Evaluation of cultivability of reclaimed soil in hollow villages in mountainous and hilly areas

Na Lei 1,2,3,4, *, Zhe Liu 1,2,3,4 and Qiguang Dong 1,2,3,4

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

*Corresponding author e-mail: 619648133@qq.com

Abstract. Reclaimed soil in hollow villages can be used to supplement cultivated land resources. In this study, reclaimed soil in hollow villages in Chengcheng County was selected as research object, and a combination of field investigation and indoor analysis was used to evaluate the cultivability of the reclaimed soil. Specific indicators for evaluation were borrowed soil thickness, Physical and chemical properties of soil, design of piece of farmland, crop growth indicators, convenience of farming, irrigation conditions, the mechanization degree. The research results have important reference significance for evaluating the quality and cultivability of the reclaimed soil.

1. Introduction
Hollow village is a special phenomenon that appears in the process of China's rural economic system reform and changes in farmers' production and lifestyle. It is also a common phenomenon in the process of the three modernizations of industrialization, urbanization, and agricultural modernization in the world [1, 2]. The emergence of hollow villages is a serious waste of land resources, endangers the rural living environment, affects social stability and development, and hinders rural economic development [3, 4]. In recent years, the state has begun to renovate hollow villages. Reclaimed land was used as a supplementary resource to ensure national food security. During the reclamation process, in order to quickly improve soil quality and save land resources, some returning materials such as fly ash, organic fertilizer, green manure, straw, wood shavings, old wall soil, and soil modifiers will be added according to local conditions [5]. Different returning materials will have effects on the physical and chemical properties such as soil organic matter content, pH value, EC value, available phosphorus and available potassium [6], and then affect soil quality.

However, the existing research has rarely been evaluated than whether the reclaimed soil is suitable for farming. In this study, reclaimed soil in hollow villages in Chengcheng County was selected as research object, and a combination of field investigation and indoor analysis was used to evaluate the cultivability of the reclaimed soil. Specific indicators for evaluation were borrowed soil thickness, Physical and chemical properties of soil, design of piece of farmland, crop growth indicators,
convenience of farming, irrigation conditions, the mechanization degree. The research results have important reference significance for evaluating the quality and cultivability of the reclaimed soil.

2. Materials and methods

2.1. Overview of the study area
Chengcheng County is located in the northeast of the Weibei Plateau in Shaanxi Province. It is between N34°55′45″-35°27′05″ and E109°109°40′30″-110°05′50″. The total area is 1121 square kilometers. Chengcheng County is located in a warm and semi-arid climate zone, and the parent material is mostly loess. Chengcheng County is a typical area for hollow village remediation in Shaanxi Province. The area of reclaimed soil is large and the research is representative. Chengcheng County has 9 towns.

2.2. Research methods
All manuscripts must be in English, also the table and figure texts, otherwise we cannot publish your paper. Please keep a second copy of your manuscript in your office. When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question. Should authors use tables or figures from other Publications, they must ask the corresponding publishers to grant them the right to publish this material in their paper.

2.2.1 Evaluation index of cultivability.
The selection of the index of arable land after remediation can fully reflect the conditional characteristics of the cultivated land, and according to the difficulty of obtaining the index, select the evaluation index that can be obtained during the actual operation. The slope determines the use of farmland capital construction and the technical facilities for remediation. Therefore, slope is one of the basic factors for assessing cultivability. Soil is the most important part of land productivity, and the content of available nutrients such as soil type, soil layer thickness, soil texture, pH value, organic matter, nitrogen, phosphorus, potassium, etc. are taken into consideration in the evaluation. At the same time, good soil environment also requires in the cultivability evaluation, so the pollution status of heavy metals, organic pesticides and nitrate to the soil is also an important evaluation index.

Since the soil for remediation is mainly used for agricultural production land, natural factors and nutrient elements are the main factors for cultivability evaluation. Combined with the actual situation of the demolition and restoration of the hollow village in Chengcheng County, the index of cultivability evaluation was determined, including external traffic, irrigation conditions, scale, soil layer thickness, terrain slope, soil texture, soil pH, soil nutrients and soil pollution.

2.2.2 Evaluation index weight.
Taking into account the research work of the land evaluation industry in recent years and the characteristics of the hollow village remediation and returning fields, Delphi method was adopted as the method for determining the index weight of cultivability.

2.2.3 Evaluation model determination.
In order to ensure the homogeneity of each evaluation unit, this study used the weighted index sum method to evaluate the appropriate farming level for the cultivated land after remediation in each project area. The formula was as follows:

\[ D = \sum_{i=1}^{n} x_i p_i \quad p_i \neq 0 \]  

\( D \) is the distinguished value of the evaluated item. \( x_i \) is the score of the evaluation index. \( p_i \) is the weight of the evaluation index. \( i \) is the evaluation index number; \( n \) is the total number of evaluation indicators.
2.2.4 Evaluation index grading method. External traffic was expressed by the ruggedness index RI, soil nutrients, the soil nutrient richness was divided into four levels including extremely high, high, medium, and low according to the second national soil census nutrient grading standards. Scale was divided into four levels according to the specific implementation of the remediation project in Chengcheng county. Irrigation conditions were comprehensively determined according to the guarantee of water resources and irrigation facilities (open channels, concealed pipes, spray drip irrigation). Soil layer thickness and terrain slope were determined based on site surveys and investigations.

3. Results and analysis
The evaluation index was classified according to the evaluation index classification method. The grading standards were shown in Table 1. According to the comparison of the scores of the project areas in Chengcheng County and the grading standards of the evaluation indicators, it was possible to determine the soil suitable grade for cultivation in the project areas of Chengcheng County.

Table 1. Grading standards of evaluation indicators

| Evaluation indicators       | Very suitable Grading | More suitable Grading | Generally suitable Grading | Unsuitable Grading | Weights |
|----------------------------|-----------------------|-----------------------|----------------------------|--------------------|---------|
| Rugged Index               | ≦ 1                   | 1.0-1.5               | 1.5-2.0                   | ≧ 2.0              | 0.13    |
| Irrigation conditions      | Satisfy               | Basic satisfaction    | Can guarantee             | difficult          | 0.15    |
| Scale/ha                   | 60-80                 | 30-60                 | 15-30                     | 0-15               | 0.05    |
| Soil layer thickness/cm    | ≦ 100                 | 70-100                | 40-70                     | ≧ 40               | 0.1     |
| Terrain slope/°             | ≦ 6                   | 6-10                  | 10-15                     | ≧ 15               | 0.08    |
| Soil texture               | Light, middle soil    | Heavy soil, clay      | Sandy soil, Silt          | Sandy soil         | 0.05    |
| Soil pH                    | 6.5-7.0               | 6.0-6.5 or 7.0-7.5    | 5.5-6.0 or 7.5-8.0        | >8.0 or <5.5       | 0.13    |
| Soil nutrients             | Extremely high        | high                  | middle                    | low                | 0.2     |
| Soil pollution             | Pollution-free        | Slight pollution      | General pollution         | Severe pollution   | 0.11    |

3.1. Evaluation Grading of overall cultivability
The evaluation results of cultivability level of the soil after remediation in the hollow village showed that 76% of the areas where the land was more suitable for farming after remediation were reclaimed in the hollow village, which 76% were very suitable for farming and 49% were more suitable for cultivation, Generally suitable and unsuitable accounted for 24%, of which 22% were generally suitable for cultivation, and 2% were unsuitable for cultivation. Details were as follows:

Very suitable for arable land: mainly distributed in Chengguan Town, Fengyuan Town and Siqian Town, the total returning area is 123 ha, and the terrain slope is less than 6 degrees. Chengguan Town has a small scale of remediation due to its location, but benefits from its proximity to administrative and commercial centers, flat terrain, fertile soil, sufficient irrigation water sources, and low soil pollution, so its overall score is high. Fengyuan Town has a large scale of renovation, but the soil nutrient content is relatively low. This is because the demolished objects in the hollow village are mainly old wall soil and the returning field and planting period is short, and the process of ripening the raw soil takes time.

More suitable farmland: mainly distributed in Liujiawa Township, Anli Town, Zhuangtou Town, etc., occupying a large number of administrative townships, with an overall area of 224 ha, this is the largest
distribution area. The slope is between 6° and 10°. This level of arable land can basically satisfy the irrigation water for farmland. The thickness of the soil layer is 70-100 cm, the soil pH is greater than 7, and the soil is alkaline. The soil nutrient content is medium, which can meet the current crop growth in the short term, but it does not contribute enough to the long-term soil nutrients. The nutrient content is relatively high in Luojiawa Township and Weizhuang Township, but due to the impact of the scale of returning land, the degree of mechanization is low, and the cost of artificial farming is high. In the later stage, it will be considered the unified management of farmland for land restoration and land use in the surrounding farmland to increase the degree of mechanization.

Generally suitable for arable land: mainly distributed in Leijiawa Township, Wangzhuang Town, Shanhua Township, with a total area of 99 ha. Individual indicators of such cultivated land have become limiting factors. Leijiawa Township and Zhuangtou Town rehabilitate have the land mainly for mountainous and hilly areas, and it is difficult to irrigate and divert water.

Unsuitable for arable land: traffic Town is inconvenient in Jiaodao, the scale of rehabilitated land is low, and the soil is barren. Many restrictive factors lead to. Tillage is classified as unsuitable in Jiaodao Town.

3.2. Score evaluation of breakdown indicators

In order to further clarify the impact of 9 indicators on the evaluation of soil cultivability after remediation, the scores of the sub-items of each township were listed in order from the highest score to the lowest. The variance analysis was performed for each indicator. The coefficient of variation was used to judge the stability of the evaluation index in the remediation field.

There was no significant difference between the soil texture, soil thickness, topographical slope, and soil pollution in the towns and townships in the remediation areas in Chengcheng County. The coefficients of variation were 0.09, 0.15, 0.11, and 0.24, respectively. Topographical slope had the highest average score, with a range of 3°-10°. The terrain was flat and conducive to mechanical farming. The soil texture was uniform, and more than 90% of the cultivated land was silty loam. The thickness of the soil layer was between 65 cm-120 cm, which can meet the requirements of crop planting. Soil pollution was low, and nitrogen source pollution and heavy metal pollution did not exist in the remediation field. There are significant differences in the scale, soil nutrients, irrigation conditions, soil pH, and ruggedness index of the towns in Chengcheng County (table 2). Among them, the largest coefficient of variation is 0.84, and the average score is only 5.57 points. The larger scales of Fengyuan Town and Anli Town are 88.83 ha and 82.36 ha, while the smallest Chengguan Town is only 4.76 ha. The scale is limited by the terrain and village structure, and there is little room for improvement in the later stage. The location of reclamation area determines the convenience of transportation, so the ruggedness index of the road is less affected by human factors, and it is difficult to significantly improve in the short term. Nutrient content such as nitrogen, phosphorus, and potassium is an important factor for crop growth in cultivated land. Therefore, low soil nutrient content has become a limiting factor affecting the arableness of the plot. The coefficient of variation of soil nutrients in the reclamation area is 0.64. Compared with other indicators, the degree of variation is large, with an average score of 5.2 points, and there is a lot of room for improvement in the later stage.

Except for the nutrient content of Chengguan Town, Luojiawa Township, and Weizhuang Township, which are in the second grade of the second soil census nutrient grading standard, the remaining townships are in the third and fourth grades. The pH range is 7.2-7.8, and the soil is alkaline. The range of change of organic matter is 10-15 g·kg$^{-1}$, the range of available potassium is 100-280 mg·kg$^{-1}$, and the range of available phosphorus is 9-25 mg·kg$^{-1}$. The low nutrient content of the land is related to the low nutrient content of the old wall soil, and it may be due to the looseness of the soil surface in these remediation areas, and the serious soil erosion under rainfall or irrigation conditions. The coefficient of variation of irrigation diversion conditions is 0.4 in remediation areas. The areas where irrigation is difficult are mainly affected by water resources. The construction of agricultural canals has not kept up with the pace of reclamation project. The main water-saving measure is drip irrigation.
Table 2. Average value and variation coefficient of evaluation index

| evaluation index         | Highest score | Lowest score | average score | Standard deviation | variation coefficient |
|--------------------------|---------------|--------------|---------------|--------------------|-----------------------|
| Rugged Index             | 13            | 3.9          | 7.52          | 2.98               | 0.40                  |
| Irrigation conditions    | 10.4          | 0            | 6.78          | 4.08               | 0.60                  |
| Scale                    | 13            | 0            | 5.57          | 4.66               | 0.84                  |
| Soil layer thickness     | 13            | 6.5          | 10.68         | 1.63               | 0.15                  |
| Terrain slope            | 13            | 10.4         | 12.07         | 1.29               | 0.11                  |
| Soil texture             | 10.4          | 7.8          | 10.03         | 0.94               | 0.09                  |
| Soil pH                  | 9.1           | 3.9          | 5.76          | 2.59               | 0.45                  |
| Soil nutrients           | 10.4          | 0            | 5.20          | 3.53               | 0.68                  |
| Soil pollution           | 10.4          | 5.2          | 9.29          | 2.21               | 0.24                  |

4. Conclusion

It can be seen that soil nutrients need to be improved, irrigation conditions need to be optimized, and the scale of renovation needs to be further expanded for reclamation project in hollow villages in Chengcheng County. The improvement of cultivability of reclaimed soil should also be strengthened in the aspects of strengthening technology, improving farming measures, strengthening farmland infrastructure construction and optimizing farmland management policies in hollow villages.

References

[1] N.Lei, Construction of hollow village comprehensive improvement technology system in the loess hilly region. Land and Resources Technology Management, 34 (2017) 118-125.
[2] L. Zhang, J.C.Han, Z.H.Ma, W.H.Zhang, J. Li, C.D.Shi, R..Zhang, Soil characteristics of hollow villages under different reclamation years in hilly areas. Journal of Soil and Water Conservation, 29 (2015) 176-180.
[3] C.Y.Li, Analysis of Morphological Characteristics and Formation Mechanism of "Hollow Village" -Taking Henan Province as an Example. Journal of Huazhong Agricultural University (Social Science Edition), 33 (2014) 95-99.
[4] X.Y.Chen, Z.C.Ren, G.F.Qin. On the Construction of New Socialist Countryside and the Problem of "Hollow Village". Journal of Yunnan Agricultural University(Social Science Edition), 4 (2013) 10-13.
[5] N.Lei,T.Q.Chen, Q.G.Dong, L.T. Luo, Analysis of soil fertilization effect of rehabilitating materials to soil in hollow village. Journal of Soil and Water Conservation, 32 (2018) 224-228.
[6] S.R.Ren, Y.C.Shao, J.Yang, Study on Effect of Reclaimed Soil Fertilizer on Homestead. Journal of Soil and Water Conservation,26 (2012) 80-83+88.