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Research on the calculation method for the natural quality score of agricultural land based on the weighted geometric method

CHEN Ying[2], GAO Yunhua[2], Li Yanqiong[5], ZHENG Honggang[2,3,4,6]

Abstract. The natural quality score of agricultural land grading is calculated using the method of weighted mean. The method can obscure the role of some restrictive factors, but makes it difficult to distinguish the natural quality score of agricultural land, so it cannot objectively reflect the natural quality when certain arable land has obvious restrictive factors. This paper takes Luliang County of Yunnan Province as example to calculate the natural quality score of agricultural land using the weighted geometric method, and compare it with the standard grain output. The results show that the weighted geometric method increases the section of calculation value of natural quality range of agricultural land, highlights the difference between natural quality of arable land and makes calculation results more accurate.

Key words. Agricultural land, natural quality score, weighted geometric method.

1. Introduction

Arable land is the most valuable agricultural resource and an important production factor. The quality of arable land has become the decisive factor in whether

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[2]Workshop 1 - College of Water Resources and Hydraulic Engineering, Yunnan Agricultural University, Kunming 650201, China

[3]Workshop 2 - Ministry of Land and Resources "Land Use—Field Base in Luliang County of Yunnan Province", Kunming 650201, China

[4]Workshop 3 - Engineering Research Center of Science and Technology of Land and Resources, Yunnan Agricultural University, Kunming 650201, China

[5]Workshop 4 - Yunnan Agricultural University Library, Kunming 650201, China

[6]Corresponding author: ZHENG Honggang

agricultural supply and demand, income and ecological goals can be achieved or not, and the differences in quality of arable land significantly affect crop output and food security. Therefore, it is especially important to evaluate the quality of arable land in a reasonable manner. The Ministry of Land and Resources promulgated in 2001 the Code for Grading and Classification of Arable Land, marking a definite standard system in China for land grading and classification. The study of grading and classification of arable land is an important means of land evaluation and a comprehensive evaluation of potential land productivity and real productivity based on land suitability analysis [1].

The natural quality score of arable land is an important parameter in the calculation of natural quality of arable land specified in the Code for Grading and Classification of Arable Land [2], which describes other arable land conditions in addition to climate conditions including the quality conditions of arable land composed of soil, topography, drainage and irrigation, that is, the extent to which arable land meets the needs of crop growth. When it comes to the calculation of the natural quality score, Wang Hongbo et al. studied the calculation method of natural quality score within the county [3], Pan Runqiu et al. put forward the calculation model of the natural quality score of arable land based on the PB neural network [4], Chen Yanqing et al. proposed the calculation method of natural quality score based on positive and negative weights [5], and geometric method and method of weighted mean are given in the Code to calculate the natural quality score. However, the method of weighted mean is generally adopted in grading from place to place, which can obscure the role of certain restrictive factors [6] and directly affect the quality of arable land. Therefore, this paper proposes to use the weighted geometric method to improve the calculation of natural quality score. Taking the grading of agricultural land in Luliang County of Yunnan Province as example, this paper applies the method of weighted mean and weighted geometric method to empirical research, hoping to provide a reference for the calculation of natural quality score of agricultural land.

2. Research method

The calculation of natural quality score is determined by the index score and the weight. Since the index factors selected for evaluating the quality of the arable land often are interrelated, simple weighted average calculation method may often cause some factors with significant restriction to be compensated by some other factors, so that the calculation result may obscure the role of some restrictive factors. For example, the effective soil thickness of a certain plot is very thin, seriously affecting the crop growth and resulting in poor quality. However, the significant deficiency of arable land is covered up after being calculated by the method of weighted mean, leaving nearly no difference between the calculated result and the natural quality score of plots with thicker soil thickness. On the other hand, the method of weighted mean has also resulted in the unjustified quality evaluation of the land before and after remediation. For example, the general paddy field with poor infrastructure has become high standard basic farmland after land reclamation. Even though the infrastructure has been improved and the actual quality has been upgraded, it remains almost unchanged before and after reclamation due to no change in land type, and the grading calculation results are not consistent with reality. In view of the above problems, it is proposed to calculate the natural quality score using the weighted geometric method.

The weighted geometric method is widely used, which is mainly used in evaluation, decision-making and forecasting. The American scholar Yager [7] put forward the concept of ordered weighted averaging (OWA) and weighted geometric averaging (WGA) operator according to the weighted geometric method, which has been widely used in economy, management and water conservancy, etc. LIU Yanxu, PENG Jian [8] et al. used OWA method to evaluate the suitability of construction and development in Dali Prefecture of Yunnan Province; XU Zeshui and DA Qingli [9] introduced a multi-attribute decision-making method based on OWA and WGA. With regard to the calculation results of natural quality score, the difference in the quality of arable land cannot be reflected in this paper. With the introduction of the calculation method of weighted mean, it is more suitable for the grading and classification of arable land to evaluate the comprehensive requirements for each factor compared with the original method. The calculation method is sensitive to index change, especially those uncoordinated indexes (that is, some are extremely good and some are extremely poor). As a result, it can more realistically reflect the natural quality of arable land. The calculation method of weighted mean is extremely sensitive to the value of 0. If the index value of natural quality score of certain arable land is 0, it will make the comprehensive evaluation result zero. Such situation is practical for some issues. For example, if a certain plot has a slope of 35??, it is obviously that it cannot be used as arable land. However, if it is actually used as arable land, the index score can be 0 in the evaluation. In addition, the concrete weighted geometric calculation formula is shown as follows:

$$C_{Lij} = \frac{\sqrt[\sum_{k=1}^{w} wk]{\prod_{k=1}^{n} f_{ijk}^{wk}}}{100} = \frac{\sqrt[\sum wk]{f_{ij\mathrm{k}}^{w_1} * f_{\mathrm{ijk}}^{w_2} \ldots\ldots * f_{ijk}^{w_k}}}{100} \tag{1}$$

Where, CLijis the natural quality score of agricultural land of the designated crop of grading unit;i is the grading unit number;j is the designated crop number; m is the number of grading units;fijk is the index score value of kth grading factor of jth designated crop in ith grading unit, and the value range is 0˜100; wk is the weight of kth grading factor.

3. Example result and analysis

3.1. Research area summary

The method is verified with example of Luliang County in Yunnan Province. Luliang County is located in the northeast of Yunnan Province and lies between latitude 24.44 -25.18 N and longitude 103.23 -104.02 E, belonging totypical plateau mountain basin. It is surrounded by mountains in the east, west and north sides with rolling hilly land in the southwest and open flatland in the middle part, of which the flatland covers an area of 772 km2, belonging to subtropical monsoon climate region.Luliang County is one of the major grain-producing counties in Yunnan Province with a total land area of 2096km2 and governing 10 townships.The county covers an area of 76.76 hectares of arable land, accounting for 38.27% of the total land area [10].The county has complex landscape features with plateau mountains, hills and basins in alternative distribution. Due to the disparity in terrain and geomorphology, the spatial distribution of temperature is significantly different, of which dam area is warmer while mountain area is colder .

The data used in the study is the state-level summary data of Achievements of Agricultural Land Grading in Luliang County, Yunnan Province. Luliang County belongs to the Central Yunnan Plateau Basin in Yunnan Province with an average elevation of about 2000 meters, where the double cropping system is prevailing, and the designated crops are rice, corn and wheat. Taking the calculation of natural quality score of rice and corn for example, evaluation indexes are separately selected for the quality evaluation of arable land in the region due to taking into account the differences between dry land and paddy field, and the major evaluation indexes are topsoil quality, profile pattern, soil organic matter content, topographical slope, soil pH value, barrier depth from the ground surface, drainage conditions and irrigation guarantee rate, as shown in Table 1 and Table 2.

Table 1. Grading Factor Index System of Agricultural Land (Paddy Field) in Luliang County

Score	Topsoil quality	Profile pattern	Soil organic matter	Soil PH	Barrier depth from the ground surface	Drainage conditions	Irrigation guarantee rate
100	Loam	Full loam, loam/sandy soil/loam		6˜7.9	60cm	Perfect drainage	Fully met
90		Loam/clay/loam	3	5.5˜6 7.9˜8.5		Basically perfect	
80	Clay	Sandy soil/clay/clay, loam/clay/clay		5.5˜5 8.5˜9		General drainage	
70		Clay/sandy soil/clay, full clay	2		30˜60cm		Basically met
60	Sandy soil	Clay/sandy soil/full gravelly soil	1˜2	4.5˜5		No drainage	Generally met
40	Gravelly soil	Full gravelly soil	0˜1		<30cm		No irrigation facility
Weight	0.16	0.18	0.1	0.11	0.05	0.22	0.18

Table 2. Grading Factor Index System of Agricultural Land (Dry Land) in Luliang County

Score	Effective soil layer thickness	Soil organic matter	Soil PH	Exposed degree of surface rock	Topographical slope	Irrigation guarantee rate
100	100cm		6˜7.9	Level 1	<2	Fully met
90		3	5.5˜6 7.9˜8.5	Level 2	2 ˜5	
80			5.5˜5 8.5˜9		5 ˜8	
70	80cm	2		Level 3		Basically met
60		1˜2	4.5˜5		8 ˜15	Generally met
50	30cm			Level 4		
40		0˜1				No irrigation facility
30	<30cm		< 4.5 >9		15 ˜25	
Weight	0.1	0.11	0.05	0.18	0.16	0.18

3.2. Analysis of calculation results

The traditional calculation method of the natural score of agricultural land is used in this paper, that is, the method of weighted mean is used to calculate the natural quality score of Luliang County, and the natural quality score of each grading unit obtained through analysis can be used to judge whether it is consistent with the actual output (converted into standard grain), so as to determine the applicability of the two methods.

If the original calculation method is used to calculate the natural quality score of rice and corn, the final score range of Luliang County is 0.611˜0.990. Taking the natural quality score of rice and corn as x-axis and the area proportion covered as y-axis according to the calculation results, the area distribution of natural quality score is analyzed in Figure 1.

It can be seen from Figure 1 that the natural quality score of rice and corn in Luliang County obtained using method of weighted mean mainly falls between 0.9-1.0, accounting for 60.10% of the total arable land area; the range of 0.8-0.9 accounts for 22.90% of the total arable land area; the range of 0.7-0.8 accounts for 16.80%.The overall natural quality score of agricultural land is on the high sidewith almost no natural quality scorewithin the range of 0.6-0.7, which cannot well reflect the differences in the quality of agricultural land and lacks disparity.The reason is that in the original calculation formula, the result after multiplying by the weight is not significant when a certain index of arable land with poor quality is very low. However, the weighted geometric method applies weight as an index to calculation, as a result of which it may decrease the calculated natural quality score of the arable land with poor certain index score, highlighting the impact of restrictive factors on arable land.

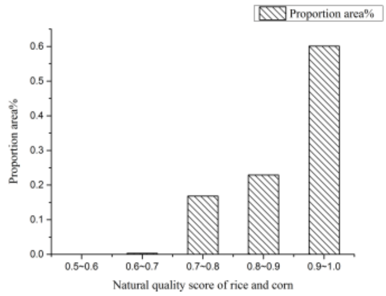

Fig. 1. Area proportion of natural quality score using geometric mean method

If the natural quality score of rice and corn in Luliang County is calculated according to Formula (1), the final score range is 0.552˜0.990. Taking the natural quality score of rice and corn as x-axis and area proportion covered as y-axis according to the calculation results, the area distribution of natural quality score is analyzed in Figure 2.

It can be seen from Figure 2 that the natural quality score of rice and corn obtained using weighted geometric method mainly falls between 0.8-0.9, accounting for 47.62% of the total arable land area; followed by the range of 0.9-1.0, accounting for 30.13%; and the arable land with the score between 0.6-0.7 accounts for 15.19%. It is obvious that the application of weighted geometric method supplements the evaluation results of arable land with poor quality and lower natural quality score in Luliang County and increases the diversity of the quality of arable land to make the evaluation results of the quality of arable land more descriptive, and highlighted the difference in the natural quality of arable land when there is a certain restrictive factor to make the evaluation results more accurate.

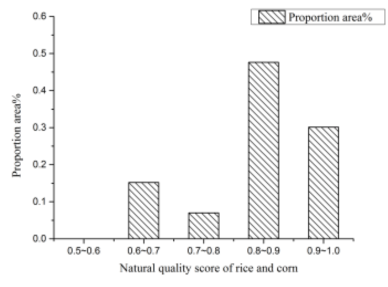

Fig. 2. Natural quality score of grading unit using weighted geometric method

To fully examine the impact of the two methods on the actual results and also to facilitate the research on comparability of the results of the two methods for the analysis of the natural quality score of agricultural land, the natural quality score is calculated separately by the original calculation method and the weighted geometric method as independent variable, and quasi-grain output is the dependent variable for linear regression, and the results are shown in Figure 3.

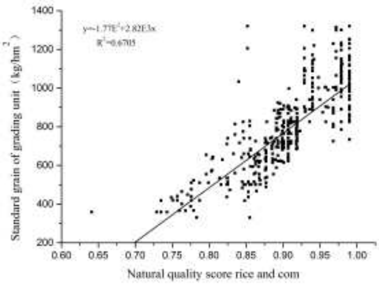

Fig. 3. Relationship between natural quality score and standard grain of grading unit (using method of weighted mean)

It can be seen from Figure 3 that there is also a positive correlation between the natural quality score and the standard grain calculated by the original method, the correlation coefficient R is 0.81 and the judge coefficient R2 is 0.6705. The distribution of natural quality score and standard grain is more concentrated with almost no distribution between 0.6-0.7, while the standard grain is between 740-1320kg within the range of 0.9-1.0, and there is a greater gap between the standard grain outputs.

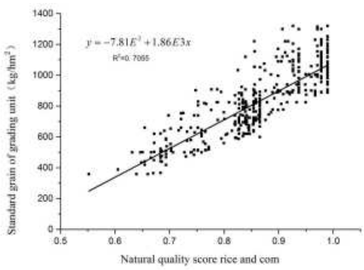

Fig. 4. Relationship between natural quality score and standard grain of grading unit (using weighted geometric method)

It can be seen from Figure 4 that there is a good correlation between the natural quality score of agricultural land and the standard grain calculated by the weighted geometric method, the correlation coefficient R is 0.84 and the judge coefficient R^2 is 0.7055. The distribution of standard grain output and natural quality score is more uniform, and the correlation is better compared with that using the method of weighted mean. As a whole, the standard grain output is on the rise with the increase in the natural quality score, indicating that the change in the quality score of each grading unit is consistent with the change trend of the corresponding standard grain output. By comparing the two results, it can be found that the results calculated using the weighted geometric method are more consistent with reality.

4. Conclusion

The results show that the natural quality score of agricultural land calculated by the weighted geometric method solves the problem that the natural quality score is not obvious due to the existence of restrictive factors. Compared with the original calculation method, the evaluation results can be better distinguished, so that the degree of discretization increases, making it easier to distinguish the good and bad natural quality of agricultural land. In addition, the result is more descriptive, the calculated result is more consistent with the actual output (standard grain output) than that calculated using the original calculation method and the result is more accurate.

The weighted geometric method can highlight the difference in the evaluation results in case of the existence of certain restrictive factor, so that it can be not only applied in the calculation of natural quality score of agricultural land, but other evaluation providing multiple factors with comprehensive evaluation to highlight the diversity and differentiation of the evaluation results.

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