Study on Reclamation of Saline-alkali Land in Akto Plain Region in Xinjiang

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Abstract. The area of saline-alkali land in Xinjiang accounts for about 1/3 of that in the whole China, so it is a key factor disturbing the economic development in local regions in Xinjiang. The paper combines field investigation and sampling with lab analysis to analyze the salinization state of soil in Akto plain region in Xinjiang, expounds the causes for salinization there, and proposes feasible governance recommendations. The findings are: 1) the project area has average total salt content of 107.1g/kg in soil horizon of 0-60cm, and belongs to strongly saline soil. The salinization type is mainly sulfate-chloride type; 2). In terms of vertical spatial distribution, the salinity mainly concentrates in soil horizon of 0-30cm, while in terms of horizontal spatial distribution, the degree of salinity takes on a trend of increasing from southwest to northeast and is closely related to topographic trend; 3) The soil in the project area belongs to halogenic parent material, and texture is silt loam in vertical uniformity. The groundwater has high mineralization and is buried deeply. The salinization is co-formed by primary and secondary reasons. The study can provide a reference frame for the governance of saline-alkali soil there.

1. Introduction
Located in the borderland, Akto belongs to concentrated and contiguous destitute areas in four districts in north Xinjiang with high concentration of impoverished people, being one of 26 key counties included in the national plan for poverty alleviation through development. To implement the strategic deployment of Party central committee and State Council about strengthening the efforts in solving tough problems of poverty alleviation and building well-off society in an all-around way, Akto implemented a batch of reclamation projects of saline-alkali soils according to the deployment of the state and the municipality for immigration relocation, the spirit of the ninth Communist party congress of the Xinjiang Uygur Autonomous Region, and the Construction Program of Relocation and Poverty Alleviation via Development for Xinjiang Uygur Autonomous Region. The study involves land
development project of relocation and poverty alleviation in Yumai township of Akto, which is the delta zone of Gaizi River and Kushan River with flat relief yet with local micro relief [1]. The natural conditions there are adverse with annual evaporation capacity of more than ten times of precipitation and even dozens of times in some years, plus the sparse vegetation, the salinization of soil is generally severe [2,3]. The paper analyzes the salinization state of soil in the project area to reveal the cause for salinization there, and proposes corresponding governance recommendations, in the hope of providing theoretical reference for the project's implementation.

2. Research Methods

2.1. Collection of samples
The field survey result shows the project area generally takes on the trend of high southwest and low northeast. Based on this, the project area was divided into 25 sampling units to collect the soil samples using earth drilling method. One surface soil sample was taken from each sampling unit, and sampling depth was 0-30cm. The samples were mixture of three subsamples. The sampling sites were laid using chessboard method, and GPS recorded the co-ordinates of sampling sites to form distribution diagram of sampling sites, as shown in Fig.1. Profile points were laid equidistantly on the central axis from southwest to northeast of project area. The profile depth was 1m and sampling depth was respectively 0-10, 10-30, 30-60, 60-100cm. A 2.5m-deep profile for observing soil is laid in the south and north of project area respectively for stratified sampling according to characteristics of soil profile. After the soil was collected, the sundries such as root system, stones, insects, etc. were picked out, then the soil was intensively mixed, and 1.0-1.5 kg was taken using quartering method and put in sample sacks, which were numbered and recorded.

Figure 1. The distribution diagram of sampling sites in the project area

Note: The yellow icons are sampling sites in surface layer of 0-30cm, blue icons are sampling sites in profile of 0-100 cm, and red icons are sampling points in profile for observing soil.
2.2. Lab analysis
After the soil samples were air-dried, they were grinded and passed 2mm nylon screen, then the indices such as pH, conductivity, water-soluble total salt, particle size composition, eight ions (K⁺, Na⁺, Ca²⁺, Mg²⁺, Cl⁻, SO₄²⁻, CO₃²⁻, HCO₃⁻) were determined. The assay and test were conducted in Soil Engineering Quality Test Center of Shaanxi Land Construction Land Engineering Institute. The Excel2010, SigmaPlot10.0 and ArcGIS10.0 were used to arrange and analyze the test data.

3. Result analysis

3.1. Degree of salinization
Table 1 shows that the salinity in soil horizon of 0-10cm in the project area is 53.7 ~ 174.9 g/kg, 22.0 ~ 107.9 g/kg for soil horizon of 10-30cm, 9.7 ~ 38.3 g/kg for soil horizon of 30-60cm, 2.5 ~ 31.7 g/kg for soil horizon of 60-100cm. The mean salinity in soil horizon of 0-60cm is 107.1 g/kg. According to the grade scale of soil salinization degree in Xinjiang Soil, the soil in the project area is strongly saline soil [4]. In terms of variation coefficient, the salinity of each soil horizon all takes on medium variation intensity (variation coefficient is 0.1 ~ 1), which may be related to fluctuating change of local microrelief in the project area.

| Soil horizon depth/cm | MAX  | MIN  | AVG  | SD   | CV   |
|----------------------|------|------|------|------|------|
| 0-10                 | 316.5| 53.7 | 174.9| 95.0 | 0.543|
| 10-30                | 292.3| 22.0 | 107.9| 98.0 | 0.908|
| 30-60                | 74.2 | 9.7  | 38.3 | 24.0 | 0.625|
| 60-100               | 60.1 | 2.5  | 31.7 | 21.5 | 0.680|

3.2. Salinization type
It is observed from Fig.2 that the fluctuation of content of each base ion in profile in the soil of project area takes on ”fat-T” shape. Not only the salinity content is very high in topsoil of 0~30cm, but also the salinization degree of soil in 30~100cm reaches the level of strongly saline soil, indicating the soil in the project area is entirely different from other regions' salinized soil whose salinity is only concentrated in topsoil and substratum salinity content is lower. Wherein, the content of Cl⁻ among anions is the largest, being 12-61g/kg, SO₄²⁻ comes the second, being 12-26 g/kg, and total content of CO₃²⁻ and HCO₃⁻ is 0.1-0.4 g/kg; among the cations, the content of Na⁺ is the largest, being 0-25 g/kg, Ca²⁺ and Mg²⁺ come next, being all 1-10g/kg, K⁺ content is extremely low, being all below 0.01g/kg. The change rule of each salt ion shows that the Cl⁻ and Na⁺ have similar change rule and the largest content, which indicates that the salinity in the salinized soil in the project area mainly exists in the form of NaCl, especially in surface layer of soil besides, the change rules of Ca²⁺, Mg²⁺ and SO₄²⁻are similar too, indicating that CaSO₄ or MgSO₄ are also the main binding mode of salinity. Thus, it is inferred that the salinization type in the project area is mainly sulfate—chloride type soil, which is provided with very strong thaw collapsibility and salt expandability that severely threat quality stability of road and irrigation and drainage works in the project area [5].
3.3. Spatial distribution of salinization

The Fig.3 shows that the change rules of salinity content in soil of project area with depth change are in substantial agreement, and generally take on the trend of gathering towards top horizon. At 30cm of soil horizon depth, the total salt content turns obviously, which indicates that the salinity content in soil horizon of 0 ~ 30cm is apparently higher than that in other soil horizons, and the range of variation is significantly higher than the soil horizon of 30 ~ 100cm. In terms of vertical distribution of salinity, the salinity in the soil in project area is mainly concentrated in top soil horizon of 0-30cm.

The ArcGIS interpolation is adopted to draw the spatial distribution diagrams of salinity content and conductivity in the soil of project area respectively. As shown in Fig.2, the spatial distribution rules of the two are basically the same and take on distributional characteristic of checker-board-
shaped patches, which is primarily influenced by fluctuating change of microrelief in the project area. In the regions with relatively higher foundation relief, the degree of salinity is more severe due to strong evaporation, and is relatively lighter in otherwise regions. However, the general trend is increasing from southwest to northeast, which is consistent with the major relief of low southwest and high northeast.

*Figure 4.* The spatial distribution diagram for level of total salt content (left) and conductivity (right) in the soil of project area
4. Discussions
The salinization of project area is co-formed by primary and secondary reasons. Firstly, it is observed from table 2 that the pH value of soil in the project area is 7-8 without large change, so the soil belongs to neutral soil to alkalescent condition, while the conductivity in different depths is largely different, which is because the project is located on the alluvial-pluvial fan plain in delta zone of Gaizi River and Kushan River, with the alluvium and diluvium from mountainous areas sedimented there, the ancient soil parent materials included therein prevalently contain soluble salts and belong to halogenic parent material. This serves as the material basis for salinization of soil there. In terms of particle size composition, the soil in the project area is dominated by silt content, and the soil texture is silty loam or silt (USDA) in vertical uniformity and belongs to homogeneous profile configuration, whose ascent height of capillary water is up to about 1.5m [6]. Light texture, smooth capillaries and active moisture operation are the best textural and profile configuration conditions for secondary salinization. Secondly, the climate there is extremely arid and belongs to continental arid climate of temperate zone with sparse precipitation and strong evaporation (mean annual evaporation is a dozen of times of annual precipitation [7]). In terms of natural conditions, the weak soil leaching provides dynamic conditions for salinization. Thirdly, the survey found that shallow groundwater there has a mineralization degree of 4.2-4.8 g/L and belongs to salt water. Besides, the groundwater is buried shallowly at about 2m, the groundwater level is located above critical buried depth for long, and the salinity continuously aggregates towards the surface, leading to relentless aggravation of secondary salinization degree there [8].

| Sampling site | Sampling depth (cm) | pH  | Conductivity (ms/m) | Particle size composition (%) | Texture (USDA) |
|---------------|---------------------|-----|---------------------|-----------------------------|---------------|
|               |                     |     |                     | Clay | Silt   | Sand   |               |
| 1             | 0-10                | 7.6 | 4.62 × 10³          | 9.50 | 73.98  | 16.52  | Silty loam    |
|               | 10-30               | 7.3 | 8.03 × 10³          | 8.06 | 82.44  | 9.50   | Silt          |
|               | 30-60               | 7.6 | 2.04 × 10³          | 8.14 | 79.44  | 12.42  | Silty loam    |
|               | 60-100              | 7.7 | 1.69 × 10³          | 7.74 | 79.30  | 12.96  | Silty loam    |
|               | 0-10                | 7.9 | 2.07 × 10³          | 5.73 | 76.46  | 17.81  | Silty loam    |
|               | 10-30               | 7.3 | 2.06 × 10³          | 7.66 | 81.72  | 10.62  | Silt          |
|               | 30-60               | 7.2 | 834                | 8.89 | 82.58  | 8.53   | Silt          |
|               | 60-100              | 7.1 | 525                | 7.77 | 82.63  | 9.60   | Silt          |
| 2             | 0-10                | 7.6 | 4.47 × 10³          | 6.79 | 79.68  | 13.53  | Silty loam    |
|               | 10-30               | 7.6 | 2.13 × 10³          | 7.92 | 86.56  | 5.52   | Silt          |
|               | 30-60               | 7.3 | 804                | 7.10 | 79.36  | 13.54  | Silty loam    |
|               | 60-100              | 7.2 | 616                | 8.23 | 81.08  | 10.69  | Silt          |
| 3             | 0-10                | 7.5 | 1.29 × 10³          | 7.54 | 78.96  | 13.50  | Silty loam    |
|               | 10-30               | 7.3 | 543                | 6.37 | 76.86  | 16.77  | Silty loam    |
|               | 30-60               | 7.0 | 338                | 6.88 | 68.14  | 24.98  | Silty loam    |
|               | 60-100              | 7.2 | 183                | 5.45 | 58.7   | 35.85  | Silty loam    |
| 4             | 0-10                | 7.2 | 8.06 × 10³          | 6.60 | 66.22  | 27.18  | Silty loam    |
|               | 10-30               | 7.7 | 2.53 × 10³          | 6.57 | 75.81  | 17.62  | Silty loam    |
|               | 30-60               | 7.6 | 1.68 × 10³          | 8.43 | 84.11  | 7.46   | Silt          |
|               | 60-100              | 7.6 | 1.51 × 10³          | 7.37 | 80.16  | 12.47  | Silt          |
5. Conclusion
In a word, although the saline-alkali soil in the project area is unused desertificated land, it can be developed into tilth resources via soil engineering measures, soil improvement measures, agro technical measures, etc. to remit the local poverty. The governance should be "dominated by control and combining prevention and treatment". Following governance recommendations are suggested:

Firstly, the salinity in top soil of project area is too high. Thus, to alleviate the late pressure of leaching and salt content restraining, the capping salt incrustation (0-10cm) should be stripped. Secondly, to avoid salinity aggregating towards high place, the relief in the project area should be leveled off and remoulded. Thirdly, the engineering measures should be adopted to build water and salt drainage works, dig new salt drainage gutters or bury buried pipes, use Kushan River or groundwater for leaching and restraining of salt content. The leaching time is advisable to be early autumn. Fourthly, considering that the buried depth of groundwater in project area is shallow and groundwater mineralization is low, it is recommended to increase well cluster construction and groundwater mining efforts there if policies permit, to make the ground water level decline to below the critical ground water level, thereby accelerating desalting of soil. Fifthly, the region with severe degree of salinity can be chemically improved by applying calciferous or acidifetous substances to raise the saturation of calcium ions in soil colloid, decrease the exchangeable sodium percentage (ESP) and improve soil quality.

Besides, although engineering measures can effectively drain salt, they drain the soil nutrients too. Thus, agro technical measures must be supplemented to solve this problem, such as putting in substantive organic fertilizers such as human excrement, green manure, cake fertilizer, excrements of livestocks, culm, wheat straw fertilizer and mixed fertilizers into saline-alkali soil. The organic fertilizers are decomposed by microbes and translated into humus. On the one hand, this can accelerate decomposing of nutrients, promote translation of nutrients, improve buffering power of soil, ameliorate the physical behaviour and salt composition of soil, On the other hand, the humus can enhance the soil permeability, enhance leaching, decrease evaporation of moisture and restrain accumulation of salt in the surface soil, and the forest belts can be planted between parcels of field to decrease the transpiration of ground. In the meanwhile, the water demand of trees is far higher than that of the common crop, which can effectively reduce groundwater level near the crop, thereby realizing biological drainage. Only combining engineering measures and agronomic practice, etc. can sustainably reclaim the saline-alkali soil [9-11].

References
[1] Yang Yiyuan. Characteristics of Stratum and Structure of Detailed Survey Area of Tuokziato in Akto of Xinjiang [J]. Science & Technology Information. 2012 (6): 419 - 419.
[2] Wang Xiaofeng. The Characteristic Analysis on Climatic Change of Akto in Last 50 years [J] Journal of Zaozhuang University. 2011 (2): 115 - 120.
[3] 2005 G B. Water Quality Standard for Farm Irrigation [S] [D]. 2005.
[4] Ma Yingwu, Zhu Binde, Yang Heng, et al., The Actuality of Saline-alkali Soil in Irrigated Area in Wusu and Governance Measures [J]. Xinjiang Water Resources. 2008 (4): 15 - 18.
[5] Yang Baocun, Liu Xinrong, He Xinghong, et al. The Experimental Study on Salt Expandibility of Salinized Soil Roadbed [J]. Chinese Journal of Underground Space and Engineering. 2009.
[6] Ying Juan, Fei Liangjun, Cheng Dongjuan. The Lab Study on Capillary Elevation Characteristics of Isotropic Soil [J]. Transactions of the Chinese Society of Agricultural Engineering 2007, 23 (6): 91 - 94.
[7] Wang Xiaofeng, Gu Li, Ji Mili, et al. The Evaporation Capacity Change Characteristics of Akto in Last 46 Years and Cause Analysis [J]. Journal of Jinggangshan University: Natural Science Edition. 2011, 32 (4): 57 - 61.
[8] Hu Kelin, Chen Hailing, Zhang Yuanpei, et al. The Spatial Distribution Characteristics of Buried Depth of Shallow Groundwater, Mineralization Degree and Nitrate Pollution [J]. Transactions of the Chinese Society of Agricultural Engineering 2009 (S1): 21 - 25.
[9] Wang Shuhong. A Brief Analysis on the Actuality of Saline-alkali Soil in Shawan County of Xinjiang and Reclamation Measures [J]. Journal of Water Resources and Water Engineering 2009, 20 (3): 135 - 139.

[10] Wang Jincai, Ying Li. The Technical Measures for Reclamation of Saline-alkali soil [J]. Modern Agricultural Sciences and Technology 2011 (12): 282 - 282.

[11] Fan Zhongsheng, Cause Analysis on Saline-alkali Soil in Akto plain Region in Xinjiang and Governance Recommendations [J], Ground Water, 2014 (3): 61 - 62.