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# The Pattern of Multiple Attribute and Multiple Layers and Multiple Dimension Grey Making Decision for Land Ecological Security Assessment

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*Abstract*—**Land ecological security assessment is the hot researching point for land resources sustainable use, based on the uncertainty of land ecological security assessment and the complexity of evaluating index, the method of grey making decision is used. At first, the concepts of absolute whiting degree and relative whiting degree of grey number are put out, and based on relative whiting degree of evaluating index, the pattern of multiple attribute and multiple level and multiple dimension grey making decision is presented in this paper. Then, the presented model is used for land ecological security assessment of ten counties of Linyi city, Shandong province，China. The grey making decision sequence and the classification of evaluation samples are determined at the same time.**

***Keywords*—land ecological security assessment; multiple dimension grey decision making; relative whiting degree; weight**

## I. INTRODUCTION

Land ecological security is ecological undertaking of all ecological economy system and its sustainable development, and it is a foundation of nation security, it also is the hot researching point for land resources sustainable use [1]. At present, the method of land ecological security assessment mainly includes principle component analysis, comprehensive index, fuzzy comprehensive assessment [2], etc, but these methods individually have different advantages and different shortcomings. Because of the uncertainly of land ecological security assessment, and the included information of assessing projects is of "part known, part unknown" grey information[3], therefore, the multiple dimension grey making decision is employed to assess land ecological security. The methods of grey relation degree and grey clustering are the common used ways of grey making decision [4]. The model of grey relation degree, due to the relation coefficient, is used for ordering the sequence, and the gained evaluating result is one dimension making decision information [5]. The grey clustering is a method of multiple dimension evaluating based on the whiting function of grey number, and it is essentially supervised clustering [6]. Because of being difficult to establish the whiting function of grey number and having the restrictively for multiple layer assessing problems, the concepts of absolute whiting degree and relative whiting degree of grey number are put out, and based on relative whiting degree of evaluating Index, the pattern of multiple attribute and multiple level and multiple dimension grey making decision is presented in this paper. The thought of the presented pattern is that the non-supervised clustering is used to evaluating lowest layer units and grey situation making decision is used to evaluating above layer units. At the same way, repeating the computing process until the top layer. Then, the presented model is used for land ecological security assessment of ten counties of Linyi city, Shandong province, China. The grey making decision sequence and the classification of evaluation samples are determined at the same time.

## II. MATHEMATICAL MODEL

Assume the making decision set is $D=\{d_1,\ d_2,\ \cdots,\ d_n\}$, and the assessment index set is ${}_1U=\{{}_1U_1,\ {}_1U_2,\ \cdots{}_1U_a,\ \cdots,\ {}_1U_q\}$, ${}_1U_a$ is the $a$ th assessment index of the first layer. According to the comparability of assessment index, the first layer's assessment indexes are synthesized into the second layer's assessment indexes, then, ${}_2U=\{{}_2U_1,\ {}_2U_2,\ \cdots{}_2U_i,\ \cdots,\ {}_1U_t\}$, ${}_2U_i$ is the $i$ th assessment index of the second layer, which is made up of the first layer's assessment indexes. Assume the decision making grade is divided onto $c$ assessment classes, the making decision assessment set is $V=\{v_1,\ v_2,\ \cdots,v_c\}$, $v_1$ represents for the first-rate decision making, $v_2$ represents for the second-rate decision making, in the same way, $v_c$ represents for the low-grade decision making .

### *A Absolute whiting degree and relative whiting degree of assessment index*

The number whose probable range we know and whose value we don't know is called as grey number [7]. The assessment indexes can be regarded as grey numbers, which are influenced by many random factors. The known values of the assessment indexes are regarded as the whiting value of grey numbers. In grey cluster problems, it is the key step to determine the whiting function of grey classes, but for the continuity of the distribution of the assessment index, the threshold value of grey classes is difficult to determine, and the application of grey clustering is restricted in some ways. To solve the problem and consider the relativity of decision making, we imitate the definition of absolute membership and relative membership in fuzzy mathematics [8], the absolute whiting function and relative whiting function is defined as follows:

**Definition 1**. Assume $\otimes$ is a grey number in the information domain, the absolute poles are individually endowed 0 and 1, the interval [0, 1] is established in the number axis. The arbitrary grey whiting value $\tilde{\otimes}(u)$ is endowed the value $\mu_{\otimes}^{0}(\tilde{\otimes}(u))$, then the function is as follows:

$$\mu_{\otimes}^{0}: U \to [0,\ 1]$$
$$\tilde{\otimes}(u) \mapsto \mu_{\otimes}^{0}(\tilde{\otimes}(u)) \qquad (1)$$

The formula (1) is called as absolute whiting function of the grey number $\otimes$. $\mu_{\otimes}^{0}(\tilde{\otimes}(u))$ is called as absolute whiting degree of the grey number $\otimes$.

**Definition 2**. Assume $\otimes$ is a grey number in the information domain, the reference poles are individually endowed 0 and 1, the interval [0, 1] is established in the number axis. The arbitrary grey whiting value $\tilde{\otimes}(u)$ is endowed the value $\mu_{\otimes}(\tilde{\otimes}(u))$, then the function is as follows:

$$\mu_{\otimes}: U \to [0,\ 1]$$
$$\tilde{\otimes}(u) \mapsto \mu_{\otimes}(\tilde{\otimes}(u)) \qquad (2)$$

The formula (2) is called as relative whiting function of the grey number $\otimes$. $\mu_{\otimes}^{0}(\tilde{\otimes}u)$ is called as relative whiting degree of the grey number $\otimes$.

According to the demand of special problems, sometimes the absolute whiting degree is computed, but the relative whiting degree is computed for the decision making. The concept of the relative whiting degree makes it easy to solve the assessment problems by using of grey theory. The method of computing whiting degree for two typical whiting functions is as follows:

$$f_A(\tilde{\otimes}(x_{ij})) = \left(\frac{\tilde{\otimes}(x_{ij}) - \tilde{\otimes}(x_i)_{\min}}{\tilde{\otimes}(x_i)_{\max} - \tilde{\otimes}(x_i)_{\min}}\right)^p \qquad (3)$$

$$f_C(\tilde{\otimes}(x_{ij})) = \left(\frac{\tilde{\otimes}(x_i)_{\max} - \tilde{\otimes}(x_{ij})}{\tilde{\otimes}(x_i)_{\max} - \tilde{\otimes}(x_i)_{\min}}\right)^p \qquad (4)$$

In the above formula, the $f_A(\tilde{\otimes}(x_{ij}))$ 、 $f_C(\tilde{\otimes}(x_{ij}))$ are the relative whiting degree, $\tilde{\otimes}(x_{ij})$ is the whiting value of $j$ th project $i$ th index, $\tilde{\otimes}(x_i)_{\max}$ is the maximum value of $i$ th whiting value, $\tilde{\otimes}(x_i)_{\min}$ is the minimum value of $i$ th whiting value, $p$ is the computing parameter, when $p=1$, the formula (3), (4) is changed into generally model.

*B The multiple dimension grey decision making pattern of multiple indexes unit system*

Assume the $k$ th unit system has $m$ assessment indexes, then the whiting index value vector of $j$ th decision making is as follows:

$${}_kX_j = ({}_kx_{1j},\ {}_kx_{2j},\ \cdots,\ {}_kx_{mj})^T \qquad (5)$$

The whiting index value matrix of $k$ th unit decision making system is as follows:

$${}_kX = ({}_kx_{ij})_{m\times n} \qquad (6)$$

In above formula, $k=1,\ 2,\ \cdots,t$ ; $i=1,\ 2,\ \cdots,m$ ; $j=1,\ 2,\ \cdots,n$ ; ${}_kx_{ij}$ is the whiting value of $j$ th index of the $k$ th unit system.

In order to overcome the influence of varying index, the raw data should be initialized by formula (3) or (4). Then the relative whiting degree matrix is as follows:

$${}_kR = ({}_kr_{ij})_{m\times n} \qquad (7)$$

Assume the decision making set is divided into $c$ classes, then

$${}_kU = ({}_ku_{ij})_{h\times j} \qquad (8)$$

In the formula $k=1,\ 2,\ \cdots,t$ ; $h=1,\ 2,\ \cdots,c$ ; $j=1,\ 2,\ \cdots,n$ ; ${}_kU$ is called as the multiple dimension grey decision making recognition matrix. ${}_ku_{ij}$ is grey relative membership which the $j$ th decision making belongs to the $h$ th pattern. The formula (8) is accord with the following equation:

$$0 \le {}_ku_{hj} \le 1,\ \sum_{h=1}^{c} {}_ku_{hj} = 1 \qquad (9)$$

Assume the ${}_ks_{ih}$ is the whiting index value of the known $c$ th decision making pattern, the matrix is as follows:

$${}_kS = ({}_ks_{ih})_{m\times c} \qquad (10)$$

According to the relativity of decision making, the assessment index of the first-rate and the last-grade can be determined by the following formulas:

$$\begin{aligned}{}_kS_1 &= ({}_ks_{11},\ {}_ks_{21},\ \cdots,\ {}_ks_{m1})^T \\ &= (\bigvee_{j=1}^{n} {}_kr_{1j},\ \bigvee_{j=1}^{n} {}_kr_{2j},\ \cdots,\ \bigvee_{j=1}^{n} {}_kr_{mj})^T\end{aligned} \qquad (11)$$

$$\begin{aligned}{}_kS_c &= ({}_ks_{1c},\ {}_ks_{2c},\ \cdots,\ {}_ks_{mc})^T \\ &= (\bigwedge_{j=1}^{n} {}_kr_{1j},\ \bigwedge_{j=1}^{n} {}_kr_{2j},\ \cdots,\ \bigwedge_{j=1}^{n} {}_kr_{mj})^T\end{aligned} \qquad (12)$$

The index of the $h$ th decision making pattern can be calculated by the following formula:

$${}_ks_{ih} = {}_ks_{ic} + \frac{{}_ks_{i1} - {}_ks_{ic}}{c-1}(c-h) \qquad (13)$$

By using formulas (11), (12), (13), then

$$ {}_kS_h = ({}_ks_{1h},\ {}_ks_{2h},\ \cdots,\ {}_ks_{mh})^T \qquad (14) $$

Assume the weight vector of assessment index is as follows:

$$ {}_kW = ({}_kw_1,\ {}_kw_2,\ \cdots,\ {}_kw_m)^T,\ \sum_{i=1}^{m} {}_kw_i = 1 \qquad (15) $$

In the above formulas, ${}_kw_i$ is the weight of the $i$ th index of the $k$ th unit system.

In order to compute the multiple dimension grey decision making recognition matrix, establishing the object function as following:

$$ \min\{F({}_ku_{hj}) = \sum_{j=1}^{n}\sum_{h=1}^{c}\{{}_ku_{hj}[\sum_{i=1}^{m}({}_kw_i|{}_kr_{ij} - {}_ks_{ih}|)^p]^{\frac{1}{p}}\}^2\} \qquad (16) $$

The physical meaning of formula (16) is that the sum of weighting grey distance between decision making and standard decision making is minimum. $p$ is the distance parameter, in general $p=1$ or $p=2$.

According to formula (16), (9), establish a new object function without equation restriction, as follows:

$$ L({}_ku_{hj}) = \sum_{j=1}^{n}\sum_{h=1}^{c}\{{}_ku_{hj}[\sum_{i=1}^{m}({}_kw_i|{}_kr_{ij} - {}_ks_{ih}|)^p]^{\frac{1}{p}}\}^2 - \lambda(\sum_{h=1}^{c}{}_ku_{hj} - 1) \qquad (17) $$

Let derivative equal zero, then the result is as follows:

$$ {}_ku_{hj} = \left(\sum_{a=1}^{c}\frac{\sum_{i=1}^{m}({}_kw_i|{}_kr_{ij} - {}_ks_{ih}|)^p}{\sum_{i=1}^{m}({}_kw_i|{}_kr_{ij} - {}_ks_{ia}|)^p}\right)^{-\frac{2}{p}} \qquad (18) $$

In the formula (18), $k = 1,\ 2,\ \cdots, t$; $a = 1,\ 2,\ \cdots, c$; $i = 1,\ 2,\ \cdots, m$; and $j = 1,\ 2,\ \cdots, n$.

The formula (18) is called as multiple dimension grey decision pattern of multiple indexes unit system. Using the formula (18) to calculate the multiple dimension decision making matrix formula (8), due to the principle of maximum membership, determine the project's class.

In the same way, using the formula (18) to calculate the multiple dimension decision making matrix of the first layer's unit system, ${}_kU\ (k = 1, 2, \cdots, t)$, which constructs the assessment indexes of the second layer's unit system.

*C The multiple dimension grey situation decision making pattern of multiple indexes unit system*

The multiple dimension grey decision making matrix is gained by using formula (18), which is not only the output of the first layer's unit system, but also the input of the second layer's unit system. Because the input information is multiple dimension information, the multiple dimension grey decision making pattern is not suit for the second layer unit system. There are $t$ assessment indexes, and every assessment index is the grey situation between decision making set and assessment set. Therefore, the decision making information of second layer unit system is gained by using the method of grey situation decision.

Assume ${}_iR$ is the assessment indexes of the second layer unit system, and let $({}_ir_{hj}) = ({}_iu_{hj})$, then

$$ {}_iR = ({}_ir_{hj})_{c\times n} \qquad (19) $$

In above formula, $i = 1,\ 2,\ \cdots, t$; $h = 1,\ 2,\ \cdots, c$; $j = 1,\ 2,\ \cdots, n$. ${}_iR$ is called as grey situation measured matrix about situation $(h, j)$. If

$$ {}_iG = \begin{bmatrix} {}_ig_{11} & {}_ig_{12} & \cdots & {}_ig_{1n} \\ {}_ig_{21} & {}_ig_{22} & \cdots & {}_ig_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ {}_ig_{c1} & {}_ig_{c2} & \cdots & {}_ig_{cn} \end{bmatrix} = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ 1 & 1 & \cdots & 1 \\ \cdots & \cdots & \cdots & \cdots \\ 1 & 1 & \cdots & 1 \end{bmatrix} = ({}_ig_{hj})_{c\times n} \qquad (20) $$

${}_iG$ is called as the first-rate grey situation measured matrix about situation $(h, j)$. If

$$ {}_iB = \begin{bmatrix} {}_ib_{11} & {}_ib_{12} & \cdots & {}_ib_{1n} \\ {}_ib_{21} & {}_ib_{22} & \cdots & {}_ib_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ {}_ib_{c1} & {}_ib_{c2} & \cdots & {}_ib_{cn} \end{bmatrix} = \begin{bmatrix} 0 & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 \\ \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & \cdots & 0 \end{bmatrix} = ({}_ib_{hj})_{c\times n} \qquad (21) $$

${}_iB$ is called as the last-rate grey situation measured matrix about situation $(h, j)$.

Assume the weight vector of the second layer unit system is as follows:

$$ W = (w_1,\ w_2,\ \cdots,\ w_t),\ \sum_{i=1}^{t} w_i = 1 \qquad (22) $$

There are $c \times n$ situation in the limited domain $V \times D$. The relative membership which the situation $(h, j)$ belongs to the first-rate situation is $u_{hj}$, the relative membership which the situation $(h, j)$ belongs to the last-rate situation is $u_{hj}^c$, and they are suit for the following equation:

$$ u_{hj}^c = 1 - u_{hj} \qquad (23) $$

In order to solve the relative membership $u_{hj}$ of situation $(h, j)$, establish the object function as follows:

$$ \min\{F(u_{hj}) = u_{hj}^2 D_1^2 + (1 - u_{hj})^2 D_2^2\} \qquad (24) $$

In formula (24), $D_1 = [\sum_{i=1}^{t}(w_i({}_ig_{hj} - {}_ir_{hj}))^p]^{\frac{1}{p}}$, and $D_2 = [\sum_{i=1}^{t}(w_i({}_ir_{hj} - {}_ib_{hj}))^p]^{\frac{1}{p}}$. Let $\frac{\partial F(u_{hj})}{\partial u_{hj}} = 0$, and the arranged result is as follows:

$$ u_{hj} = \left\{1 + \left\{\frac{\sum_{i=1}^{t}[w_i({}_ig_{hj} - {}_ir_{hj})]^p}{\sum_{i=1}^{t}[w_i({}_ir_{hj} - {}_ib_{hj})]^p}\right\}^{\frac{2}{p}}\right\}^{-1} \qquad (25) $$

According to formula (20), (21), the formula (25) is changed into the following formula:

$$u_{hj} = \left\{ 1 + \left\{ \frac{\sum_{i=1}^{t} [w_i (1 - {}_i r_{hj})]^p}{\sum_{i=1}^{t} [w_i ({}_i r_{hj})]^p} \right\}^{\frac{2}{p}} \right\}^{-1} \quad (26)$$

The formula (26) is called as the pattern of multiple dimension grey situation decision making.

For the assessment indexes of the second layer unit system, ${}_iR$, $i = 1, 2, \cdots, t$, by use of the formula (26), the relative membership matrix of situation $(h, j)$ is gained as follows:

$$U = (u_{hj})_{c \times n} \quad (27)$$

The matrix formula (27) is called as the multiple dimension grey situation decision making recognition matrix. In order to enhance differentiated degree, the relative membership of every column can be unitary. Let

$$H_j = \sum_{h=1}^{c} h \cdot u_{hj} \quad (28)$$

Where $H_j$ is called as class variance feature value. By using the formula (28), the class variance feature value vector can be computed as follows:

$$H = (H_1, H_2, \cdots, H_n) \quad (29)$$

According to the principle of maximum membership, the belonged cluster of every project is determined by formula (27). According to the principle that the smaller class variance feature values, the better the project, the sequence of decision making and the best project can be determined.

Obviously, the formula (18) is suitable for the low layer's decision making, and the formula (26) is suitable for the high layer's decision making. The formula (18) and (26) are called as the pattern of multiple attribute and multiple layers and multiple dimension grey decision making system.

## III. EXAMPLE

With the development of our country's economy, we are up against many problems such as economy growth, society development, more population, deficient resource, environment frailty, region difference etc. Rationally assessing land ecological security is of important significance in theory and practice. City region and nine county regions of Linyi city of Shandong province constitute assessment project set, $A$={city region（$A_1$）, Yinan county（$A_2$）, Tancheng county（$A_3$）, Yishui county（$A_4$）, Cangshan conuty（$A_5$）, Fei conuty（$A_6$）, Pingyi county（$A_7$）, Junan county（$A_8$）, Mengyin county（$A_9$）, Linchu county（$A_{10}$）}.

### *A Assessing object system*

According to the principle of constituting object system, twenty five indexes are selected as assessing object. The assessing index system is made up of resource supporting system, society supporting system, economy supporting system and environment supporting system. The first layer unit system includes assessing object as follows:

Resource supporting system ($B_1$): population density ($B_{11}$), population natural rising rate ($B_{12}$), one's average tilled land ($B_{13}$), one's average greenbelt ($B_{14}$), greenbelt covering rate ($B_{15}$), afforest covering rate ($B_{16}$), one's average water demand ($B_{17}$).

Society supporting system ($B_2$): one's average living area ($B_{21}$), one's average road area ($B_{22}$), road net density ($B_{23}$), water popularizing rate ($B_{24}$), natural gas popularizing rate ($B_{25}$), hospital number of every ten thousand people ($B_{26}$), school number of very ten thousand people ($B_{27}$).

Economy supporting system ($B_3$): one's average GDP ($B_{31}$), one's average city keeping construction fund ($B_{31}$), tenement investment rate of GDP ($B_{33}$), public service installation investment rate of GDP ($B_{34}$), technology investment rate of GDP ($B_{35}$).

Environment supporting system ($B_4$): purgation rate of dirt water ($B_{41}$), purgation rate of industrial dirt water ($B_{42}$), harmless dealing with rate of living garbage ($B_{43}$), year's average density of $SO_2$ ($B_{44}$), year's average density of $NO_2$ ($B_{45}$), one day's average value of noise ($B_{46}$).

The object characteristic value of four assessing systems constituted matrix as $\boldsymbol{X}_1'$, $\boldsymbol{X}_2'$, $\boldsymbol{X}_3'$, $\boldsymbol{X}_4'$, in order to save paper, the raw data is left out.

### *B Computing the relative whiting degree of Assessing index*

By using the formula (3), (4), and let $p = 1$, the relative whiting degree of the assessment indexes of the first layer unit system is calculated as follows.

$${}_1R^T = \begin{bmatrix} 0.736 & 0.000 & 0.538 & 0.743 & 1.000 & 0.646 & 0.467 \\ 0.964 & 0.824 & 0.590 & 0.212 & 0.000 & 0.295 & 0.993 \\ 0.525 & 0.756 & 0.282 & 0.010 & 0.150 & 0.128 & 0.785 \\ 1.000 & 1.000 & 0.410 & 0.775 & 0.214 & 0.000 & 0.820 \\ 0.791 & 0.864 & 0.923 & 0.000 & 0.040 & 0.380 & 0.000 \\ 0.338 & 0.841 & 0.513 & 0.166 & 0.036 & 0.382 & 0.226 \\ 0.626 & 0.894 & 0.000 & 0.572 & 0.411 & 0.466 & 0.235 \\ 0.683 & 0.834 & 0.333 & 0.542 & 0.236 & 1.000 & 0.204 \\ 0.000 & 0.864 & 0.103 & 1.000 & 0.219 & 0.572 & 1.000 \\ 0.683 & 0.635 & 1.000 & 0.482 & 0.483 & 0.189 & 0.387 \end{bmatrix}$$

In order to save the paper, the relative whiting degree matrix of the assessment indexes of the other first layer unit system is omitted.

### *C Assessing of the first unit system*

At first, using formula (11), (12), (13), computing the standard decision making pattern matrix of resource supporting system ($B_1$), and let $c = 3$, then

$${}_1S = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0.5 & 0.5 & 0.5 & 0.5 & 0.5 & 0.5 & 0.5 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

The method of variance objective determining weight is used to determine the weight of assessment indexes of resource supporting system [9]. The weight vector is as follows:

$_1W = (0.135, 0.128, 0.146, 0.157, 0.136, 0.132, 0.165)$

Second, let distance parameter $p = 1$, using formula (18) to compute the multiple dimension grey decision making recognition matrix, the result is as follows:

$$_1\boldsymbol{U} = \begin{bmatrix} 0.291 & 0.324 & 0.208 & 0.361 & 0.252 & 0.180 & 0.206 & 0.265 & 0.335 & 0.232 \\ 0.509 & 0.421 & 0.449 & 0.408 & 0.384 & 0.482 & 0.538 & 0.500 & 0.393 & 0.579 \\ 0.200 & 0.256 & 0.343 & 0.231 & 0.364 & 0.338 & 0.257 & 0.235 & 0.271 & 0.189 \end{bmatrix}$$

In the same way, other three the first layer unit system's weights and recognition matrixes are computed as follows:

$$W_2 = (0.134, 0.149\ 0.145, 0.149, 0.149, 0.152, 0.122)$$

$$W_3 = (0.180, 0.218, 0.195, 0.201, 0.205)$$

$$\boldsymbol{W}_4 = (0.180, 0.166, 0.167, 0.146, 0.172, 0.168)$$

$$_2\boldsymbol{U} = \begin{bmatrix} 0.312 & 0.326 & 0.276 & 0.239 & 0.243 & 0.222 & 0.472 & 0.181 & 0.182 & 0.220 \\ 0.414 & 0.495 & 0.399 & 0.437 & 0.514 & 0.529 & 0.366 & 0.383 & 0.357 & 0.562 \\ 0.275 & 0.179 & 0.325 & 0.324 & 0.244 & 0.249 & 0.163 & 0.437 & 0.461 & 0.219 \end{bmatrix}$$

$$_3\boldsymbol{U} = \begin{bmatrix} 0.533 & 0.051 & 0.108 & 0.223 & 0.063 & 0.223 & 0.127 & 0.068 & 0.089 & 0.140 \\ 0.301 & 0.108 & 0.262 & 0.407 & 0.136 & 0.435 & 0.334 & 0.149 & 0.201 & 0.401 \\ 0.165 & 0.841 & 0.630 & 0.370 & 0.801 & 0.342 & 0.539 & 0.783 & 0.710 & 0.459 \end{bmatrix}$$

$$_4\boldsymbol{U} = \begin{bmatrix} 0.384 & 0.289 & 0.187 & 0.291 & 0.195 & 0.181 & 0.134 & 0.151 & 0.224 & 0.277 \\ 0.372 & 0.538 & 0.490 & 0.509 & 0.378 & 0.552 & 0.664 & 0.468 & 0.497 & 0.421 \\ 0.244 & 0.173 & 0.323 & 0.200 & 0.427 & 0.267 & 0.202 & 0.381 & 0.279 & 0.303 \end{bmatrix}$$

### *D Assessing of the second unit system*

At first, the assessing results of the first layer unit system are changed into the input information of the second layer unit system, namely $_1U$, $_2U$, $_3U$, $_4U$. The method of variance objective determining weight is used to determine the weight of assessment indexes of the second layer assessment indexes. The weight vector is as follows:

$$W = (0.187, 0.193, 0.392, 0.228)$$

Using formula (25), and let $p = 2$, compute the multiple dimension grey situation decision making recognition matrix, the gained result is as follows:

$$\boldsymbol{U} = \begin{bmatrix} 0.570 & 0.073 & 0.051 & 0.166 & 0.039 & 0.095 & 0.089 & 0.030 & 0.055 & 0.077 \\ 0.343 & 0.214 & 0.301 & 0.559 & 0.166 & 0.651 & 0.492 & 0.194 & 0.220 & 0.562 \\ 0.087 & 0.713 & 0.648 & 0.276 & 0.795 & 0.253 & 0.420 & 0.776 & 0.725 & 0.362 \end{bmatrix}$$

According to the principle of maximum grey membership degree, the conclusion is that the 1-th cluster type includes city region ($A_1$), the 2-th cluster type includes Yishui county ($A_4$), Fei conuty ($A_6$), Pingyi county ($A_7$) and Linchu county ($A_{10}$), the 3-th cluster type includes Yinan county ($A_2$), Tancheng county ($A_3$), Cangshan conuty ($A_5$), Junan county ($A_8$) and Mengyin county ($A_9$). From the ecological security supporting conditions to see, city region ($A_1$) has strongly advantages of resource supporting, society supporting, economy supporting and environment supporting. City region ($A_1$) which belongs to the 1-th cluster type is rational.

Using the formula (27), (28), compute the class variance feature value vector as follows:

$$H = (1.517, 2.641, 2.597, 2.110, 2.757, 2.158, 2.331, 2.746, 2.670, 2.285)$$

According to the principle that the smaller the class variance feature value, the better the decision making, the sequence of the decision making set is as follows:

$$A_1 \succ A_4 \succ A_6 \succ A_{10} \succ A_7 \succ A_3 \succ A_2 \succ A_9 \succ A_8 \succ A_5$$

Obviously, the city region ($A_1$), Yishui county ($A_4$) and Fei conuty ($A_6$) are relative better in the condition of land ecological security. But Mengyin county ($A_9$), Junan county ($A_8$) and Cangshan conuty ($A_5$) are relatively worse.

In order to compare the results, by using principle component analysis again, the result is basically same as that of presented method in this paper. This shows that the method presented by authors is valid.

## IV. CONCLUSION

The study of land ecological security assessing approach is of importance for theory and practice. Based on the relative whiting degree of assessment index, the pattern of multiple attribute and multiple layers and multiple dimension grey decision making is put out, and the presented assessing method is used to evaluate land ecological security of Linyi city, Shandong province, China, the result is in accordance with practice. The assessing information not only includes the sequence of decision making but also the clustering type that the projects belong to.

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