Study on the Change Characteristics of Soil Salinity in Heavy Salinized Area of Xinjiang

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Abstract. In view of the problems of soil salinity, barren and other obstacles in the process of reclamation and utilization of heavy salinized land in Xinjiang, the heavy salinization area was selected as the research object, and the spatial variability of different salinity ions and its correlation were studied by using geostatistics and ground-penetrating radar technology. The results showed that the largest anion content in the soil of each layer of the study area was Cl-, followed by CO\(_3^{2-}\), the largest cationic content is Na\(^+\), followed by Ca\(^{2+}\), Cl\(^-\) and Na\(^+\). The variation law is basically the same, and the salt ion content of the whole section has the variability of intensity; the soil salinity in the study area showed "micro S" in the vertical direction. The characteristics of the table polymerization is not obvious, mainly related to artificial tillage; through spatial interpolation analysis, it is found that the salinity of soil in the study area has obvious characteristics of banded spatial distribution, the salinity of soil gradually increases from the southwest to the northwest, and the type of salinization is mainly chloride type. Detected by radar, in the study area deep in the 30cm, there is a dense salt plate layer in the soil, and the correlation analysis shows that the salt plate material is mainly CaCO\(_3\). This study provides a theoretical basis and reference for the zoning, improvement, management and rational utilization of salt in the heavy salinized region of Xinjiang.

1. Introduction
Soil salinization is an important factor affecting agricultural production and ecological environment [1-2]. The arid climatic conditions have caused serious soil salinization in Xinjiang, and various types of salinization, known as the "world salt and alkali soil museum." According to statistics, the total area of saline-alkali soil in Xinjiang is about 2.18×10^7 hm\(^2\), accounting for 22.01% of the area of saline-alkali land in China [3-4]. The area of 31.1% of the existing cultivated land area is harmed by...
salinization, which directly threatens the development of Xinjiang oasis agriculture. Salinized land is also an important land resource. Scientific utilization and improvement of saline soil have great economic and social significance, and research on salt variation characteristics is the premise and basis for regional salinization treatment and improvement. At present, the research on soil salinity characteristics in heavy salinization areas in Xinjiang mainly focuses on the statistical characteristics of soil salinity and its salt segregants [5-6], the characteristics of space-time changes [7-8], the relationship between salt and groundwater and its influencing factors [9-10] and other aspects. Combined with ground penetrating radar technology, the study on the chemical composition and spatial distribution characteristics of saline soil is rare. This paper takes the primary salinization area of Akto in Xinjiang as the research object, and uses ground penetrating radar and GIS technology, combined with geostatistics method, to analyze the spatial distribution pattern of soil salinization and clarify the variation characteristics of salt segregants. It provides a scientific basis for the regional management and ecological environment protection of heavy salinized soil in Xinjiang.

2. Research area overview
Akto County is located in the western border of China, in the southwest of Xinjiang Uygur Autonomous Region, in the eastern part of the Pamir Plateau, on the western edge of the Tarim Basin. The terrain is high in the southwest and low in the northeast. The terrain can be divided into mountain pastoral areas and plain agricultural areas. The surface soil type is only powder. Clay, the thickness of the soil layer is above 1m. The climate is warm and temperate with a continental arid climate. The annual drought is less rain and snow, the average annual precipitation is 60 mm, and the average annual water surface evaporation is 1400 mm. The mountain soil parent material generally contains soluble salt, which is transported in the plain irrigation area along with rivers and agricultural irrigation. Due to low rainfall, large evaporation, shallow groundwater burial, unsound drainage, arid climate, absolute increase in soil moisture, and weak leaching, there is a strong and extensive salt accumulation process in the irrigation area, forming different degrees of soil in the irrigation area. The secondary salinization, the proportion of saline soil to the total cultivated area is 35% [11].

3. Research method

3.1. Sample Collection
According to the field plan of the study area, one field is selected as the sampling field for every two fields, and a sample line is set in each of the excavation area and the filling area in the sampling field. The sample layout is based on the checkerboard method. The sampling depth is 60cm, and the layering is as follows: 0-20, 20-40, 40-60cm. After mixing each layer of soil sample, leave about 250g and put it into the ziplock bag, and number it, and record the geographical coordinates of each sampling point with GPS. A total of 72 soil samples. Five soil profile sampling points are laid along the southeast to northwest central axis of the project area with a sampling depth of 100 cm. The stratification is as follows: 0-10, 10-20, 20-30, 30-40, 40-60, 60-80, 80 -100 cm, a total of 35 soil samples. The sampling point distribution is shown in Figure 1.
3.2. Analysis
The collected soil samples are naturally air-dried in a well-ventilated room, and the residual plant roots and small stones are removed from the sample. After the soil sample is air-dried, the 2 mm nylon mesh is ground for use. The water-soluble total salt and eight ions were determined (K⁺, Na⁺ were determined by flame photometry; Ca²⁺ and Mg²⁺ were determined by EDTA complex metric titration, Cl⁻ was determined by silver nitrate titration, SO₄²⁻ was determined by EDTA indirect titration, CO₃²⁻, HCO₃⁻) and other indicators, the specific determination method of each indicator refers to "Soil Agrochemical Analysis Method". The test data was collated and analysed using Excel2010, SigmaPlot10.0 and Surfer11.0.

4. Result analysis

4.1. Statistical characteristics of soil salinity in different soil layers
It can be seen from Table 1 that the salt content of 0-20 cm soil layer in the study area is 1.64~158.53 g/kg, the average content is 47.09 g/kg; the salt content of 20-40cm soil layer is 1.33~134.39 g/kg. The average content is 44.12 g/kg; the salt content of 40-60cm soil layer is 1.18~156.03 g/kg, and the average content is 42.36 g/kg. The coefficient of variation reflects the degree of dispersion of the data. CV<10% is a weak variation, 10%≤CV<100% is moderate variability, and CV≥100% is strong variability. It can be seen that the total salt content of different soil layers in the study area is moderately variability, indicating that the spatial distribution of soil total salt content in the study area is relatively uneven and spatial heterogeneity is strong.

| Depth/ cm | MAX       | MIN | MEAN  | STD      | CV  |
|-----------|-----------|-----|-------|----------|-----|
| 0-20      | 158.53    | 1.64| 47.09 | 35.31    | 0.75|
| 20-40     | 134.39    | 1.33| 44.12 | 36.78    | 0.83|
| 40-60     | 156.03    | 1.18| 42.36 | 42.99    | 1.01|

4.2. Spatial characteristics of soil salinity in different soil layers
The vertical spatial distribution of soil total salt content in the project area is shown in Figure 2. The soil salinity content of the five sections is basically the same as the depth, which is mainly oscillating...
type, that is, the salt aggregates in the middle or shows the volatility in a certain depth. And the fluctuation characteristics from the northeast to the southwest of the project area become more and more obvious. The reason is that mechanical tillage will turn over the topsoil with high salt content before remediation to different depths of soil, and at the same time start a new salt accumulation process. The soil profile shows low surface and bottom salt content, while the middle part (20-80cm) features high salt content.

![Fig. 2 Vertical spatial distribution of soil total salt content in the project area](image)

Using the Kriging interpolation method, the spatial distribution of soil salinity in different soil layers in the project area was plotted. As shown in Figure 3, the spatial distribution of salt in the 0-20, 20-40 and 40-60 cm soil layers was basically consistent, the distribution of plaque-like plaques is present, and the points with higher salt content are basically in the same position, which is mainly related to the higher salt content of soil parent material. With the increase of depth, the area of plaque with higher soil salinity increased, which was mainly due to mechanical tillage of surface soil (0-20 cm), which destroyed the original salt accumulation layer.

![Fig. 3 Spatially distributional patterns of each soil salt ion](image)

4.3. Soil salt segregant characteristics
It can be seen from Fig.4 that the change of the content of each base ion in the soil of the project area is “micro S” type, which has a certain surface aggregation, but the content of each salt segregant in the soil in the range of 40-80 cm changes. It is not obvious, and it is completely different from other areas where the salt is concentrated only on the surface layer of the soil, while the salt with lower salt...
content is lighter. Among them, the anion has the most abundant Cl⁻ content, the content is between 12-61g/kg, followed by CO₃²⁻, the content is between 12-26g/kg, and the SO₄²⁻ content is between 0.1-0.4g/kg; The cation has the most abundant Na⁺ content, the content is between 0-25 g/kg, followed by the Ca²⁺ and Mg²⁺ content between 1-10g/kg, and the K⁺ content is extremely low, and the content is below 0.01g/kg. From the variation of salt segregants, the changes of Cl⁻ and Na⁺ are similar and the content is the most, indicating that the salinity of the salinized soil in the project area mainly exists in the form of NaCl, especially in the surface layer of the soil. In addition, the changes of Ca²⁺ and CO₃²⁻ are similar, indicating that CaCO₃ is also the main combination of salt. This indicates that there is a hard calcium deposit in the soil section of the study area, which becomes an obstacle to washing salt and salt.

![Fig.4 Soil salt segregant content change chart](image)

4.4. Soil profile barrier diagnosis

The formation of the salt layer is due to the accumulation of salt-bearing groundwater under evaporation and may also be accompanied by the precipitation of gypsum or other cement. The salt layer is hard and dense, and has a high salt content, which is different from the silty clay layer. If there is a salt raft layer in the soil layer, the electromagnetic wave will change in the process of underground propagation due to the different nature of the medium, which makes the radar image exhibit variability. It can be seen from Fig. 5 that the radar image is abnormal at about 30 cm, the electromagnetic wave signal is accelerated, the amplitude is increased, and the electromagnetic wave amplitude fluctuation amplitude is significantly higher than the previous several fields. It is indicated that the three fields are likely to have a salt layer at a depth of 30 cm. This phenomenon is caused by the difference in structure and composition from the salt raft layer and the upper soil layer.
4.5. Correlation analysis of soil salt segregants

The correlation analysis of soil salt segregants can not only reveal the existence and migration of salt in the soil, but also reflect the migration trend of salt to some extent. It can be seen from Table 2 that the positive correlation between soil salinity and Cl\(^-\) and Na\(^+\) is extremely significant, while the positive correlation with Ca\(^{2+}\) and CO\(_3^{2-}\) reaches a significant level; Cl\(^-\) and SO\(_4^{2-}\) are both Ca\(^{2+}\) and Mg\(^{2+}\). The positive correlations of Na\(^+\) and K\(^+\) are extremely significant, and there is also a significant correlation between Cl\(^-\) and SO\(_4^{2-}\). The correlation between Na\(^{+}\) and Ca\(^{2+}\), Mg\(^{2+}\) and K\(^+\) is significant, and the negative correlation between CO\(_3^{2-}\) and Ca\(^{2+}\) ions is significant because of the soil. When the concentration of Ca\(^{2+}\) is increased, a CaCO\(_3\) salt disk is formed to lower its concentration.

| Matrix of the correlation coefficients of salt ion |
|-----------------------------------------------|
| Na\(^+\) | K\(^+\) | Ca\(^{2+}\) | Mg\(^{2+}\) | Cl\(^-\) | SO\(_4^{2-}\) | CO\(_3^{2-}\) | Total salt |
|-----------|--------|-----------|-----------|--------|-----------|-----------|-----------|
| Na\(^+\)  | 1.000  | ——        | ——        | ——     | ——        | ——        | ——        |
| K\(^+\)   | 0.201* | 1.000     | ——        | ——     | ——        | ——        | ——        |
| Ca\(^{2+}\)| 0.123* | 0.015     | 1.000     | ——     | ——        | ——        | ——        |
| Mg\(^{2+}\)| 0.233* | 0.028     | 0.057     | 1.000  | ——        | ——        | ——        |
| Cl\(^-\)  | 0.199**| 0.121**   | 0.118**   | 0.103**| 1.000     | ——        | ——        |
| SO\(_4^{2-}\)| 0.168**| 0.152**   | 0.148**   | 0.134**| 0.121*    | 1.000     | ——        |
| CO\(_3^{2-}\)| 0.157**| 0.080     | -0.170**  | 0.020  | 0.059     | 0.051     | 1.000     |
| Total salt| 0.820**| 0.086     | 0.103*    | 0.032  | 0.814**   | 0.005     | 0.102*    |

Note: * represents a significant difference (p < 0.05), ** represents a significant difference (p < 0.01)

5. Conclusion

(1) The most anion content in the soil of the study area is Cl\(^-\), followed by CO\(_3^{2-}\), the most cation content is Na\(^+\), followed by Ca\(^{2+}\), Cl\(^-\) and Na\(^+\) are basically the same; the whole section salt segregant content has medium-strength. The variability indicates that the vertical distribution of soil salt segregant content in the study area is uneven, and the surface layer is affected by self-heating factors and human factors, and the spatial heterogeneity is strong.

(2) The soil salinity in the study area showed a “micro S” type change in the vertical direction, and the aggregation characteristics were not obvious, which was mainly related to artificial tillage. Through spatial interpolation analysis, it was found that the soil salinity in the study area had obvious spatial distribution characteristics of the strip, soil. The salt content increases from the southwest to the northwest, and the salinization type is mainly chloride.

(3) Through radar detection, it is found that there is a dense salt disk layer in the soil at a depth of about 30 cm in the study area. Correlation analysis shows that there is a significant negative correlation
between CO$_3^{2-}$ and Ca$^{2+}$ ions, which indicates the salt disk in the soil of the study area. The layer is mainly CaCO$_3$.

The spatial distribution of soil salinization in the project area is not balanced. When the salt is washed in the next step, the determination of the flushing quota, the land preparation and preparation before washing, and the implementation of chemical improvement measures are all based on the horizontal variation of soil salinity. Conduct targeted implementation and implement precise governance. In order to ensure a good salt washing effect, for the excavation area where there is a salt pan layer in the project area, a salt discharge hole is required before the water is poured.

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