Evaluation method of new cultivated land quality in Guanzhong Plain of Shaanxi Province: Taking Longting Town land consolidation project as an example

J Li¹,²,³,⁴,⁵, H Guo¹,²,³,⁴ and C S Shi¹,²,³,⁴

¹ Institute of Land Engineering & Technology, Shaanxi Land Construction Group Co. Ltd., Xi’an, Shaanxi 710075, China
² Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xin Group Co. Ltd., Xi’an, Shaanxi, China
³ Key Laboratory of Degraded and Unused Land Consolidation Engineering, Ministry of Land and Resource, Xi’an, Shaanxi 710075, China
⁴ Shaanxi Provincial Land Reclamation Engineering Technology Research Center, Xi’an, Shaanxi 710075, China

E-mail: lijuan8136@163.com

Abstract. In order to evaluate the quality of newly cultivated land as for the land reclamation project of Guanzhong Plain in Shaanxi Province, and to meet the requirements of seeking a simple and quick, convenient and accurate and universal method, this paper adopted the Analytic Hierarchy Process. The main evaluation index was selected to construct the judgment matrix. The weight coefficient of each index was determined. Each index was scored and the total score of new cultivated land was calculated. The quality of the new cultivated land was evaluated and the improvement suggestions were given. An analysis on quality of the new cultivated land - Longting Town in the land remediation project of Longting Town was conducted. After evaluation, the score of the new cultivated land was 62.8, which was a qualified level, and measures were proposed to improve the quality of the land and fertility. This method will provide a practical application for the evaluation of new cultivated land quality in other land reclamation project in temperate semi-arid plains.

1. Introduction
With the occupation of arable land because of economic development and the increasing demand for food due to population growth, it is imminent to solve the problem of maintaining the quantity and improving the quality of cultivated land. In order to achieve the dynamic balance of the total arable land, an important way is land consolidation and reclamation. China implemented the policy of "balancing the quantity of cultivated land being taken up and made up" so as to stick to the red line of 1.8 billion acres arable land [1]. While ensuring that the total area of arable land does not decrease, maintaining quantity and improving quality of arable land are important measures to promote food production and solve the contradiction between people and land. In this case, carrying out new farmland quality evaluation after finishing land reclamation project can reach the goal of project acceptance and give directional guidance on how to improve the quality of cultivated land.

The specific implementation of the quality evaluation of newly cultivated land includes the selection of indicators affecting the quality of cultivated land, site observation of cultivated land and post-sampling laboratory tests. Then, the evaluation of the quality of cultivated land can be carried out basing on the observational results and measurement results. Evaluation can be achieved through programming, mathematical methods, GIS software and other means. Hu et al [2] developed an application system that is compatible with the acceptance scheme by visual programming language Visual Basic 6.0, which can evaluate the cultivated land pollution index and the productivity of cultivated land. Luo [3] quantitatively compared the quality of newly cultivated land and the surrounding high-yield and middle-yield fields by using fuzzy mathematics comprehensive evaluation method. Li et al. [4] proved the feasibility of GIS-based comprehensive evaluation of the quality of newly cultivated farmland in small-scale in Karst hilly areas, which provided ideas and methods for the application of GIS in the evaluation of the quality of newly cultivated farmland at small scales. The ultimate goal of using various evaluation methods is to achieve a comprehensive, objective and accurate evaluation of the quality of arable land. The current study mainly focus on the hilly areas [4-6] and the valley areas [7], and researches on the farmland quality evaluation resembling that of the Guanzhong Plain in Shaanxi Province are rare.

This paper takes the newly cultivated land in Guanzhong Plain of Shaanxi Province as the object for quality evaluation. Tomographic analysis is used to select evaluation indicators suitable for the region, and scores and calculations are made. According to the comprehensive scores, comprehensive assessment of cultivated land quality can be carried out. Taking the Longting Town Land Renovation Effort Compensation and Balance Project as an example, the new farmland quality evaluation process in the plain area is given to provide reference for the new cultivated land quality evaluation of the acceptance and compensation of farmland compensation and balance projects in temperate semi-arid plain areas.

2. Method for evaluation of the quality of newly cultivated land
Completion and acceptance of land consolidation and reclamation projects include the following seven parts: technical files, engineering tasks, newly cultivated land quality, newly cultivated land, land ownership, fund management, and management and maintenance measures [2]. The acceptance of newly cultivated land acting as an important and complicated content of acceptance requires comprehensive on-site measurement and combination with laboratory testing and literature research.
In order to complete the evaluation of the land consolidation and reclamation project in Guanzhong Plain, this paper focuses on how to carry on the new farmland quality evaluation.

2.1. Evaluation process

The procedure of newly cultivated farmland evaluation is shown in Figure 1. According to the quality requirement of farmland basing on Classification Rules for Agricultural Land and Regulations for Acceptance of Land Development and Consolidation, main indexes are selected to perform the evaluation. The indexes are shown in Table 1, and the index can be added or removed according to actual situation. Then, the weight of the indexes is calculated. The evaluation standards are given and experts would mark each index. According to the weight and score of each index, the total score is obtained. Then, the quality evaluation of newly cultivated land finishes.

![Figure 1. The procedure of quality evaluation of the new cultivated farmland.](image)

### Table 1. Evaluation criteria for quality evaluation of new cultivated land.

| Evaluation index | 80~100 (excellent) | 60~80 (qualified) | <60 (unqualified) |
|------------------|--------------------|------------------|-------------------|
| Flatness $A_1$   | $\leq 3^\circ$     | $3^\circ$~$6^\circ$ | $>6^\circ$        |
| Contiguous degree $A_2$ | field plots contiguous, easy for mechanical farming | field plots are relatively concentrated and contiguous, easy for mechanical farming | field plots much scattered, not easy for mechanical farming |
| Mastery $A_3$    | Field Road and Production Road form into a network, near settlements, transportation is convenient | Field Road is less, Production Road form into a network, Production Road can reach all tillage fields | No Field Road, Production Road is less and its distribution is uneven, traffic conditions is quite inconvenient |
| Macro layout $A_4$ | The proportion of various types of land is | The proportion of various types of land is less | The proportion of various types of land is |
Soil texture\textsuperscript{[4]}$A_5$
\begin{align*}
\text{coordinated and the layout is reasonable} & \quad \text{coordinated and the layout is less reasonable} & \quad \text{not coordinated, the layout is not reasonable} \\
\text{loam} & \quad \text{powder soil} & \quad \text{sandy soil} \\
7.0-8.0 & \quad 8.1-9.0 & \quad 9.1-10.0 \\
<0.5\% & \quad 0.5-1.0 & \quad >1.0 \\
>30 \text{ g/kg} & \quad 10-30 \text{ g/kg} & \quad <10 \text{ g/kg} \\
\end{align*}

Total nitrogen $A_9$
\begin{align*}
>1.5 \text{ g/kg} & \quad 0.75-1.5 \text{ g/kg} & \quad <0.75 \text{ g/kg} \\
>20 \text{ g/kg} & \quad 5-20 \text{ g/kg} & \quad <5 \text{ g/kg} \\
>150 \text{ g/kg} & \quad 50-150 \text{ g/kg} & \quad <50 \text{ g/kg} \\
\end{align*}

Available phosphorus $A_{10}$
\begin{align*}
\leq 0.2 \text{ mg/kg} & \quad 0.2-1.0 \text{ mg/kg} & \quad \text{Cd} \\
\leq 15 \text{ mg/kg} & \quad 15-20 \text{ mg/kg} & \quad \text{As} \\
\leq 35 \text{ mg/kg} & \quad 35-100 \text{ mg/kg} & \quad \text{Cu} \\
\leq 35 \text{ mg/kg} & \quad 35-350 \text{ mg/kg} & \quad \text{Pb} \\
\leq 90 \text{ mg/kg} & \quad 90-350 \text{ mg/kg} & \quad \text{Cr} \\
\leq 100 \text{ mg/kg} & \quad 100-300 \text{ mg/kg} & \quad \text{Zn} \\
\leq 40 \text{ mg/kg} & \quad 40-60 \text{ mg/kg} & \quad \text{Ni} \\
\end{align*}

Available potassium $A_{11}$
\begin{align*}
\end{align*}

Cultivated land pollution index $[8]$ $A_{12}$
\begin{align*}
\text{Cd} & \quad \text{Cd} & \quad \text{Cd} & \quad — \\
\text{As} & \quad \text{As} & \quad \text{As} & \quad 20-30 \text{ mg/kg} \\
\text{Cu} & \quad \text{Cu} & \quad \text{Cu} & \quad 100-400 \text{ mg/kg} \\
\text{Pb} & \quad \text{Pb} & \quad \text{Pb} & \quad 350-500 \text{ mg/kg} \\
\text{Cr} & \quad \text{Cr} & \quad \text{Cr} & \quad 350-400 \text{ mg/kg} \\
\text{Zn} & \quad \text{Zn} & \quad \text{Zn} & \quad 300-500 \text{ mg/kg} \\
\text{Ni} & \quad \text{Ni} & \quad \text{Ni} & \quad 60-200 \text{ mg/kg} \\
\end{align*}

Note: $A_5$: topsoil organic matter content; $A_6$: total nitrogen; $A_{10}$: available phosphorus, $A_{11}$: available potassium.

Those were divided according to the national second soil census classification criteria for standard division.

2.2. Determination of the weight index by using the judgment matrix

Analytic Hierarchy Process method (AHP method) is used to determine the weights of the indicators [2]. After making an objective judgment on the multiple indicators of the system, the corresponding quantitative values of the relative importance of each indicator in comparison with other indicators are given. Then, the judgment matrix is established and the weight of the relative importance of all the indicators is calculated. The sum of the weight of all indicators is 1. In practical application, we can sort the weights of each index, and finally plan and make decisions and choose the solutions to the problems according to the sorting results.

2.2.1. Establishment of a judgment matrix. Experts are asked to compare the importance of indicators $A_i$ and $A_j$ in Table 1 to the quality of newly cultivated land. If $A_i$ is more important than $A_j$, take $b_{ij}=K$. $K$ is in the range of 1 to 9, and the greater the degree of importance, the $K$ value is larger. If $A_i$ and $A_j$ are equally important, then take $b_{ij}=b_{ji}=1$. If $A_j$ is more important than $A_i$, then take
bij=1/K, as shown in Table 2. The judgment matrix B is obtained by traversing all 12 indicators. The number of indicators can be increased or decreased according to the actual situation.

\[
B = \begin{bmatrix}
b_{11} & b_{12} & L & b_{1,12} \\
b_{21} & b_{22} & L & b_{2,12} \\
L & L & L & L \\
b_{12,1} & b_{12,2} & L & b_{12,12}
\end{bmatrix}
\]

| \( A_i \) compared to \( A_j \) | Quiet unimportant | Unimportant | Very important | Most important | Less important | Important | Most important | Quiet | Equal |
|---|---|---|---|---|---|---|---|---|---|
| Value of \( b_{ij} \) | 1/3 | 1/5 | 1/7 | 1/9 | 3 | 5 | 9 | 7 | 1 |

Note: Degree is between the two degrees next to each other in Table 2, the value of \( b_{ij} \) can be 8, 6, 4, 2, 1/2, 1/4, 1/6, 1/8.

2.2.2. Weight coefficient calculation. Calculate the eigenvectors of the judgment matrix, which is the weight coefficient of each index

\[
M_i = \prod_{j=1}^{n} b_{ij}
\]

where \( n \) is the number of evaluation indicators, and then \( M'_i \) is calculated according to the equation

\[
M'_i = \sqrt[n]{M_i}
\]

Finally, \( W_i \) as the weight coefficient is calculated basing on the equation

\[
W_i = \frac{M'_i}{\sum_{j=1}^{n} M'_j}^{[5]}
\]

Finally, it is necessary to test the consistency of the weighting coefficients obtained, which can verify whether the judgment matrix is successfully established and accurately reflect the importance of each evaluation index in affecting the quality of arable land. The calculations involved are calculated using Excel.

3. Application

Taking the project of balancing land occupation and land reclamation in Longting Town, Hancheng City as an example to evaluate the quality of newly cultivated land. First, the evaluation indicators are determined, which are flatness \( A_1 \), contiguous degree \( A_2 \), accessibility \( A_3 \), macro layout \( A_4 \), soil texture \( A_5 \), soil pH \( A_6 \), total salt \( A_7 \), tillage organic matter content \( A_8 \), total nitrogen \( A_9 \), available phosphorus \( A_{10} \), available potassium \( A_{11} \), cultivated land pollution index \( A_{12} \). Then, the weight coefficient of 12 indicators is determined.

3.1. Determination of the judgment matrix

After 12 indicators being selected, the value of matrix elements of the judgment matrix is determined according to the relative importance of \( A_i \) to \( A_j \). The cell content of the \( A_i \) column in Table 3 is the value of the matrix element of judgment matrix i.e. \( B_{ij} \).
Table 3. The relative importance level of Ai in comparison with Aj.

|   | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | A11 | A12 |
|---|----|----|----|----|----|----|----|----|----|-----|-----|-----|
| A1 | 1  | 1/2| 1/3| 1/4| 1/8| 1/7| 1/7| 1/9| 1/8| 1/8  | 1/6  | 1/5  |
| A2 | 2  | 1  | 1/2| 1/3| 1/9| 1/6| 1/6| 1/8| 1/7| 1/6  | 1/5  | 1/4  |
| A3 | 3  | 2  | 1  | 1/2| 1/8| 1/5| 1/5| 1/7| 1/6| 1/5  | 1/4  | 1/3  |
| A4 | 4  | 3  | 2  | 1  | 1/7| 1/5| 1/5| 1/6| 1/5| 1/4  | 1/3  | 1/2  |
| A5 | 8  | 6  | 5  | 4  | 1  | 4  | 4  | 1/2| 4  | 4  | 4  | 7   |
| A6 | 6  | 5  | 4  | 3  | 1/4| 1  | 2  | 1/4| 1/3| 1/3  | 2    |
| A7 | 6  | 5  | 4  | 3  | 1/4| 1/2| 1  | 1/5| 1/4| 1/4  | 1/4  | 1/2  |
| A8 | 9  | 7  | 6  | 5  | 2  | 4  | 5  | 1  | 2  | 2    | 2    | 6    |
| A9 | 7  | 5  | 4  | 3  | 1/3| 3  | 3  | 1/2| 1  | 2    | 2    | 3    |
| A10| 7  | 5  | 4  | 3  | 1/4| 2  | 2  | 1/2| 1/2| 1    | 2    | 3    |
| A11| 6  | 4  | 3  | 2  | 1/5| 2  | 2  | 1/2| 1/2| 1/2  | 1    | 3    |
| A12| 4  | 3  | 3  | 2  | 1/7| 1/2| 1/2| 1/6| 1/3| 1/3  | 1    | 1    |

3.2. Calculation of the weight coefficient

Calculate the weight coefficient from the judgment matrix. First, calculate Mi according to $M_i = \prod_{j=1}^{12} b_{ij}$ as shown in Table 4. Then $M_i$ is calculated basing on equation (1) As shown in Table 4. $M'_i$ is calculated according to on equation (2), and finally, the weight coefficient $W_i$ is calculated based on equation (3).

In order to judge whether these two indexes are objectively compared with each other, the consistency of the results is tested. The consistency index C.I. and the random consistency ratio C.R. are calculated according to the method of Ref. [9]. The consistency index C.I.=0.0027. For C.R.=C.I./R.I. and R.I.=1.54 in the 12th order matrix according to Ref. [9], the random consistency ratio C.R. is calculated to be 0.0018. The C.I. and C.R. are both less than 0.01. Therefore, the judgment matrix has satisfactory consistency.

Table 4. Weight coefficient.

|   | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  |
|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| $M_i$ | 6.1512 | 1.5310 | 5.9524 | 1.9048 | 34406 | 3.3333 | 0.0703 | 3.6288 | 7560 | 630  | 43.2 | 0.0159 |
|     | $\times 10^{-9}$ | $\times 10^{-7}$ | $\times 10^{-6}$ | $\times 10^{-4}$ | $\times 10^{6}$ | $\times 10^{6}$ | $\times 10^{6}$ | $\times 10^{6}$ | $\times 10^{6}$ | $\times 10^{6}$ | $\times 10^{6}$ | $\times 10^{6}$ |
3.3. Score according to monitoring results of newly cultivated land’s quality in Longting Town

The actual assessment of the newly cultivated land’s quality includes the actual field observation and taking sample back to the laboratory for testing. The two parts are combined for evaluation.

3.3.1. Score of field road, layout and so on. The field observations show that the plots were of high flatness. There is almost no gradient. The plots are concentrated and contiguous. All types of land are reasonable distributed, which is close to village and convenient in transportation. The layout, quantity and quality of the road in the field are all good. Therefore, the scores of the four evaluation index are as followed, which are 95, 93, 95, 95 points for flatness $A_1$, contiguity $A_2$, accessibility $A_3$, macroscopic layout $A_4$, respectively.

3.3.2. Score of testing results of soil samples.

A. Score of soil texture etc.

The testing results of soil texture $A_5$, soil pH $A_6$, total salt $A_7$, topsoil organic matter content $A_8$, total nitrogen $A_9$, available phosphorus $A_{10}$, available potassium $A_{11}$ and their evaluation criteria (from Table 1 in this paper) are shown in Table 5.

| Index                        | Testing results | Score |
|------------------------------|----------------|-------|
| Soil texture $A_5$           | Silty sand     | 65    |
| Soil pH $A_6$                | 8.35           | 72    |
| Total salt $A_7$             | 1.6            | 55    |
| Topsoil organic matter content $A_8$ | 5.195417   | 56    |
| Total nitrogen $A_9$         | 0.186042       | 50    |
| Available phosphorus $A_{10}$ | 2              | 52    |
| Available potassium $A_{11}$ | 48.02083       | 58    |

B. Pollution index

In order to ensure that the edible part of the crop planted on newly cultivated land is not polluted, the situation of land pollution needs to be evaluated. According to the relevant national and local food hygiene standards, the soil heavy metal contents of newly cultivated land in Longting Town were evaluated. In detail, soil samples are collected and the content of heavy metal elements is determined. The heavy metal elements in newly cultivated land being tested include Cd, As, Cu, Pb, Cr, Zn and Ni. The test results are compared with those of Table 1 to get the score of each individual item (Table 6). Then the N.C.Nemerow index method is used to calculate multi-factor integrated pollution index, and to get the comprehensive score of cultivated land pollution index [10-11].
where $F$ is the comprehensive score of the cultivated land pollution index, and $F_{\text{ave}}$ is the average value of the individual pollution items of the soil, and $F_{\text{imax}}$ is the maximum score of the individual pollution items. The project's land pollution index score is calculated to be 94 points.

### Table 6. Test results and scores of heavy metal content.

| Testing results (g/kg) | Score |
|------------------------|-------|
| Cd                     | 0.118571 | 88 |
| As                     | 10.55143 | 88 |
| Cu                     | 14.55786 | 92 |
| Pb                     | 13.63571 | 92 |
| Cr                     | 25.11214 | 95 |
| Zn                     | 28.77143 | 96 |
| Ni                     | 18.03357 | 93 |

3.3.3. **Final total score.** The scores of the above 12 evaluation indexes and their respective weight coefficients are summarized in Table 7. According to the formula, the total score of new farmland quality evaluation of Longting Town Project is 62.8, reaching the qualified level. It can be seen that the overall macro-layout of cultivated land in this project is good. The soil is not polluted and of high cleanliness. The reason for its low quality is that the soil texture and the fertility need to be improved. Problem of slight salinization needs to be solved. Rational fertilization and ploughing system needs to be set. As time goes by, after time of baptism, soil reaches maturation and ultimately becomes fertile farmland.

### Table 7. Scores and weights of quality evaluation indicators for Longting Town New Cultivated Land Project.

| Index                              | Score | Weight Coefficient |
|------------------------------------|-------|--------------------|
| Flatness $A_1$                     | 95    | 0.0128             |
| Contiguous degree $A_2$            | 93    | 0.0167             |
| Mastery $A_3$                      | 95    | 0.0227             |
| Macro layout $A_4$                 | 95    | 0.0303             |
| Soil texture $A_5$                 | 65    | 0.2169             |
| Soil pH $A_6$                      | 72    | 0.0684             |
| All salt $A_7$                     | 55    | 0.0496             |
| Topsoil organic matter content $A_8$ | 56   | 0.2179             |
| Total nitrogen $A_9$               | 50    | 0.1302             |
| Available phosphorus $A_{10}$      | 52    | 0.1059             |
| Available potassium $A_{11}$       | 58    | 0.0847             |
Cultivated land pollution index $A_{12}$

|   |   |   |
|---|---|---|
|94 | 0.0438 |

4. Conclusion
In this paper, the acceptance of newly cultivated land in the land consolidation and reclamation project in China is investigated. Taking the Guanzhong Plain in Shaanxi Province as the research object and the whole evaluation process is illustrated by the Longting Town Land Improvement Project.

(1) The steps of the method are clear and the key steps are the determination of the main evaluation index, the construction of the judgment matrix, the calculation of the weight coefficients and the consistency test.

(2) The difficulty of this evaluation method lies in the construction of a judgment matrix that objectively and accurately reflects the importance of each evaluation index. That is to say, the determination of the matrix elements of the judgment matrix should try to avoid the subjective influence of man and satisfy the consistency test.

(3) The method has the advantages of simple and quick, convenient in calculation and with strong accuracy. Based on this, it is possible to evaluate the quality of newly cultivated land in the temperate semi-arid plains. Based on the evaluation results, a constructive suggestion is given on how to enhance the ground fertility.

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