Research on the Spatial Differentiation of Soil Salinization in the north of the Yellow River in Jinan City

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Abstract. In this paper, Xiyan Village and Dongyan Village of Jiyang County, Jinan City were taken as the research areas to conduct research and analysis on the spatial distribution law of soil salinity in the spring of 2019. Spatial distribution of soil salt ions in different soil layers were drawn to research spatial distribution characteristics of soil ions. The results show that soil in the research areas was highly mineralized and the negative ions in the chemical components were mainly SO42- and Cl-. In the horizontal direction, the content of Mg2+ and Cl- in all layers all presented the trend of increasing gradually from northwest to southeast. The peak value of ion content occurred in the Midwest.

1. Introduction
At present, the research on soil salinization focuses on two directions: (1) conducting the dynamic research on soil water and salt transport to establish the models of soil salinization, and to evaluate and predict the trend of soil salinization; (2) conducting spatial and temporal variation research on regional soil salinity to analyze the influence factors. In the 1960s, Nielson put forward Convection Dispersion Equation (CDE), which proved the relationship between mass flow and diffusion in soil solute during transport by experiments[1]. Schoup built a hydrologic history model to analyze the accumulation of soil salt in the research areas in 1940-2000 and hold that the main cause of deep groundwater salinization is water supply [2]. Xiaomei Fan [3], Ao Zhang [4] established a groundwater level, salinity and soil salinization Grey Relational Degree Model to analyze the key environmental factors of soil salinization in the Yellow River Delta. In this paper, the research on the law of spatial distribution of soil salt in the salinization areas in North Yellow River of Jinan City was conducted based on geological surveys and served as a basis for analyzing the factors affecting soil salinization.

2. Research Methods
2.1. Sample Collection
2.1.1. Sampling points layout
The sampling points were mainly on the low-lying and bare ground areas near to irrigation ditches. At the same time, the research area was covered as much as possible. 17 soil sampling points were selected in Dongyan Village and Xiyan Village by adopting GPS positioning technology (Figure 1).

2.1.2. Sampling season and time
The sampling time was in April 2019 before spring irrigation. when it was drought, the salt was weakly leached and the groundwater migration was relatively simple. And the evaporation and surface salt accumulation were large. Moreover, as winter wheat was grown here, the land had not been
ploughed for half a year, so the human disturbance was less in favor of the analysis on the distribution law.

2.1.3. Sampling methods
3 soil samples were collected in each sampling point in a stratified way in the depths of 0-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, 50-75 cm and 75-100 cm, so there were totally 357 soil samples.

![Sampling Point Distribution](image.jpg)

**Figure 1. Sampling Point Distribution**

2.2. Analysis of Tests
The samples were bagged and brought back to the laboratory. After drying and crushing, they were screened with a 1 mm sieve. The soil ion content was measured according to the procedures (Table 1).

| Soil Salt Ions | Measuring Methods              | Soil Salt Ions | Measuring Methods              |
|---------------|-------------------------------|---------------|-------------------------------|
| Mg$^{2+}$, Ca$^{2+}$ | Atomic absorption spectrometry | HCO$_3^-$ | Double indicator neutralization titration |
| Cl$^-$       | Silver nitrate titration     | SO$_4^{2-}$  | EDTA-indirect titration       |

2.3. Data Processing
The correlation analysis and principal component analysis of soil salt ion content were carried out by SPSS. The spatial interpolation processing on Cl$^-$, SO$_4^{2-}$, HCO$_3^-$, Mg$^{2+}$ and Ca$^{2+}$ content was performed by applying Kriging of ARCGIS.

3. Characteristics of Soil Salinization

3.1. Type Characteristics of Soil Salinization
The ion data of the soil in the plough layer (0-20 cm) was analyzed and the conclusions are: the soil ions in the research areas were mainly negative ions such as SO$_4^{2-}$ and Cl$^-$ and the main positive ion was Ca$^{2+}$, secondly was Mg$^{2+}$ (Table 2). The salt type of the soil was mainly chloride-sulfate type, accounting for 75% of the total area of the research areas. The next was sulfate type, accounting for 16.7%, and then sulfate-chloride type, accounting for 8.3%.
Table 2. Topsoil Ion Content

| Ions   | Average (cmol·kg⁻¹) | Ions   | Average (cmol·kg⁻¹) |
|--------|---------------------|--------|---------------------|
| Ca²⁺   | 0.033±0.024         | HCO₃⁻  | 0.047±0.016         |
| Mg²⁺   | 0.028±0.025         | Cl⁻    | 0.140±0.018         |
| SO₄²⁻  | 0.495±0.195         |        |                     |

3.2. Profile Characteristics of Soil Salt Ion Content

Based on the soil salt ion content average of each profile layer, it can be seen that the phenomenon of surface convergence of the soil salinity in the research areas was remarkable, and the salt ions in the soil decreased with the increase of soil depth. The content of HCO₃⁻, Ca²⁺ and Mg²⁺ changed a little in vertical direction. The distribution situation of Ca²⁺ and Mg²⁺ was basically consistent. The content of SO₄²⁻ decreased with the increase of the depth. The content of Cl⁻ showed a significant trend of decrease in the soil layer of 0-30 cm and increased sharply in 40-50 cm. In the total soil ions, the sum of SO₄²⁻ far surpassed that of other ions, and the next was Cl⁻.

![Figure 2. Characteristics of Soil Profile Salt Ion Content](image)

According to the coefficient of variable of soil profile ion content (Figure 3), the CV values of Ca²⁺, Mg²⁺ and Cl⁻ were between 10-100%, showing a medium vertical variability; the CV values of SO₄²⁻ and HCO₃⁻ were <10%, presenting a weak vertical variability.
3.3. Correlation Analysis of Soil Salt Ions

There was a certain correlation between the salt ions in the soil. The correlation analysis conducted can reflect the law of soil migration and show the change trend of the salinity (Table 3). The Cl\textsuperscript{-} in the topsoil of the research areas was positively correlated with all other ions. The positive correlation between Ca\textsuperscript{2+} and Mg\textsuperscript{2+} and between Cl\textsuperscript{-} and SO\textsubscript{4}\textsuperscript{2-} was significant. There was a negative correlation between Ca\textsuperscript{2+} and HCO\textsubscript{3}\textsuperscript{-} and between Ca\textsuperscript{2+} and SO\textsubscript{4}\textsuperscript{2-}, because with the increase of the concentration of Ca\textsuperscript{2+}, Ca\textsuperscript{2+} and HCO\textsubscript{3}\textsuperscript{-} as well as Ca\textsuperscript{2+} and SO\textsubscript{4}\textsuperscript{2-} in the soil interacted and formed the precipitation of CaCO\textsubscript{3} and CaSO\textsubscript{4}, making the concentration of the ions decreased.

Table 3. Correlation Analysis of Topsoil Salt Ions

|       | Ca\textsuperscript{2+} | Mg\textsuperscript{2+} | HCO\textsubscript{3}\textsuperscript{-} | Cl\textsuperscript{-} | SO\textsubscript{4}\textsuperscript{2-} |
|-------|------------------------|------------------------|-------------------------------|------------------------|------------------------|
| Ca\textsuperscript{2+}| 1.000                  | 0.745                  | -0.330                        | 0.620                  | -0.050                 |
| Mg\textsuperscript{2+}| 1.000                  | 0.039                  | 0.920                         | 0.356                  |                        |
| HCO\textsubscript{3}\textsuperscript{-}| 1.000                  | 0.271                  | 0.345                         |                        |                        |
| Cl\textsuperscript{-}| 1.000                  |                        |                                |                        |                        |
| SO\textsubscript{4}\textsuperscript{2-}|                        |                        |                                |                        | 1.000                  |

4. Soil Ion Content Spatial Distribution

The Cl\textsuperscript{-}, SO\textsubscript{4}\textsuperscript{2-}, HCO\textsubscript{3}\textsuperscript{-}, Mg\textsuperscript{2+} and Ca\textsuperscript{2+} in the soil of the research areas were taken as the factors for variation analysis and the dominant factor was selected in accordance with the standard that the accumulative contribution rate shall be more than 85%. The first dominant component in the topsoil was positively correlated with all the salt ions and significantly positive correlated with Mg\textsuperscript{2+} and Cl\textsuperscript{-} (Table 4). Therefore, Mg\textsuperscript{2+} and Cl\textsuperscript{-} were selected for the spatial analysis of ion distribution by using GIS Kriging interpolation.

Table 4. Factor Loading Matrix

|       | 1     | 2     |
|-------|-------|-------|
| Ca\textsuperscript{2+}| 0.758 | -0.563 |
| Mg\textsuperscript{2+}| 0.975 | -0.095 |
| HCO\textsubscript{3}\textsuperscript{-}| 0.153 | 0.880 |
| Cl\textsuperscript{-}| 0.950 | 0.079 |
| SO\textsubscript{4}\textsuperscript{2-}| 0.433 | 0.715 |

4.1. Spatial Distribution of Mg\textsuperscript{2+} Content

The distribution situation of the Mg\textsuperscript{2+} Content in the soil of the research areas is shown as figure 4. The Mg\textsuperscript{2+} Content in every soil layer all gradually increased from northwest to southeast. The peak of the Mg\textsuperscript{2+} Content in 0-10 cm soil layer appeared in the middle and west of the research areas. And with the increase of the depth of the soil, the proportion of the high content area among the whole research areas was gradually decreased.
4.2. Spatial Distribution of Cl⁻ Content

The distribution situation of the Cl⁻ Content in the soil of the research areas is shown as figure 5. The Cl⁻ Content in every soil layer gradually decreased from the center of the area to the periphery. And the high content area extended from northwest to southeast.

4.3. Analysis of Results

The spatial interpolation analysis results of Mg²⁺ and Cl⁻ content in the research areas show that the soil salt ions all gradually increased from northwest to southeast. The main reasons: the geomorphologic pattern in the region is that there is a flat slope in the west and a low depression in most areas in the east, so the buried depth of groundwater decreases gradually from north to south, the low-lying areas have poor drainage and are prone to soil salinization. At the same time, the ditches in the research areas are mainly distributed in the south and east, so under the influence of river infiltration, the groundwater is buried shallow and salinization degree is deepened.

5. Conclusion

Upon the research, it is found that there is a certain correlation between the spatial distribution of soil water and salt and the factors such as groundwater buried depth, evaporation and human disturbance. The conclusions are drawn as follows: (1) The type of soil in the research areas is mainly chloride-sulfate type; (2) The salt ions in the soil show a trend of decrease with the increase of the soil depth with significant surface convergence phenomenon. The soil layer of 10-40 cm is a ploughed fallow layer where the soil salt ions mixes, so the law of distribution presented is not obvious and the content distribution is unstable; (3) Under the influences of geomorphology, groundwater, surface channels and other factors, the distribution of soil salt in the horizontal direction shows a law of gradual increase from northwest to southeast.

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7. References

[1] Harvey R w, Metge D W, Barber L B, et al. Effects of altered groundwater chemistry upon the pH-dependency and magnitude of bacterial attachment during transport within an organically contaminated sandy aquifer[J]. Water Research, 2010, 44(4): 1062-1071

[2] Schoups G, Hopmans J W, Young C A, et al. Sustainability of irrigated agriculture in the San Joaquin Valley, California[J]. Proceedings of the National Academy of Sciences, 2005, 102(43): 15352-15356

[3] Xiaomei Fan, Gaohuan Liu, Zhipeng Tang, Longcang Shu, Analysis of factors affecting soil salinization in the Yellow River Delta [J]. Journal of Soil and Water Conservation, 2010, 24(01): 139-144

[4] Ao Zhang, Zhenhua Wang, Jiulong Wang, Wenhao Li, Influence of groundwater on soil water and salt distribution under evaporation conditions [J]. Agricultural Research in the Arid Areas, 2015, 33(06): 229-233+253