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Land quality evaluation based on sustainable development for gully erosion control and land consolidation project of Yan'an, China

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Abstract. Based on the three land consolidation projects in Yan'an region, the differentiation of the soil capacity, texture, available nutrients, pH etc before and after land consolidation were analyzed, and a comprehensive evaluation of soil quality before and after consolidation was done in this study. The results show that: (1) After the gully-land consolidation, the soil capacity, nitrogen, available P, available K and conductivity are increased, while the organic matter and pH are decreased. With one-year's cultivation, the soil capacity decreased and the organic matter increased. After the slope-land consolidation, the soil physical and chemical properties have similar trends with the gullies, but the change is more significant. (2) No matter for gully or slope, the soil quality declines where the land just get consolidated, and the slope has more significant declining. With one-year's cultivation, the soil quality of the gully has more rapid recovery with one grade uplift. (3) The correlation coefficient method was used to give a comprehensive evaluation of the soil quality, to considerate of the changes of the coefficients of the factors and the evaluation object. The evaluation can well reflect the actual situation of the soil quality, give reference to the soil quality evaluation for consolidated land, and the results may provide basis for the performance evaluation of the Yan'an land consolidation projects.

1. Introduction

Land consolidation is one of the main measures to increase the area and improve the quality of cultivated land, but also an important guarantee for the dynamic balance of cultivated land (Coelho, et al.2001; Rafael ,2002). Since 18 million mu arable land red line was proposed in “The Eleventh National Economic and social development five-year plan” in 2006, increasing emphasis was paid to the cultivated land protection and food security by Chinese government. Cultivated land quality was referred to unprecedented attention (Karlen, et al.2003). Soil is the basis of agricultural and food production, so we must pay attention to the impact on soil quality in land consolidation.



Yan'an gully erosion control and land remediation project is the central support major projects, with the investment of 5.24 billion yuan. The project has positive significance to increase cultivated land, ensure food security, consolidate the achievements of "Return Farmland to Forest" Program, promote the construction of ecological civilization and the development of a new socialist countryside on the Loess Plateau. From 2011, Yan'an City totaled finished 12.6 million mu of land consolidation and made remarkable achievements.

A number of experts have evaluated the quality of the soil for land consolidation (Xu et al., 2009; Wang et al., 2013), but the similar research has not been found in Yan'an area because the project carried out not for a long time. In addition, there is no suggestion to land consolidation methods in this area through the research of soil quality. Therefore, this article take three different land consolidation project of Baota area as examples, study the changes regulation in soil quality before and after land consolidation, provide effective recommendations to improving the method and promoting the healthy development of land consolidation. Through the evaluation of soil quality before and after land consolidation, provide the basis evaluating the effectiveness of land consolidation projects of this area.

2. Materials and Methods

2.1. General situation of study area

Yan'an Baota district, the location of which ranging from latitude 36°11' to 37°02', longitude 36°11' to 37°02', has a semi humid to semi dry continental monsoon climate. It is 96 km length from north to south and 76 km width from east to west. The mean annual precipitation is 562.1 mm and it is unevenly distributed within the year. The mean monthly precipitation of June to September takes about 70% of the annual precipitation. The study area locates at the middle of loess plateau, belonging to the Loess Hilly and Gully Region. The terrain of the area is higher at the west, lower at the east with the uplifted middle part, gentle at the Fenchuan River basin in the south part and is relatively gentle and relatively fluctuate at the north part. The research area has terrain fragmentation, ravine crossbar, heavy gully incised, big terrain slope and severe soil erosion. It is 31.1-107.3 km east away from the main stream of Yellow River; the middle-north part is the middle reaches of Yan River with an area of 2347 km², and the south part belongs to the Fenchuan River basin with an area of 1209 km². The whole research area is multistage tributary developed with ravines covered. The surface water in the summer can easily form strongly erosive flow, which causes geologic hazard, such as landslide, etc. frequently.

Select three typical land consolidation project of Kowloon Quan gully, Yang Wan gully in Nanniwan town and Yangjuan gully in Liqu town for the study. Kowloon Quan gully, southwest - northeast orientation, 9.5 km length and 200-350m width; Yang Wan gully, northwest - southeast orientation, about 11 km length and 150-250m width, converge the Kowloon Quan gully in the town center of Nanniwan; Both of two gully reclaimed to agricultural land for a long time. Yangjuan gully, north -south orientation, 30-100m width, hilly and gully relative elevation of 100m, the gully reclaimed to agricultural land for short time and most of farmland located in the hilly slopes.

2.2. Soil sampling and analysis

Kowloon Quan gully land consolidation in the channel, added land has been cultivated for a year, Yang Wan gully land consolidation is also in gully and not yet farming, land consolidation of Yangjuan gully conducted in slope, not yet farming. Selected typical added cultivated land on the upstream, midstream and downstream of three gullies, with vicinity unformed land as a control, obtain two periods soil samples before and after land consolidation project. Sampling points using GPS positioning and totally 18 sampling points was investigated. From 0-10 cm, 10-20 cm, 20-30 cm 3 levels collecting samples. Indoor analysis included soil texture, organic matter, available P, available K, total N, pH, conductivity and bulk density, all indicators are measured by classical methods.

2.3. Data calculation and analysis

Conventional data sorting was completed using Excel 2007 software, correlation analysis was performed using Spss17.0 software.

3. Results

3.1. Changes in soil properties after land consolidation

In land consolidation, mechanical rolling, deep plowing of the soil, topsoil stripping and backfill possible impact soil bulk density, organic matter and available nutrients and other physical and chemical properties. If topsoil stripping insufficient or backfill uneven, resulting in some surface nutrient loss or mixed uneven. These are all not conducive to the cultivation of the soil.

3.1.1. Soil bulk density. Through statistical analysis, got the differences situation of surface soil bulk density before and after land consolidation. As can be seen from Figure 1, before the land consolidation, bulk density of the three project areas was relatively high, reached 1.40-1.56 g / cm³. After the land consolidation, Kowloon Quan gully which cultivate one year falling slightly, while Yangwan gully and Yangjuan gully just finished land levelling increased than before. Yang Wan gully change more significantly than other two gullies. Research shows that the bulk density of this region is higher than normal, mechanical compaction lead a higher bulk density and made a disadvantage effects on farming. However, after a year of farming, bulk density has been reduced, toward the direction conducive to farming.

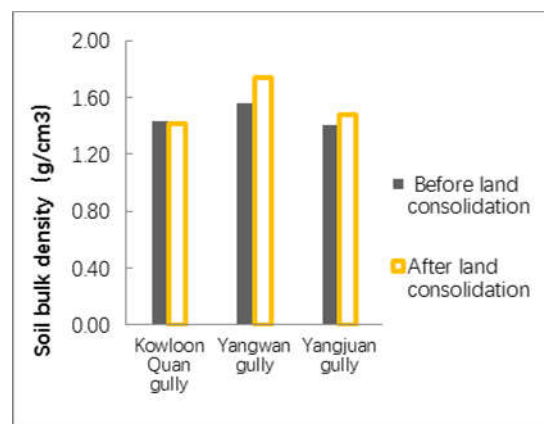


Figure 1. Soil bulk density before and after land consolidation.

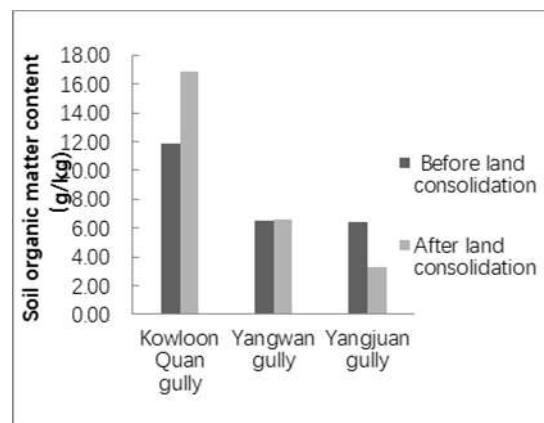


Figure 2. Soil organic matter content before and after land consolidation.

3.1.2. Soil organic matter content. Figure 2 shows, before land consolidation, Kowloon Quan gully has the highest organic matter content, reached 11.8k / kg, Yangwan gully and Yangjuan gully was lower with the content of about 6k / kg. After the land consolidation, Kowloon Quan gully organic matter content increased, and which of Yangjuan gully decreased, while Yangwan gully changed inconspicuous. The data shows that slope, because topsoil stripping or backfill uneven, surface soil organic matter content less than arable land so many years. The gully has high soil organic matter content, so it has little effect on land consolidation disturbance. After a year of farming, topsoil organic matter increased significantly.

3.1.3. Soil texture. Through the experimental data to calculate the sampling point samples of sand, silt and clay composition percentage. According to the texture analysis, all sampling points are silty loam soil both before and after land consolidation. The clay, sand and silt content of three project areas changed inconspicuous before and after the consolidation. Description land consolidation of this region have little effect on soil texture.

Table 1. Soil sand, silt and clay composition of before and after land consolidation.

	Sand content (%)		Silt content (%)		Clay content (%)	
	Before land consolidation	After land consolidation	Before land consolidation	After land consolidation	Before land consolidation	After land consolidation
Kowloon Quan gully	19.44	21.62	73.11	74.59	7.45	7.17
Yangwan gully	19.99	18.35	72.68	73.88	7.33	7.77
Yangjuan gully	19.07	17.89	73.04	74.63	7.67	7.49

3.1.4. Soil available P, available K, total N content. As can be seen from Table 2, after land consolidation, available p, available K content of Kowloon Quan gully decreased slightly, total N content increased. Three indicators of Yangwan gully all have increased. In addition to available p content, the other two indicators of Yangjuan gully rose. This data shows that due to an effective topsoil backfill or land plowing, available nutrient content of consolidation land which not for a long time increased, but after farming one year, nutrient decreased slightly and lower than that consolidation land.

Table 2. Soil available P, available K, total N content of before and after land consolidation.

	Available P(mg/kg)		Available K(k/kg)		Total N(mg/g)	
	Before land consolidation	After land consolidation	Before land consolidation	After land consolidation	Before land consolidation	After land consolidation
Kowloon Quan gully	3.98	3.54	0.25	0.22	0.44	0.63
Yangwan gully	2.70	3.76	0.24	0.30	0.65	0.79
Yangjuan gully	5.85	5.95	0.23	0.21	0.67	0.75

3.1.5. Soil pH value. pH value which suitable for crop growth is generally between 6.5 and 7.5. Too high or too low is not conducive to crop growth. As can be seen from the figure 3, each sample point in the project area are alkalescency soil, surface soil pH at 7.8-8.7 before land consolidation. After

land consolidation, whether it is a single point or on the whole, the average soil pH has been reduced compared with before.

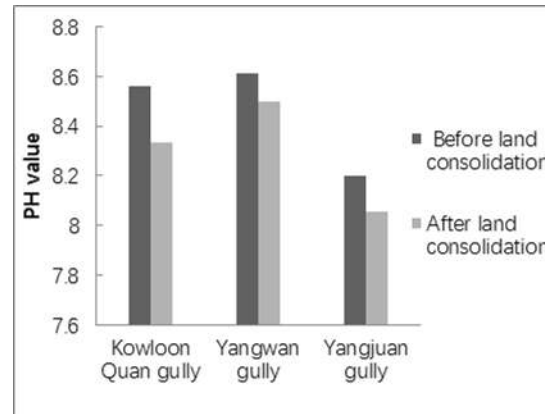


Figure 3. Soil pH value before and after land consolidation

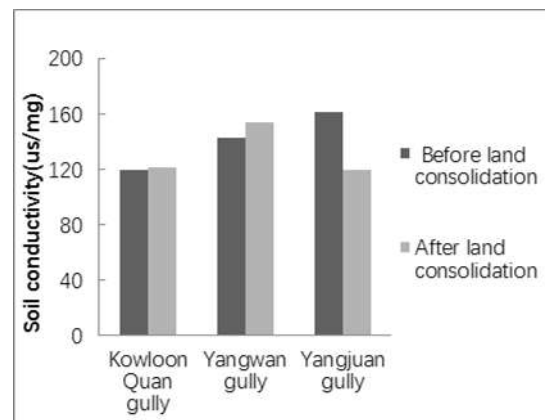


Figure 4. Soil conductivity before and after land consolidation

3.1.6. Soil conductivity. Soil conductivity is measured indicators of soil water-soluble salt. Due to the shallow water table of Yan'an, soil secondary salinization problem is serious. Therefore, conductivity have a major impact on the soil quality in this region. As can be seen from the figure 4, Kowloon Quan gully has the lowest and yang wan gully has the highest soil conductivity value. After land consolidation, soil conductivity of Kowloon Quan gully and yang wan gully is higher than before, and which of Yangjuan gully is lower than before. Therefore, in Yan'an gully land consolidation, some techniques should be taken to improve the soil salinization problem.

3.2. Soil quality evaluation

3.2.1. The evaluation index selecting. According to the principles of soil quality evaluation index selection, referring to the results of previous studies, combining with the characteristics of Yan'an gully, soil bulk density, texture (clay content), available P, available K, total N, organic matter, pH, conductivity and were selected as the evaluation factors (Andrews et al., 2002, Luo et al., 2012, Yue et al., 2011).

3.2.2. Standardization of the soil quality evaluation index. Since each soil quality evaluation index from different angles to reflect the status of soil quality and dimension between the measured value of each index is very different, it is not equivalent to treat these indicators, and standardization of

treatment, which is non-dimensional treatment, is needed. There are many dimensionless methods, this paper select membership functions to be standardized. Membership function is determined based on a range of relationship between indicators evaluating and the soil function. It can be divided into S-shaped, parabolic, anti-S-type three curvilinear relationship (Andrews et al.,2004; Mihara,1996).

"S" refers to the type of membership function values within a certain range of evaluation factors were positively correlated with soil functions, while lower or higher than this range, changes in the index value of the evaluation factors on soil function is very small. Soil organic matter content, total N, available P, available K belong to this category. The calculated as follows:

$$u(x) = \begin{cases} 1 & (x \geq b) \\ \frac{x-a}{b-a} & (a < x < b) \\ 0 & (x \leq a) \end{cases} \quad (1)$$

Anti-"S" type membership function value is that factors negatively correlated with soil functions, while lower or higher than this range, changes in the index value of the evaluation factors on soil function is very small. In this study, the conductivity in this category. The calculated as follows:

$$u(x) = \begin{cases} 1 & (x \leq a) \\ \frac{b-x}{b-a} & (a < x < b) \\ 0 & (x \geq b) \end{cases} \quad (2)$$

In above two formula, $u(x)$ is the membership function; x is the actual value of the evaluation index indicator; a , b denote the lower and upper threshold indicators.

Referring to the previous point of view, combined with the actual situation of soil properties in the study area, determine the critical values of these indicators (Table 3).

Table 3. "S" type and anti-"S" type membership function evaluation limits

Evaluation Indicator	Organic matter content(g/kg)	Available P(mg/kg)	Available K(k/kg)	Total N(mg/g)	Conductivity (μ s/mg)
a	3	1.5	0.05	0.5	100
b	20	10	0.35	2	200

Parabolic membership function, namely the evaluation index value factors on soil function has a best suitable range, exceed this range, with the degree of deviation increases, the impact on soil functions more unfavorable, when soil loses its direct access to a certain value function. pH, bulk density and texture (clay content) in this category. Membership function formula is as follows:

$$u(x) = \begin{cases} 1 & (b_1 \leq x \leq b_2) \\ \frac{x-a_1}{b_1-a_1} & (a_1 < x < b_2) \\ \frac{a_2-x}{a_2-b_2} & (b_2 < x < a_2) \\ 0 & (x \leq a_1 \text{ 或 } x \geq a_2) \end{cases} \quad (3)$$

In the formula, $u(x)$ is the membership function; x is the actual value of the evaluation index factor; a_1 , a_2 , b_1 , b_2 denote the critical value of the evaluation indexes. In this study, based on actual soil in

the study area and the reference point of previous studies, determine the critical values of soil pH, bulk density, clay content in Table 4.

Table 4. Turning point in the value of the parabolic membership function

Turning point	Bulk density (g/cm ³)	pH	Texture (clay content) (%)
a1	1.0	6.5	5
b1	1.2	7.5	20
b2	1.4	8	25
a2	1.6	8.5	35

3.2.3. The weights of each evaluation factor. In determining the weights of evaluation factors, Delphi and AHP method was use more to determine the weight in previous studies. These two methods influenced by subjective factors. Therefore, in this study, the correlation coefficient method was chosen to determine the weights (Zhang et al., 2008). Specific calculation method is calculating the correlation coefficient between the individual evaluation first, and then averaging the correlation coefficient between certain evaluation, and evaluation of the average value accounting for all correlation coefficients than the average of the sum of the individual evaluation as index weights. The correlation coefficients and weight between each index in Table 5.

Table 5. The average correlation coefficient and weight of evaluation indicator

Evaluation indicator	Average correlation coefficient	Weight
Organic matter	-0.1202	0.2057
Bulk density	0.1109	0.1897
Available P	-0.0026	0.0045
Available K	0.1429	0.2445
Total N	0.0518	0.0885
pH	0.0293	0.0501
Conductivity	-0.0741	0.1268
Texture	-0.0528	0.0903

3.2.4. The calculation of soil quality composite index. In this paper, the weighted sum method was used to calculate the soil quality index as follow (Xu et al., 2005):

$$SQI = \sum_{k=1}^n Ki \times Ci \quad (4)$$

In the formula, SQI is the soil quality index, Ci is the membership value of each evaluation index, Ki is the right of the i-th evaluation index weight, n is the number of evaluation indexes.

Table 6. Soil quality index before and after the land consolidation

	Soil quality index	
	Before land consolidation	After land consolidation
Kowloon Quan gully	0.5680	0.6346
Yangwan gully	0.4470	0.4158
Yangjuan gully	0.4951	0.4343

Based on soil quality class values composite index (Table7), before land consolidation, soil quality of Kowloon Quan gully was the highest level to Class II, and Yang Wan gully was the lowest level

reached only V. After the Land-consolidation, whether in the gully or slope, soil quality has declined, Yangjuan gully declined more significant, reduced one level. But through a year's farming, soil quality of Kowloon Quangou improved significantly, rising from Class II to Class I. Thus, compared to the slope, gully land consolidation project has less damage to soil quality, and after a year of farming, it recovers quickly and better than unconsolidated land.

Table 7. The composite indicator values of soil quality grade

Soil quality grade	I	II	III	IV	V	VI
Composite indicator values	0.60-0.65	0.55-0.60	0.50-0.55	0.45-0.50	1.40-0.45	0.35-0.40

4. Conclusion

(1) Both the physical and chemical properties of soil in the area where after the land consolidation have changed. After the consolidation of the gullies, the soil capacity, nitrogen, phosphorus, potassium and conductivity are increased, while the organic matter and pH are decreased. After one-year's cultivation, the value of each factor all going toward farming-beneficial direction. After the slope-land consolidation, the soil physical and chemical properties have similar trends with the gullies, but the change is more significant. Therefore, more attention should be paid to the topsoil backfill during the land consolidation process; scarification process is needed for the plough layer when the new farmland is cultivated for the first time, fertilization should be done for part of the land according to actual situation, and the salinization should be taken into consideration.

(2) Whether for the gully or slope, the soil quality of the land where just has consolidation is all declined, with more significant trend in Yangjuan gully where downgrade one level. Therefore, the gully-land consolidation has less destroyed for the soil quality compare with the slope-land consolidation, and can be rapidly recovery after one-year's cultivation to even better soil quality than the unconsolidated land. The gully land has better irrigating condition, therefore is more suitable for land consolidation than the slope land. Also, the consolidated land in this research area has more potential, the soil quality can be improved through ploughing and fertilization.

(3) The correlation coefficient method was used to give a comprehensive evaluation of the soil quality, to considerate of the changes of the coefficients of the factors and the evaluation object. The evaluation can well reflect the actual situation of the soil quality, give reference to the soil quality evaluation for consolidated land, and the results may provide basis for the performance evaluation of the Yan'an land consolidation projects.

Acknowledgments

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