Evaluation System for Farmers' Satisfaction Degree in the Green Energy Saving Rebuilding of Rural Residence

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Abstract In view of the present situation of measuring a green residence just by energy saving and environmental protection, we propose that we should build the rural residence more from the farmer's view and set up an evaluation system based on farmers satisfaction. A total of 16 factors affecting the farmers' satisfaction degree of green energy saving rebuilding of rural residence are selected. Questionnaire survey on 110 peasant households is carried out under different situations in Guanzhong region in Shaanxi Province, so as to obtain the importance score of evaluation index. During constructing the evaluation system for farmers' satisfaction degree, Factor Analysis Method is used to classify the related influencing factors. Subjective analysis of Analytic Hierarchy Process and the objective analysis of Factor Analysis Method are combined together to determine the weights of factors at different grades. Then, the final evaluation model is obtained, which provides guidance for the further green energy saving rebuilding of rural residence in China.

Key words Green rebuilding, Farmers satisfaction degree, AHP, Factor analysis, Evaluation model, China

Green energy saving rebuilding of rural residence refers to the rebuilding of existing rural constructions by green energy saving techniques, mainly including the rebuilding of housing construction, interior space, construction equipment, conventional energy, and new energy systems of residences. Corresponding rebuilding methods are adopted according to local climate and environment, in order to save resources and protect environment. Different from general energy saving, green energy saving can protect environment and reduce pollution while saving energy. At present, China has more than 40 billion square meters construction areas in both rural and urban areas. And the annual building energy consumption reaches 376 million tce, accounting for 27.60% of the total social terminal energy consumption. Among them, rural residence accounts for more than 60% of the total housing areas, which is about 25 billion square meters and the annual energy consumption of which is as high as 100 billion kilowatt hour[1]. Therefore, green energy saving rebuilding of rural residence is of great significance, which brings substantial changes in rural areas, improves the living conditions of farmers, and saves the consumption of energy. However, current green energy saving rebuilding of rural residence only stresses on the energy saving of buildings, and neglects the acceptance of farmers. Thus, farmers often do not respond positively. According to the problems in the rebuilding at present, we put forward that rebuilding of green houses should be evaluated from the satisfaction degree of farmers. Issues farmers cared about are investigated by questionnaire survey. A satisfaction evaluation system suitable for the green energy saving rebuilding of rural residence is established. Finally, corresponding suggestions are put forward based on the evaluation results, so as to improve the level of green energy saving rebuilding of rural residence in China.

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1 Questionnaire design and investigation

A total of 16 factors affecting the farmers' satisfaction degree of green energy saving rebuilding of rural residence are selected (Table 1). Questionnaire survey on 110 peasant households is carried out under different situations in Guanzhong region, Shaanxi Province, China. This investigation adopts the forms of questionnaires and interviews. In order to ensure the objectivity and fairness, leading questions are not permitted during the investigation. A total of 110 questionnaires are sent out and all of them are available. According to preliminary statistical analysis, there are 103 effective questionnaires, representing a 97.27% response rate.

Likert scale is adopted as an evaluation method. According to the farmer's personal experience to each question, appropriate score for each question is given. The lowest score is 1, indicating it is not worth the money and unacceptable. The highest score is 5, indicating it is well worth the money and farmers are quite willing to accept it. The degree gradually increases from score 1 to 5. Finally, the composite score is obtained in order to reflect the farmers' satisfaction degree with their residences after green rebuilding. At the same time, the same method is adopted to rank the importance of factors. Table 1 reports the importance scores of the factors.

2 Construction of the evaluation index system of satisfaction degree

An evaluation index system of farmers' satisfaction degree with green energy saving rebuilding of rural residences is established, which includes the indices at three grades. The first-grade index is the overall satisfaction degree of farmers with green rebuilding of rural residences. The second-grade index is the key factor selected from the satisfaction degree indices by factor analysis. The third-grade index is the factors with multi-collinearity affecting the farmers' satisfaction degree with green energy saving rebuilding of rural residences.

Table 1 Importance scores of the evaluation indices for the farmers' satisfaction degree with the green energy saving rebuilding of rural residences

Index	Content of the index	Highest score	Mean score	Scoring rate
Water saving(X_1)	Cost and convenience degree of water saving and the cost for corresponding renovation	5	2.55	0.510
Electricity saving(X_2)	Cost and convenience degree of electricity saving and the cost for corresponding renovation	5	2.73	0.546
Coal (gas) saving(X_3)	Cost and convenience degree of coal (gas) saving and the cost for corresponding renovation	5	3.18	0.636
Door and window rebuilding (X_4)	Cost and convenience degree of heating saving and the cost for corresponding renovation	5	4.45	0.890
Wall rebuilding (X_5)	Acceptability degree of the cost for door and window green rebuilding	5	4.55	0.910
Roof rebuilding (X_6)	Acceptability degree of the increased cost for wall green rebuilding	5	3.82	0.764
Ground rebuilding (X_7)	Acceptability degree of the increased cost for roof green rebuilding	5	3.45	0.690
Spatial arrangement(X_8)	Acceptability degree of the increased cost for the rebuilding of reasonable spatial arrangement	5	2.36	0.472
New energy-saving equipment(X_9)	Acceptability degree of the increased cost for the new energy-saving equipment	5	2.91	0.582
Exterior ornamentation (X_{10})	Beauty of exterior part after green rebuilding of residences	5	3.45	0.690
Interior ornamentation(X_{11})	Beauty of interior part after green rebuilding of residences	5	4.36	0.872
Overall comfort(X_{12})	Overall comfortable degree after green rebuilding of residences	5	4.24	0.848
Happiness index(X_{13})	Increased degree of the happiness index after green rebuilding of residences	5	3.36	0.672
Solar energy(X_{14})	Convenience degree brought by solar energy	5	3.12	0.624
Methane tank(X_{15})	Convenience degree brought by methane tank	5	2.82	0.564
Other new energy(X_{16})	Convenience degree brought by other new energy	5	2.24	0.448

2.1 Establishment of hierarchical structure model Factor Analysis Method[2] is used to establish the hierarchical structure model for the evaluation index system of satisfaction degree[3-5]. In order to ensure the equal status of variables in analysis, standardized processing (Z-score transformation) of original evaluation index data is carried out by using the normal standardized method in SPSS software, so as to obtain a new data table. Then, KMO and Bartlett tests on statistical data are carried out. Test result shows that the coefficient is 0.835 and there is statistical significance. Therefore, it is appropriate to carry out factor analysis on the original data.

Rotation of factors is carried out by the maximum variance method. Table 2 reports the variance decomposition of common factors after rotation. Through analysis, we obtain 4 common factors, the eigenvalues of which explain 80.189% of the variance. Thus, the dimension reduction of original index is realized.

Table 2 Total variance decomposition of common factors

Common factor	Initial value			Extracted sums of squared loadings			Rotated sums of squared loadings		
	Eigenvalue	Contribution rate//%	Cumulative contribution rate//%	Eigenvalue	Contribution rate//%	Cumulative contribution rate//%	Eigenvalue	Contribution rate//%	Cumulative contribution rate//%
1	6.168	37.299	37.299	6.168	37.299	37.299	5.097	30.608	30.608
2	3.749	22.180	59.478	3.749	22.180	59.478	4.072	25.201	55.809
3	1.824	11.401	70.879	1.824	11.401	70.879	2.140	13.372	69.182
4	1.490	9.311	80.189	1.490	9.311	80.189	1.921	11.008	80.189

Table 3 reports the factor loading matrix after rotation, indicating the variables providing main information for factors. According to Table 3, it is concluded that common factor 1 has positive correlation with the acceptability degrees of the increased costs for door and window, wall, roof ground and other residences rebuilding, which mainly reflects the acceptability degree of green rebuilding cost of rural residences. Common factor 2 has positive correlation with the increase of new energy-saving equipment, exterior ornamentation, interior ornamentation, overall comfort and the happiness index after rural residence rebuilding, which mainly reflects the increasing degree of the practical performance after rebuilding. Common factor 3 has positive correlation with the convenience degrees brought by solar energy, methane tank, and other new energy, as well as the benefits brought by water, electricity, and coal (gas) savings, which reflects the energy consumption after rebuilding. Common factor 4 has correlation with the expectation degree of spatial arrangement and the unused new energy during green rebuilding of rural residence, which belongs to the expectations for green rebuilding of rural residence.

Table 3 Factor loading matrix after rotation

Index	Common factor 1	Common factor 2	Common factor 3	Common factor 4
Water saving(X_1)	0.168	0.047	0.920	−0.041
Electricity saving(X_2)	0.022	0.266	0.874	−0.047
Coal (gas) saving(X_3)	0.112	−0.284	0.893	0.019
Door and window rebuilding (X_4)	0.879	0.063	0.373	0.086
Wall rebuilding (X_5)	0.840	−0.110	0.209	−0.053
Roof rebuilding (X_6)	0.800	−0.109	−0.233	0.081
Ground rebuilding (X_7)	0.929	0.063	0.101	0.072
Spatial arrangement(X_8)	0.002	0.217	−0.111	0.852
New energy-saving equipment(X_9)	−0.315	0.827	−0.106	0.329
Exterior ornamentation (X_{10})	0.274	0.773	0.043	0.104
Interior ornamentation(X_{11})	0.198	0.951	−0.052	0.108
Overall comfort(X_{12})	0.053	0.822	0.363	0.292
Happiness index(X_{13})	0.262	0.826	0.128	0.087
Solar energy(X_{14})	0.402	0.140	0.889	−0.114
Methane tank(X_{15})	−0.144	0.263	0.977	0.086
Other new energy(X_{16})	0.365	0.052	0.198	0.903

Hence, the four second-grade indices are rebuilding cost, practical degree, energy consumption, and rebuilding expectation. And X_1 – X_{16} are the 16 third-grade indices. Table 4 reports the hierarchical structure model of these indices.

Table 4 Hierarchical structure of the satisfaction degree evaluation index system

Target layer	Criterion layer	Index layer
Satisfaction degree with the green rebuilding of rural residence (F)	Rebuilding cost(F_1)	Door and window rebuilding (X_4)
		Wall rebuilding (X_5)
		Roof rebuilding (X_6)
		Ground rebuilding (X_7)
	Practical degree(F_2)	New energy-saving equipment(X_9)
		Exterior ornamentation (X_{10})
		Interior ornamentation(X_{11})
		Overall comfort(X_{12})
		Happiness index(X_{13})
	Energy consumption(F_3)	Water saving(X_1)
		Electricity saving(X_2)
		Coal (gas) saving(X_3)
		Solar energy(X_{14})
		Methane tank(X_{15})
	Rebuilding expectation(F_4)	Spatial arrangement(X_8)
		Other new energy(X_{16})

2.2 Determination of index weight[6]

2.2.1 Weight of the second-grade indices to first-grade indices. Variance contribution of factor F_j ($j=1,2,\cdots p$) to all the variables is the square sum of the elements in the jth row in matrix, that is, $\lambda_j=\sum_{i=1}^{p}a_{ij}^2$. It is an index evaluating the relative importance of common factor. Greater value of V_j indicates bigger contribution of F_j. Thus, variance contribution of common factor is usually used as the weight. In reality, if ranking the variance contributions of common factors, their eigenvalues are also in the same order. Hence, we have

$$\lambda_j=\sum_{i=1}^{p}a_{ij}^2=V_j \quad (1)$$

The first-grade index can be expressed as:

$$F=\frac{\lambda_1}{\sum_{j=1}^{m}\lambda_j}F_1+\frac{\lambda_2}{\sum_{j=1}^{m}\lambda_j}F_2+\cdots+\frac{\lambda_m}{\sum_{j=1}^{m}\lambda_j}F_m \quad (2)$$

where $\frac{\lambda_j}{\sum_{j=1}^{m}\lambda_j}$ is the jth common factor, that is, the weight of the jth second-grade index to the first-grade index[7].

The corresponding eigenvalues of the 4 common factors are 5.097, 4.072, 2.140 and 1.921, respectively. The overall evaluation value of farmers' satisfaction degree can be calculated according to equation (2):

$$F=0.39F_1+0.31F_2+0.16F_3+0.14F_4 \quad (3)$$

2.2.2 Weight of third-grade index to second-grade index. Weight of third-grade index can be determined by the Analytic Hierarchy Process. Through the investigation, farmers give the scores of the importance degrees of factors affecting their satisfaction degree, the result of which is shown in Table 1. Quantification of the results is conducted for the convenience of comparison. And the criteria scale of Analytic Hierarchy Process is used to construct the comparison judgment matrix[8].

(1) Construction of judgment matrix. Based on the analysis on the scores of the importance degrees of factors in Table 1, a total of 4 judgment matrixes with relative importance are obtained:

$$R_1 = \begin{bmatrix} 1 & 1 & 4 & 5 \\ 1 & 1 & 4 & 5 \\ 1/4 & 1/4 & 1 & 2 \\ 1/5 & 1/5 & 1/2 & 1 \end{bmatrix}$$

$$R_2 = \begin{bmatrix} 1 & 1/3 & 1/7 & 1/3 & 1/2 \\ 3 & 1 & 1/5 & 1 & 2 \\ 7 & 5 & 1 & 5 & 5 \\ 3 & 1 & 1/5 & 1 & 1 \\ 2 & 1/2 & 1/5 & 1 & 1 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 1 & 1/2 & 1/3 & 1/3 & 1/2 \\ 2 & 1 & 1/3 & 1/3 & 1 \\ 3 & 3 & 1 & 1 & 2 \\ 3 & 3 & 1 & 1 & 2 \\ 2 & 1 & 1/2 & 1/2 & 1 \end{bmatrix}$$

$$R_4 = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$$

(2) Consistency test and single-grade sequencing. In order to obtain a reasonable conclusion by Analytic Hierarchy Process, consistency test on the judgment matrix is carried out. In order to judge the consistency of judgment matrix, consistency index (CI) and random consistency index (CR) should be calculated. Their calculation equations are:

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{4}$$

$$CR = \frac{CI}{RI} \tag{5}$$

where n is the order of matrix, and RI is the mean consistency index. Since consistency error of judgment matrix differs at different orders, the requirements of CI value are different. RI is introduced to evaluate the satisfying consistency of judgment matrix at different orders. As for the judgment matrix at 1 – 9 orders, the values of RI are 0, 0, 0.58, 0.89, 1.11, 1.25, 1.35, 1.40, 1.45 and 1.49, respectively[9]. When $CR < 0.1$, it is believed that the judgment matrix has satisfying consistency.

Eigenvalue λ and eigenvector W of judgment matrix R should be calculated when carrying out single-grade arrangement. $\lambda max = max(\lambda)$ means satisfying $RW = \lambda max W$. Normalized calculation of eigenvector W is carried out; and the components of eigenvector W are the weights of corresponding elements. Hence, the calculation result is:

$$R_1 = \begin{bmatrix} 0.408 & 0.408 & 0.421 & 0.385 \\ 0.408 & 0.408 & 0.421 & 0.385 \\ 0.102 & 0.102 & 0.105 & 0.154 \\ 0.082 & 0.082 & 0.053 & 0.076 \end{bmatrix} \rightarrow \begin{bmatrix} 1.622 \\ 1.622 \\ 0.463 \\ 0.293 \end{bmatrix} \rightarrow \begin{bmatrix} 0.406 \\ 0.406 \\ 0.115 \\ 0.073 \end{bmatrix} = W_1$$

$$R_2 = \begin{bmatrix} 0.063 & 0.043 & 0.082 & 0.040 & 0.053 \\ 0.188 & 0.128 & 0.115 & 0.120 & 0.211 \\ 0.438 & 0.638 & 0.574 & 0.600 & 0.533 \\ 0.188 & 0.128 & 0.115 & 0.120 & 0.105 \\ 0.125 & 0.064 & 0.115 & 1.120 & 0.105 \end{bmatrix} \rightarrow \begin{bmatrix} 0.280 \\ 0.760 \\ 2.776 \\ 0.655 \\ 0.529 \end{bmatrix} \rightarrow \begin{bmatrix} 0.056 \\ 0.152 \\ 0.555 \\ 0.131 \\ 0.106 \end{bmatrix} = W_2$$

$$R_3 = \begin{bmatrix} 0.091 & 0.059 & 0.105 & 0.105 & 0.078 \\ 0.182 & 0.118 & 0.105 & 0.105 & 0.154 \\ 0.273 & 0.353 & 0.316 & 0.316 & 0.308 \\ 0.273 & 0.353 & 0.316 & 0.316 & 0.308 \\ 0.182 & 0.118 & 0.158 & 1.158 & 0.154 \end{bmatrix} \rightarrow \begin{bmatrix} 0.473 \\ 0.664 \\ 1.565 \\ 0.565 \\ 0.769 \end{bmatrix} \rightarrow \begin{bmatrix} 0.087 \\ 0.133 \\ 0.313 \\ 0.313 \\ 0.154 \end{bmatrix} = W_3$$

$$R_4 = \begin{bmatrix} 0.5 & 0.5 \\ 0.5 & 0.5 \end{bmatrix} \rightarrow \begin{bmatrix} 1 \\ 1 \end{bmatrix} \rightarrow \begin{bmatrix} 0.5 \\ 0.5 \end{bmatrix} = W_4$$

Judgment matrix of rebuilding cost R_1 is:

$W_1 = [0.406, 0.406, 0.115, 0.073]^T$ $\lambda_{max} = 4.004$; $CI = 0.001$; $CR = 0.001$.

Judgment matrix of practical degree R_2 is:

$W_2 = [0.056, 0.152, 0.555, 0.131, 0.106]^T$ $\lambda_{max} = 5.016$; $CI = 0.004$; $CR = 0.0036$.

Judgment matrix of energy consumption R_3 is:

$W_3 = [0.087, 0.133, 0.313, 0.313, 0.154]^T$ $\lambda_{max} = 5.002$; $CI = 0$; $CR = 0.0005$.

Judgment matrix of rebuilding expectation R_4 is:

$W_4 = [0.5, 0.5]^T$ $\lambda_{max} = 2$, $CI = 0$, $CR = 0$.

Their random consistency indices CR are all smaller than 0.1 and have all passed the consistency test.

According to the results of single ranking at the same grade, weights of single-grade sequencing are obtained by weighing:

$$F_1 = 0.406X_4 + 0.406X_5 + 0.115X_6 + 0.073X_7 \tag{6}$$

$$F_2 = 0.056X_9 + 0.152X_{10} + 0.555X_{11} + 0.131X_{12} + 0.106X_{13} \tag{7}$$

$$F_3 = 0.087X_1 + 0.133X_2 + 0.313X_3 + 0.313X_{14} + 0.154X_{15} \tag{8}$$

$$F_4 = 0.500X_8 + 0.500X_{16} \tag{9}$$

Hence, the finally evaluation model is obtained by bringing equations (6)(7)(8)(9) into equation (3):

$$F = 0.014X_1 + 0.021X_2 + 0.050X_3 + 0.158X_4 + 0.158X_5 + 0.045X_6 + 0.028X_7 + 0.070X_8 + 0.017X_9 + 0.047X_{10} + 0.172X_{11} + 0.041X_{12} + 0.033X_{13} + 0.050X_{14} + 0.025X_{15} + 0.070X_{16}$$

3 Conclusion

The evaluation system for farmers' satisfaction degree is an open system. And the influencing factors of satisfaction degree can be reasonably adjusted with in-depth study and practice. Due to the classification of influencing factors and the hierarchy of the evaluation system for farmers satisfaction degree, we carry out field investigation and use the Analytic Hierarchy Process and Factor Analysis Method to evaluate the results obtained. It can be concluded that this model has certain practical value and has certain conductive significance to the further green energy saving and rebuilding of rural residences in China.

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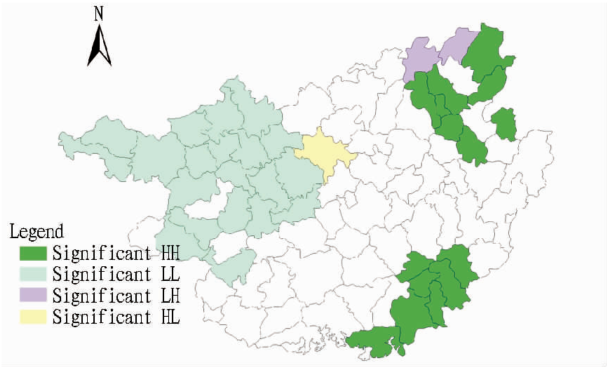

Fig. 2 LISA clustering of rural per capita net income in Guangxi (1996)

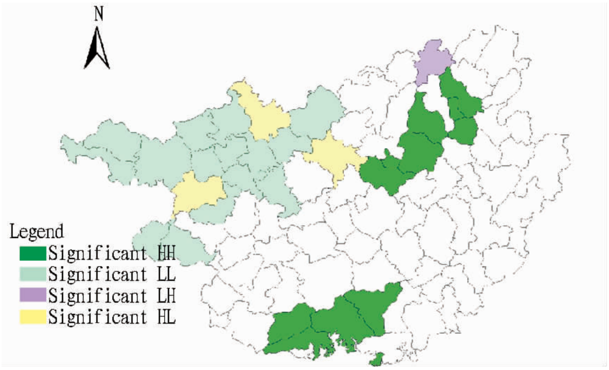

Fig. 3 LISA clustering of rural per capita net income in Guangxi (2007)

3 Conclusion and suggestions

By using ESDA technology which takes the spatial correlation measure technology as core and GIS technology, we can discern directly the spatial distribution characteristics of regionalized difference. In addition, due to the consideration of spatial effect, it is beneficial to unveil the spatial heterogeneity and spatial correlation of rural economic difference, so it is suitable for researching the problems of rural regional economic difference. On the whole, the spatial difference of rural economy of Guangxi tends to dwindle, the spatial interaction among counties is increasingly strengthened, and the county economy and the surrounding areas tend to develop in tandem. But the basic framework of imbalanced development of rural regional economic development has not been changed radically. The developed regions concentrate in the southeastern and central Guangxi, while the northern Guangxi is still the underdeveloped agricultural region. In order to change the status quo of underdeveloped regions which arises from the factors of location and history, as far as I'm concerned, we should endeavor to do as follows:

Firstly, Taking advantage of the establishment of China-ASEAN Free Trade Area, and the historical opportunity of the development of Beibu Gulf Economic Zone, Guangxi should adjust the irrational factors in the process of economic development; develop the stagnant regional economy vigorously; promote the rural economic development of these regions.

Secondly, we should adjust the agricultural industrial structure actively, and develop modern agriculture. The local government should develop the local economy actively, and pay attention to the development of modern agriculture and characteristic agriculture, for example one village with one characteristic product and one region with one characteristic product. We should also take advantage of the local characteristics, and develop the agriculture of region by using the concept of agricultural industrial cluster so as to elongate the agricultural industrial chain. In the meanwhile, the agricultural management department of autonomous region should coordinate the development of Guangxi's agriculture and lay out rationally the agricultural industry in whole region so as to offer good developmental environment and policy guidance for agricultural development.

Thirdly, we should reinforce the construction of agricultural infrastructure, quicken the pace of land circulation, exert the advantage of the concentrated management of land, and introduce powerful agricultural enterprises to propel the development of local agricultural industry.

Fourthly, we should coordinate the development of agricultural industrial service, for example, perfecting the agricultural logistics system in order to formal modern agricultural industrial system. We should also support the agricultural technology vigorously and strengthen farmers' vocational training.

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