Three dimensional evaluation on soil improvement effect of saline alkali soil in Yellow River Delta

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Abstract. It is necessary to evaluate the effect of soil improvement after land consolidation for productivity improvement, but the current evaluation method is relatively single. In this paper, based on the data of soil salt content from monitoring and sampling, the statistical characteristics were analyzed by SPSS software, and the three-dimensional distribution map was constructed by using GMS10.0 software for IDW interpolation. The results showed that the soil salt content in 2019 decreased significantly by 31.29% compared with that in 2018 from the characteristics of cultivated layer, and the effect of soil improvement was obvious. From the profile characteristics, the soil salt content in the study area is characterized by "surface accumulation". The salt content of soil profile decreased significantly at maize maturity stage compared with that before sowing. The decrease rates of soil salt content at different depths were 70.11% (0-20cm), 77.43% (20-40cm), 77.31% (40-60cm), 83.34% (60-80cm) and 65.26% (80-100cm), respectively. The decrease rate of 60-80cm soil layer was the largest. The results can be used as a reference for single index or comprehensive index three-dimensional visualization evaluation of soil improvement effect.

1. Introduction

Soil improvement is an important part of land consolidation, but it has not been paid enough attention for a long time due to large investment, long cycle and difficult evaluation. In the land consolidation project, it mainly focuses on the stripping and backfilling of topsoil and the protection of soil layers, such as mechanical tillage to break the hardening, fine leveling to reduce waterlogging and other measures. The relevant evaluation mainly focuses on the establishment of an index system for comprehensive evaluation of the plough layer [1]. In saline alkali areas, it is more difficult to improve the newly developed cultivated land, especially the soil salt content is difficult to effectively decline [2]. In the northern Songnen Plain, the method of combining foreign soil with straw was used to reduce the salt content in the topsoil [3]. Soil reconstruction and other measures are also used in the improvement of saline alkali land in the land consolidation project area [4]. In the aspect of improvement effect evaluation, single or comprehensive surface evaluation is generally carried out by analyzing and comparing soil pH, total salt, desalination rate, salt ion and crop yield [5], but there are few studies on single or comprehensive evaluation at a deeper level. In the use of cultivated land, the root system of crops is not only active in the surface of cultivated land (0-20cm). The whole soil environment plays an important role in the growth and development of crops, under the influence of water and capillary. Therefore, the evaluation of soil improvement effect should be more comprehensive, and the research of three-
dimensional evaluation method needs more attention. Some studies have explored the use of remote sensing image spectral data, electromagnetic induction earth conductivity meter measurement data, soil sampling data or their coupling data to conduct three-dimensional assessment of soil salinity through spatial interpolation \cite{6-7}. But these studies only focus on one-time point, lack of comparative study before and after improvement. Therefore, this paper takes a typical plot of a land consolidation project in Lijin County of the Yellow River Delta as the research area. Based on the soil salt content data obtained from the monitoring and sampling test of the sample plot, the statistical characteristics were analyzed by using SPSS software, and IDW interpolation and a three-dimensional distribution map were built by using gms10.0 software. The soil improvement effects were compared and analyzed, and the three-dimensional evaluation of soil salt improvement in different periods method was discussed.

2. Materials and methods

2.1. Overview of the study area

Lijin county is located in the northeast of Shandong Province, on the southwest coast of Bohai Sea, and on the north side of the Yellow River Estuary. The geographical coordinates are 118°07′-118°54′E, 37°22′-38°12′N. The terrain is high in the southwest and low in the northeast, high near the Yellow River and low far away from it. The average altitude is 11.5-2m, and the natural gradient is 1:11000. Lijin county is located in the warm temperate semi humid monsoon climate zone, with mild climate, sufficient light, four distinct seasons, dry in winter and spring, rainy in summer and drought in late autumn. The Yellow River is the only natural river and the main fresh water source in Lijin county. The available land is 12.67×10⁴ hm², the cultivated land is 5.33×10⁴ hm², and the natural and artificial grassland is 2.67×10⁴ hm². Grain crops are mainly wheat and maize, and economic crops are mainly cotton. The study area is located in Tingluo Town, Lijin County. The total area of the project area is 797.68hm², the construction scale is 672.15hm², the newly increased cultivated land area is 268.95hm², and the newly increased cultivated land rate is 40.01%. During the renovation of the project area, land leveling, irrigation and drainage, field roads, farmland protection and ecological environment maintenance projects were implemented.

2.2. Data sources

After the implementation of land remediation engineering measures, typical fields were selected to set up soil improvement test areas. Mechanical ploughing and fine leveling measures were taken, and irrigation and drainage conditions were improved to regulate water and salt movement on the surface and soil profile. Organic fertilizer and straw were applied to improve soil structure, improve soil organic matter and fertility. Combined with crop planting, chemical fertilizer was applied to regulate soil available nutrients. In order to monitor the effect of soil improvement, monitoring points were evenly set up in the soil improvement test area. A total of 54 monitoring points were set up, and the control area of each point was about 40m². Soil samples were collected before sowing and after harvest for monitoring. Soil samples were collected from 5 layers of soil profile (0-20), [20-40), [40-60), [60-80), [80-100) cm by soil drill. About 1kg of soil was collected for each sample, which was sealed in a sample bag and brought back to the laboratory. After natural air drying and grinding, the soil salt content (g/kg) was determined by 1:5 soil water ratio extraction, drying and weighing method.

2.3. Research method

2.3.1. Analysis of soil salinization characteristics

Referring to the relevant soil salinization classification standards, the soil salinization degree was divided into five grades: non salinization, mild salinization, moderate salinization, severe salinization and saline soil. The corresponding salt content (g·kg⁻¹) ranges were: (0, 1), [1, 2), [2, 4), [4, 6), [6, +∞). SPSS software was used to analyze the statistical characteristics of soil salinization in plough layer
before and after one year, characteristics of soil salinization of profile before and after maize sowing and harvest based on sample points, and to preliminarily compare and evaluate the improvement effect.

2.3.2. Three dimensional evaluation of soil salt content before and after improvement
Firstly, the section distribution function method and GMS10.0 software were used to construct the three-dimensional discrete data model of soil salinity in the study area, and then the regional three-dimensional grid data model was constructed to obtain the three-dimensional structure map of the study area. Then, the three-dimensional inverse distance weight method (IDW) was used to estimate and simulate the three-dimensional spatial distribution of soil salinity. In order to make the section feature display more obvious, three typical sections are selected for analysis by section tool. Based on the three-dimensional simulation results, the distribution trend of soil salt content in the vertical direction was analyzed, and the change degree of soil salt in different periods during the improvement process was compared from a three-dimensional perspective to characterize the improvement effect.

3. Results and analysis

3.1. Changes of soil salt content based on descriptive statistics
Based on the classical statistical analysis of the soil salt content in the plough layer from 2018 to 2019, the statistical characteristics are obtained, and the results are shown in Table 1.

| Year | Min/g·kg⁻¹ | Max/g·kg⁻¹ | AVG/g·kg⁻¹ | SD/g·kg⁻¹ | CV.  |
|------|------------|------------|------------|----------|-----|
| 2018 | 1.920      | 9.760      | 3.743      | 1.734    | 0.463 |
| 2019 | 0.560      | 7.040      | 2.572      | 1.583    | 0.616 |

It can be seen from the table that after one year of continuous soil improvement measures, regardless of the maximum value, minimum value or average value, the salt content of topsoil in 2019 decreased significantly compared with that in 2018, with an average decrease of 31.29%, and all showed moderate variability.

The classical statistical analysis of soil profile salt content before maize sowing(BS) and after maize maturity(AM) in the study area was carried out, and the statistical characteristics of soil profile were obtained, as shown in Table 2.

| Depth /cm | BS | AM | BS | AM | BS | AM | BS | AM |
|-----------|----|----|----|----|----|----|----|----|
| (0~20)    | 0.460 | 0.380 | 9.760 | 6.400 | 3.238 | 0.968 | 2.478 | 0.996 | 0.765 | 1.028 |
| (20~40)   | 0.280 | 0.060 | 9.820 | 2.520 | 3.739 | 0.844 | 3.048 | 0.591 | 0.815 | 0.701 |
| (40~60)   | 0.700 | 0.300 | 9.570 | 1.220 | 3.310 | 0.751 | 2.508 | 0.217 | 0.758 | 0.289 |
| (60~80)   | 0.120 | 0.140 | 8.180 | 1.160 | 3.835 | 0.639 | 2.848 | 0.320 | 0.743 | 0.500 |
| (80~100)  | 0.140 | 0.400 | 8.560 | 1.540 | 3.397 | 0.548 | 2.547 | 2.156 | 0.750 | 0.742 |

According to table 2, the maximum salt content of each soil layer before maize sowing ranged from 8.180 to 9.820 g·kg⁻¹, while the maximum salt content after maize maturity ranged from 1.160 to 6.400 g·kg⁻¹, which was significantly lower than that before maize sowing. The maximum values of the two periods appeared in 20-40 cm soil layer and 0-20 cm soil layer respectively, showing the characteristics of surface accumulation of salinity. From the average value, the salt content of each soil layer after maize mature decreased significantly compared with that before sowing. And the salt content of surface soil
before maize sowing was lower than that of other depths, and the salt content changed irregularly with the depth of soil layer, showing a fluctuating trend of increasing and decreasing. The soil salt content of each layer decreased with the increase of soil depth after maize maturity. From the coefficient of variation, the overall variation of maize before sowing was moderate, and the variability decreased slightly with the increase of soil depth, and the degree of variability was relatively stable, which was related to the reduction of differences in tillage and fertilization. The coefficient of variation of 0-20cm soil layer after maize mature was the largest, which showed strong variation, which may be related to the imbalance of irrigation, evaporation, light, absorption and groundwater influence in maize growth stage; other soil layers showed medium variation, which was lower than that before sowing.

To sum up, the soil salt content of each soil layer after maize mature was significantly lower than that before sowing, and the effect of soil improvement was significant.

3.2. **Change of soil salinity based on three-dimensional model**

The 3D mesh model of the monitoring area is shown in figure 1. The 3D scatter data model of soil salt content before maize sowing and after mature is shown in figure 2, and the 3D spatial distribution is shown in figure 3.

It can be seen from figure 2(left) that the soil salt content is higher in the western, Eastern and central parts of the monitoring area before maize sowing. It can be seen from figure 2(right) that the soil salt content is higher in the west and north of the monitoring area after the maize maturity period. It can be seen from figure 3 that the soil salt content in the study area is mainly in the low value area with salt content of \(<1\text{ g·kg}^{-1}\), no matter before sowing or after maize maturity. The high value areas of soil salt content in the two periods were distributed in the southwest, northeast and middle of the study area, and the salt content in some areas was more than 6 g·kg\(^{-1}\). The salt content of soil after maize mature decreased significantly compared with that before sowing, and the area with salt content \(>6\text{ g·kg}^{-1}\) became smaller, and the salt mostly accumulated in the deep soil layer in the middle and southwest. This shows that the effect of soil improvement is better. In order to more intuitively compare and analyse the profile characteristics of soil salinity in the study area, three typical sections were extracted according to the overall characteristics of spatial distribution of salinity in the two periods (figure 4).
It can be seen from the figure that at the A-A' section from southwest to northeast of the study area, the low value area with salt content less than 1 g·kg⁻¹ is mainly area after maize mature, while the high value area with salt content more than 6 g·kg⁻¹ is the main area before maize sowing. Before maize sowing, the trend of soil salt content in profile showed that the soil salt content gradually decreased with the increase of soil depth in the area with high surface soil salt content, which belonged to "surface accumulation" profile type. After the maize mature, in the area with low salt content of surface soil (near a), the soil salt content increased with the increase of soil depth, belonging to the "bottom accumulation" profile type. In this section, the soil salt content of each soil layer depth after maize mature was significantly lower than that of each soil layer depth before maize sowing.

On the B-B' section, most of the areas in the two periods showed different degrees of salinization. From the vertical distribution of soil salinity, in the area with high surface salinity, the soil profile is characterized by "surface accumulation". The area with low salt content in the surface layer (close to b) before sowing of maize showed "bottom accumulation" profile type. In the middle part of maize before sowing and the two ends of maize maturity, the soil salinity of the whole soil profile belongs to the same salinization level. It can be seen from the space that the soil salt content before maize sowing presents the distribution characteristics of low in the middle and high at both ends, while the soil salt content during maize maturity presents the distribution characteristics of high in the middle and low at both ends. In the section close to B, the soil salt content in maize mature stage was significantly lower than that before sowing. In the middle part of the cross section, the soil salt content in the mature stage of maize was significantly higher than that before sowing.

On the C-C 'section, the soil salt content near C' was significantly higher than that near C when the area where C-C' and A-A' intersected before maize sowing. And the area near C shows the profile feature of "surface accumulation type", and the area near C shows the profile feature of "bottom accumulation type". In general, the soil profile after maize mature is characterized by high in the middle and low at both ends, and the profile type of "surface accumulation" appears in the middle; the whole soil profile near C' belongs to the same salinization level. Compared with before sowing, the soil salt content of each soil layer depth after maize mature decreased significantly. From the profile distribution, after the soil improvement, the soil salt content of each typical section after maize mature decreased in varying degrees compared with that before sowing, and the soil improvement effect reached the expected goal.
4. Conclusion
In conclusion, after one year of continuous soil improvement measures, the soil salt content in 2019 decreased significantly compared with that in 2018, by 31.29%, and the effect of soil improvement was obvious. The salt content of soil profile in maize mature stage decreased significantly than that before sowing, and the decrease rates of soil salt content in different soil depths were 70.11% (0-20cm), 77.43% (20-40cm), 77.31% (40-60cm), 83.34% (60-80cm) and 65.26% (80-100cm), respectively. Among them, the depth of 60-80 cm soil layer decreased most significantly, with a decrease of 83.34%. No matter from the point statistical characteristics, or three-dimensional evaluation, it shows that the effect of soil improvement is significant.

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