzzy. Thus, according to FUZZY theory, we took the evaluation of indicator layer on criteria layer as the first level evaluation, and took the evaluation of criteria layer on target layer as the second level evaluation, then, we obtained a two level three layer fuzzy comprehensive evaluation model[13-14]. The specific steps are as follows:

The first step is to determine the evaluation indicator set.

Assume the factor set of comprehensive benefit evaluation (criteria layer) as $B=\{B_1, B_2, \cdots, B_n\}$. Divide the factor set into m sub-factor sets (indicator layer): $C_i=\{C_{i1}, C_{i2}, \cdots, C_{ij}\}$, $i=1, 2, \cdots m$, $j=1, 2, \cdots, s$.

The second step is to take level one evaluation.

Conduct comprehensive evaluation for every sub-factor set.

(1) Remark set. $V=\{V_1, V_2, \cdots, V_n\}$. In this comprehensive evaluation model, there are four grades: Excellent, Good, Average and Poor. There are both qualitative and quantitative evaluation indicators. At the time of specific evaluation, we divided the project area into different intervals according to characteristics of the project area, and qualitative indicators were divided into different grades and given with uniform standard score, as listed in Table 1.

Table 1 Standard score of evaluation indicators

Interval (or grade)	Quantitative indicators	Qualitative indicators	Remark set
4	10	8	V_1 (Excellent)
3	8	6	V_2 (Good)
2	6	4	V_3 (Average)
1	4	2	V_4 (Poor)

(2) Weight set. According to AHP theory, we invited senior experts to evaluate importance of every indicator in the evaluation indicator system by 1 – 9 scale method, and obtained judgment matrix of importance degree between $A-B$ and $B-C$. The consistency was checked by the square root method, and obtained the weight Q_{A-B} and Q_{B-C} of corresponding indicator. Then, we averaged the sum of weight values and determined final weight of each indicator. Assume $A_i=Q_{A-B}\otimes Q_{B-C}=\{a_{i1}, a_{i2}, \cdots, a_{ij}\}$, of which $\otimes$ signifies the compositional operation in broad sense.

(3) Fuzzy evaluation. We took the sub-factor set $C_i=\{C_{i1}, C_{i2}, \cdots, C_{ij}\}$ and remark set $V=\{V_1, V_2, \cdots, V_n\}$ as a fuzzy map, and determined the subordinate degree matrix of remarks in remark set V corresponding to factors in sub-factor set by Delphi method, then the fuzzy evaluation matrix R_i could be determined. Suppose $R_i-\{r_{ijk}\}$ as subordinate degree of fuzzy evaluation. In the equation, $r_{ijk}=d_{ijk}/d$, d_{ijk} is the number of experts with the k – th evaluation in the ij – th evaluation indicator of the sub-factor set, and d is the total number of experts participating in the evaluation. The fuzzy evaluation sample of experts is shown in Fig. 2.

According to FUZZY theory and using compositional operation of fuzzy matrix, we obtained comprehensive evaluation vector $\underset{\sim}{B}_i$ of C_i, $\underset{\sim}{B}_i=A_i\otimes R_i$.

The third step is to take level two evaluation. Taking every sub-factor set C_i as one factor, and using $\underset{\sim}{B}_i$ as its single factor to evaluate, we obtained that it is a fuzzy map from factor set B to remark set V, $R=\{\underset{\sim}{B}_1, \underset{\sim}{B}_2, \cdots, \underset{\sim}{B}_n\}$. Took every $\underset{\sim}{B}$ as a part of R, give them weight as per their importance $\underset{\sim}{A}=\{a_1, a_2, \cdots, a_n\}$, so the level two comprehensive evaluation is $\underset{\sim}{B}=\underset{\sim}{A}\otimes R$.

The fourth step is to conduct comprehensive evaluation. In the corresponding remark set, $V=\{V_1, V_2, \cdots, V_n\}$, assign every remark with specific score, calculate final score of the comprehensive benefits, suppose the final score as W, then $W=\Sigma h_k y_k$, of which h_k is the value of vector B in level two comprehensive evaluation and y_k is the score of remark corresponding to Excel-

Fuzzy evaluation sample form of expert on comprehensive benefit indicators of land consolidation

Project name:______ The name of experts:_____ Evaluation date:

Evaluation indicators	Excellent	Good	Average	Poor
Operating costs per unit area C_{11}				
Rate of return on project investment C_{12}				
The payback period of project investment C_{13}				
Annual rate of return of the project C_{14}				
The total investment of the project C_{15}				
……	……	……	……	……

Note: Please make tick in corresponding level blank. "√"

Fig. 2 Fuzzy evaluation sample form of expert on comprehensive benefit indicators of land consolidation

lent, Good, Average and Poor. In accordance with the maximum subordination principle and final score, we obtained the comprehensive evaluation results.

3 Case study

On the basis of the previously established comprehensive evaluation model, we took the case of land consolidation project in Shangyao Town, Datong District, Huainan City in Anhui Province to verify the application of the comprehensive evaluation model.

3.1 Weight determining

3.1.1 Construction of the importance judgment matrix and calculation. According to AHP theory, we set 1 – 9 scale. On the basis of consulting inspection and acceptance experts of related land consolidation projects, we evaluated factor set and sub-factor set, and built target layer and indicator layer judgment matrix. Using the square root method and keeping four decimal digits, we conducted consistency inspection and single hierarchy ranking, and obtained weight values of factors and sub-factors (shown in Table 2 to 6).

Table 2 Factor set judgment matrix $A-B$

A	B_1	B_2	B_3	B_4	Weight
B_1	1	4	3	1	0.395 3
B_2	1/4	1	1	1/3	0.114 1
B_3	1/3	1	1	1/3	0.122 6
B_4	1	3	3	1	0.367 9

Note: $\lambda_{max}=4.010\ 4$; $CI=0.003\ 5$; $RI=0.9$; $CR=0.003\ 8$.

Table 3 sub-factor set judgment matrix B_1-C

B_1	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	Weight
C_{11}	1	2	1/2	1/5	1/2	1/4	1/2	1	0.068 2
C_{12}	1/2	1	1	1	2	1	1	1	0.117 9
C_{13}	2	1	1	1/2	3	1	1	1	0.135 3
C_{14}	5	1	2	1	2	2	2	1/3	0.177 8
C_{15}	2	1/2	1/3	1/2	1	1/3	1/3	1/3	0.062 4
C_{16}	4	1	1	1/2	3	1	1	2	0.160 9
C_{17}	2	1	1	1/2	3	1	1	1	0.135 3
C_{18}	1	1	1	3	3	1/2	1	1	0.142 3

Note: $\lambda_{max}=8.949\ 8$; $CI=0.135\ 7$; $RI=1.41$; $CR=0.096\ 2$.

Table 4 sub-factor set judgment matrix B_2-C

B_2	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	Weight
C_{21}	1	1	1	1	5	3	0.228 0
C_{22}	1	1	2	2	4	5	0.301 4
C_{23}	1	1/2	1	1	2	2	0.163 0
C_{24}	1	1/2	1	1	2	2	0.163 0
C_{25}	1/5	1/4	1/2	1/2	1	1/2	0.062 3
C_{26}	1/3	1/5	1/2	1/2	2	1	0.082 4

Note: $\lambda_{max}=6.146\ 1$; $CI=0.029$ ta2; $RI=1.24$; $CR=0.023\ 6$.

Table 5 sub-factor set judgment matrix B_3-C

B_3	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{36}	Weight
C_{31}	1	1/2	1/2	1	1	1	0.118 5
C_{32}	2	1	1	3	4	3	0.304 6
C_{33}	2	1	1	1/2	4	3	0.226 0
C_{34}	1	1/3	2	1	2	1	0.156 7
C_{35}	1	1/4	1/4	1/2	1	1/3	0.069 8
C_{36}	1	1/3	1/3	1	3	1	0.124 4

Note: $\lambda_{max}=6.440\ 1$; $CI=0.088\ 0$; $RI=1.24$; $CR=0.071\ 0$.

Table 6 sub-factor set judgment matrix B_4-C

B_4	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}	C_{46}	Weight
C_{41}	1	1/2	1/3	1/3	1/2	1/3	0.069 3
C_{42}	2	1	1	1	3	2	0.228 9
C_{43}	3	1	1	1	3	2	0.244 9
C_{44}	3	1	1	1	2	1/2	0.181 7
C_{45}	2	1/3	1/3	1/2	1	1/2	0.093 5
C_{46}	3	1/2	1/2	2	2	1	0.181 7

Note: $\lambda_{max}=6.260\ 3$; $CI=0.052\ 1$; $RI=1.24$; $CR=0.042\ 0$.

3.2 Calculation of benefit evaluation value

3.2.1 Determining of fuzzy judgment matrix. We contacted 10 experts on inspection and acceptance of land consolidation projects in the form of questionnaire. Through statistics and arrangement of investigation results, we calculated the subordination degree rijk of indicators corresponding to remarks, $r_{ijk}=d_{ijk}/d$, of which d_{ijk} is the number of experts with the k – th evaluation in the ij – th evaluation index of the sub-factor set, and d is the total number of experts participating in the evaluation. Then we obtained the fuzzy evaluation matrix R_i of sub-factor (indicator layer), and the questionnaire sample form is shown as the table. The weight of factor set and sub-factor is Q_{A-B} and Q_{B-C} respectively. The final weight is A_i, and $A_i=Q_{A-B}\otimes Q_{B-C}=\{a_{i1}, a_{i2}, \cdots, a_{ij}\}$ (listed in Table 7).

3.2.2 Comprehensive evaluation. According to final weight and sub-factor set fuzzy matrix (subordination degree), we carried out following comprehensive evaluation: $\underset{\sim}{B}_i=\underset{\sim}{A}_i\otimes\underset{\sim}{B}_i=\{b_{i1}, b_{i2}, b_{i3}, b_{i4}\}$, where $i=1, \cdots, 4$, then $R=\{B_1, B_2, \cdots, B_4\}^T$

Thus

$$\underset{\sim}{B}=\underset{\sim}{A}\otimes R=\underset{\sim}{A}\otimes\{\underset{\sim}{B}_1, \underset{\sim}{B}_2, \cdots, \underset{\sim}{B}_4\}^T=\{b_1, b_2, b_3, b_4\}$$

is the summary value of comprehensive evaluation, and the results are listed in Table 8.

Through assigning each grade remark according to standard score of evaluation indicator, we obtained the vector of remark score. Suppose the final score to be W, then $w=\Sigma h_k y_k$, of which h_k is the summary value of vector B, y_k is the score corresponding to remark grade, and the final score is 7.9772.

From Table 8, it can be seen that the comprehensive evaluation summary vector $\underset{\sim}{B} = (0.4295, 0.2621, 0.1759, 0.1325)$. According to the maximum subordination principle of FUZZY theory, the maximum value of comprehensive benefit evaluation is 0.429 5, indicating that the comprehensive benefit of this time land consolidation belongs to excellent level. Besides, the final score of comprehensive benefit of land consolidation in the project area is 7.977 2. Corresponding to the standard score table, this time of land consolidation could be deemed as excellent. Thus, the qualitative and quantitative results are consistent with each other. With the aid of Matlab software, we plotted the block diagram for remarks of comprehensive benefits of land consolidation. Using this model, we calculated comprehensive benefits of this time of land consolidation. The results are shown in Fig. 3. In indicates that both results are basically consistent with each other, verifying that this method, model and quantitative indicators are feasible to judge the comprehensive benefits of land consolidation.

Table 7 The subordination degree of fuzzy evaluation and the final weight

Indicator	Weight	Excellent	Good	Average	Poor	Indicator	Weight	Excellent	Good	Average	Poor
C_{11}	0.026 9	0.4	0.4	0.1	0.1	C_{26}	0.009 4	0.5	0.3	0.1	0.1
C_{12}	0.046 6	0.2	0.3	0.3	0.2	C_{31}	0.014 5	0.4	0.3	0.2	0.1
C_{13}	0.053 4	0.4	0.3	0.2	0.1	C_{32}	0.037 3	0.4	0.2	0.2	0.2
C_{14}	0.070 3	0.4	0.3	0.3	0	C_{33}	0.027 7	0.3	0.3	0.2	0.2
C_{15}	0.024 7	0.3	0.3	0.2	0.2	C_{34}	0.019 2	0.4	0.2	0.2	0.2
C_{16}	0.063 7	0.7	0.1	0.1	0.1	C_{35}	0.008 6	0.5	0.2	0.2	0.1
C_{17}	0.053 5	0.5	0.4	0.1	0	C_{36}	0.015 3	0.4	0.3	0.1	0.2
C_{18}	0.056 3	0.3	0.3	0.2	0.2	C_{41}	0.025 4	0.4	0.2	0.2	0.2
C_{21}	0.026 0	0.4	0.4	0.1	0.1	C_{42}	0.084 2	0.6	0.1	0.2	0.1
C_{22}	0.034 4	0.5	0.2	0.2	0.1	C_{43}	0.090 1	0.4	0.3	0.1	0.2
C_{23}	0.018 6	0.4	0.4	0.1	0.1	C_{44}	0.066 8	0.5	0.3	0.1	0.1
C_{24}	0.018 6	0.6	0.2	0.1	0.1	C_{45}	0.034 4	0.3	0.3	0.1	0.2
C_{25}	0.007 1	0.6	0.2	0.1	0.1	C_{46}	0.066 9	0.3	0.2	0.3	0.2

Table 8 Comprehensive evaluation results

Evaluation results	Review point	Evaluation summarizing
Excellent	10	0.429 5
Good	8	0.262 1
Average	6	0.175 9
Poor	4	0.132 5

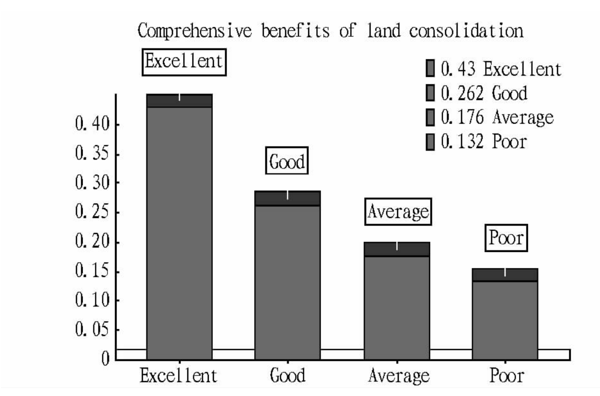

Fig. 3 Block diagram for comprehensive benefits fitted by Matlab software

4 Conclusion

Among issues concerning multiple scheme comprehensive evaluation, due to AHP not suitable for obtaining weight value of schemes, we established a model on the basis of combining AHP and FUZZY theory. This model obtains weight value of every level indicator by AHP, determines property value of each scheme by FUZZY method, and finally obtains the evaluation results. The data processing is achieved through Excel and Matlab software. In summary, as a comprehensive evaluation system based on qualitative analysis, this model can comprehensively and effectively reflect characteristics of land consolidation, better evaluate overall value of land consolidation, and provide guidance opinion for making decisions for inspection and acceptance of land consolidation projects. Therefore, it has certain extension value in the benefit evaluation of land consolidation projects.

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(To page 26)

on the one hand, uses optimized structure of agriculture system and advanced agricultural technology, to promote the utilization rate of agricultural resources, reduce waste and increase the value-added of the agricultural resources; on the other hand, uses good ecological environment to protect the existing agricultural resources, thereby effectively promoting the sustainable use of agricultural resources. It is necessary to train a group of eco-agriculture construction personnel, to guide the development of ecological agriculture in various regions; improve the environmental awareness of the village cadres and farmers. Only when the resources and environment awareness of village cadres and farmers is improved, can they pay attention to the protection of the ecological environment in the development of agricultural production, so as to promote the sustainable use of agricultural resources.

In order to improve the production potential of the land in Guizhou Province, we need to pay attention to the following aspects:

(1) Increasing vegetation. According to the law of vertical and hierarchical structure of plant communities, taking actions that suit local circumstances to plant shrub, herb and ground layer vegetation; carrying out environmental transformation and natural repair in the ecologically deteriorated regions.

(2) Strengthening the construction of basic grain ration farmland. With the growth of the population, the per capita amount of food is constantly declining, and the farmers and herdsmen blindly reclaim the land under the production conditions of low grain yield, further making the ecological environment of agriculture in the province deteriorate. Accelerating the construction of basic grain ration farmland in rural areas is a premise of fundamental solution to the problem of food security.

(3) Exploring the development of animal husbandry. The development of the ecological animal husbandry is one of the effective measures to increase food security.

(4) Strengthening the construction of rural energy such as biogas. In order to ensure the results of returning farmland to forest and forest conservation, it is necessary to accelerate the development of ecological agriculture, and vigorously adopt various measures, to greatly enhance the production capacity of the land in Guizhou Province.

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