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Simulation of Salt Transport in Saline-alkali Soil under Different Control Modes

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Abstract: In order to ascertain the difference in the improvement effects of the two modes of water storage and drainage on saline-alkali soil. The method of simulating test plots was adopted to establish a closed water storage test area and an opened drainage test area. The interannual dynamic characteristics of soil salinity at different levels are analyzed. [Results] Under the water storage mode and drainage mode, the salt content of 0-100 cm soil was in a downward leaching migration state. Under the water storage mode and drainage mode, the soil salinity of each layer showed a trend of first decreasing and then increasing from 2015 to 2019. The horizontal migration of soil salinity in the water storage mode is mainly the interannual circular migration from the far end of the pool to the end of the near pool and then to the end of the far pool. The horizontal movement of soil salt in drainage mode is mainly one-way movement from the far end of the pool to the near end of the pool.

Keywords: Water storage; Drainage; Salinity; Migration.

1. Introduction

Soil salinization is one of the important land degradation problems faced by my country in adhering to the red line of 1.8 billion mu of arable land and ensuring food security. my country has about 27 million hectares of saline-alkali land, which is widely distributed in the northwest, north China, northeast and coastal areas [1]. Salinized soil is very difficult to use. On the one hand, as the salt accumulates in the soil, the physical conditions of the soil are degraded, such as decreased structural adhesion and poor aeration. The increase in salt will also inhibit seed germination, change the water environment around the plant root system, and increase the external root system. The osmotic pressure of the plant inhibits the absorption and utilization of water and nutrients by plants, thereby affecting plant growth and development [2], which is not conducive to ecological or agricultural land; on the other hand, soil salinity such as chloride, sulfate, magnesium ions, etc. The increase of s will increase the corrosiveness of building substrates such as concrete and steel bars [3], which is not conducive to being used as construction land.

With the gradual emergence of land-use contradictions in my country, how to manage and use saline-alkali land reasonably has gradually become a research focus. Scholars have done a lot of research on the management and utilization of saline-alkali land. The cultivation of salt-tolerant plants such as rice has become the first choice[4], but the salt-tolerance of plants has its upper limit, which is not suitable for application in saline-alkali soils with high salt content, nor does it fundamentally solve the problem of salinization. Using chemical modifiers such as inorganic polymer PAFS, gypsum, epoxy resin, silicate [5-7] to improve saline-alkali land, although the effect is more significant, but the cost is higher, and the addition of exogenous substances will be extremely large Improve the physical and chemical properties of the soil, resulting in other unexpected risks. Compared with biological improvement and chemical improvement, the traditional washing and pressing of salt can quickly leaching out the salt in the target soil, and the scope of application is more extensive, but the water resources in saline-alkali areas have become the largest limit condition.

In view of the differences in water resources conditions in different regions, two governance modes have been gradually developed, namely, drainage and salt washing and water storage and pressure salt treatment. This paper analyzes the advantages of drainage and water salt washing and storage and pressure salt based on the long-term dynamic changes of soil salt in the water storage and drainage modes. It is expected to provide a reference for the improvement and utilization of saline-alkali land according to local conditions.

2. Research Methods

2.1. Design of simulation test area

The simulation test area was built in 2009 and consists of a water storage model area and a drainage model area. The specifications (length × width × height) were 23.0 m×1.5 m×2.0 m. The main body was made of brick-concrete structure by pouring cement, and the surrounding walls and ground were waterproofed with concrete and waterproof materials to eliminate the interference of the surrounding soil moisture on the test. The main body of the water storage mode area was composed of a reservoir and a test soil tank, with an additional water storage adjustment tank. The drainage mode area was composed of two parts: a drainage tank and a test soil tank. To prevent soil loss, the soil tank and the water storage tank (drainage Use geotextile to isolate the two between the pool. The experiment set up two treatments: water storage and pressure salt treatment and drainage washing salt treatment. The water storage treatment was to put a certain amount of water in the reservoir, and use the regulating tank to restore the increase and decrease of the water caused by factors such as irrigation, precipitation, and evaporation, so that the water level was maintained at 50 cm throughout the year. Drainage treatment uses irrigation and precipitation to wash salt, and regularly discharge the accumulated water in the drainage pool. During the test, the same amount of water was provided for storage and drainage. The schematic diagram of the simulated test area was shown in Figure 1.

The soil sample used in the simulation test area is the saline-alkali soil in the Lubotan area. The soil of 0-200 cm is stripped every 30-40 cm and transported back to the simulation test area. After air drying, crushing and sieving (5 mm), it is filled in the test soil tank. The soil filling mode and the filling amount of the water storage mode area and the drainage mode area are the same. The background values of saline-alkaline soil are: total salt content of 0.77%, pH value of 9.33, Cl- content of 0.37%, HCO3- content of 0.08%, and SO42- content of 0.66%. After the construction of the simulation test area is completed, a corn-wheat rotation will be carried out, and the amount of sowing, fertilization, and irrigation will remain the same.

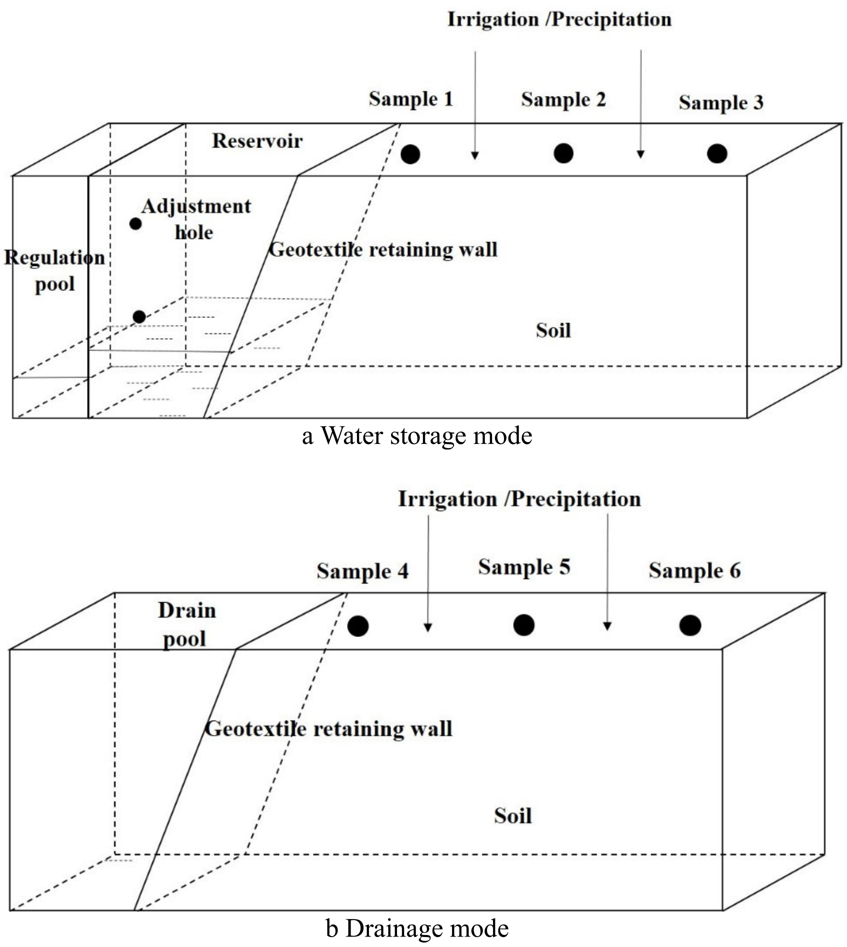


Figure 1. Schematic diagram of the simulated test area

2.2. Sample collection and index determination

In June and October of 2015, 2017, and 2019 (after each crop is harvested) at the end of the near pond (samples 1 and 4), the middle part of the soil (samples 2 and 5), and the end of the far pond (Sample points 3 and 6) , soil samples of 0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm, and 80-100 cm was collected to determine the total salt content of the soil(Fig.1).

2.3. Statistical analysis

The test data used SPSS (PASW Statistics 16.0) for one-way analysis of variance, and Excel 2012 and Sigmaplot 12.5 were used for data sorting and graphing.

3. Result Analysis

3.1. Differences in interannual changes in soil salinity between water storage and drainage modes

The interannual changes in the salt content of each soil layer under the water storage mode and the drainage mode showed a trend of first decreasing and then increasing from 2015 to 2019(Table 1). The soil salt content was the lowest in 2017. The soil salt content of each layer in the water storage model in 2015 was lower than that in the drainage model. Only the 0-60 cm soil salt content was lower than the drainage model, and the 60-80 cm soil salt content was higher than the drainage model in 2017. Soil salt content of 0 -100 cm in the storage mode is higher than that in the drainage mode in 2019. Only in 2015 the difference between the soil salt content of 60-100 cm between the storage mode and the drainage mode reached a significant level, and the difference in the soil salt content of each layer of the water storage mode and drainage mode in 2017 and 2019 reached a significant level.

The soil salt content of 0-20 cm and 80-100 cm under the water storage mode in 2019 was significantly higher than that of 2015 and 2017. And the soil salt content of 0-20 cm in 2019 increased by 193% and 569% compared with 2015 and 2017, respectively. The salt content of 80-100 cm soil in 2019 increased by 155% and 158% compared to 2015 and 2017. The salt content of soil 40-60 cm in 2019 increased by 155% compared with 2017. The interannual variation of other soil layers were not reached a significant level. Under the drainage mode, only the soil interannual variability of 20-40 cm reached a significant level, which was reduced by 59% and 48% respectively in 2017 and 2019 compared to 2015. From the perspective of the soil salt content of each layer, the soil salt content in the water storage mode and the drainage mode showed a trend of gradually increasing from top to bottom. Under the water storage mode, there was no significant difference in the soil salt content of each layer in 2015. With the time past by, the difference gradually appeared: the soil salt content of 60-100 cm in 2017 was significantly higher than that of 0-20 cm soil, and compared with 20-60 cm soil. There is no significant difference in soil; in 2019, the salt content of 80-100 cm soil was significantly higher than that of 0-60 cm soil, but there was no significant difference from 60-80 cm soil. Under the drainage mode, only in 2015 there were significant differences in the salt content of each layer of soil. The salt content of 80-100 cm soil was significantly higher than that of 0-40 cm soil, but there was no significant difference with 40-80 cm soil.

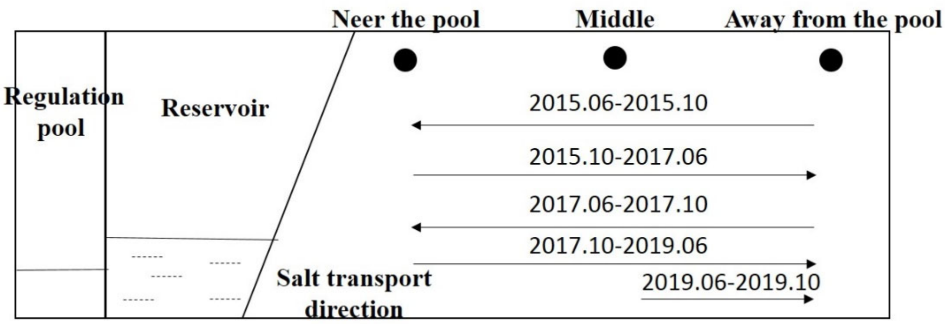
Table 1. Inter-annual variation of soil salt content

Soil layer (cm)	2015		2017		2019	
	Water storage	Drain	Water storage	Drain	Water storage	Drain
0-20	1.28 aB	2.21 aA	0.56 aB	1.55 aA	3.76 aA	2.17 aA
20-40	1.61 aA	2.92 aA	0.99 aA	1.19 aB	2.30 aA	1.51 aAB
40-60	2.52 aAB	4.56 aA	1.39 aB	2.19 aA	3.55 aA	3.26 aA
60-80	2.70 bA	5.40 aA	2.70 aA	1.66 aA	4.96 aA	4.70 aA
80-100	2.87 bB	6.32 aA	2.85 aB	2.75 aA	7.34 aA	5.59 aA

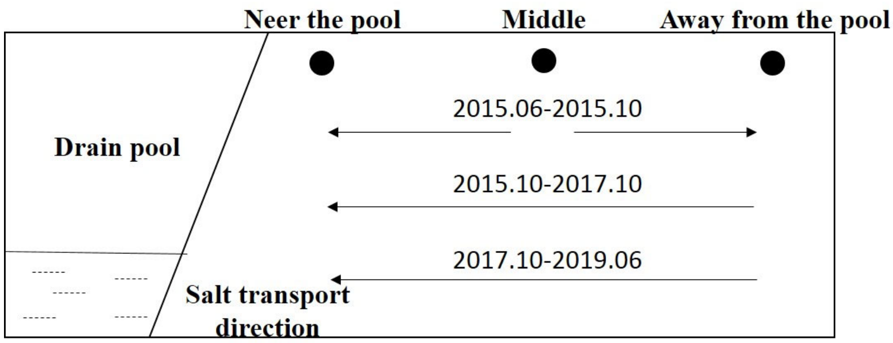
Note: Different lowercase letters indicate significant differences between different treatments in the same soil layer in the same year (P<0.05), and different capital letters indicate significant differences between different years in the same soil layer under the same treatment (P<0.05)

3.2. 3.2 Horizontal movement of soil salt

The soil salinity of 0-100 cm migrated from the far end of the pond to the near end of the pond from June to October in 2015 (Fig.2), and The soil salinity of 40-100 cm moved towards the far end of the pool from October 2015 to June 2017. The salt migrated to the near end of the pool from June to October 2017. The salt migrated to the to the far end of the pool from October 2017 to June 2019, and The salt migrated from the middle to the far end of the pool in October 2019.From June 2015 to October 2015, the soil salt content increased significantly at both ends of the soil, while the salt content in the central part changed little, and the salt may gradually migrate from the central part to the two ends. The soil salt content The content of the soil is decreasing, and the salt in the horizontal direction migrates from the far end of the pond to the end of the near pond during October 2015 to October 2017. The increase of 0-60 cm soil salt content was relatively uniform, and the soil salt content of 60-100 cm near water had a large increase, The increase in the central and original pools wass relatively uniform and the salt in the horizontal direction migrates towards the end of the pond.



a Water storage mode



b Drainage mode

Figure 2. Horizontal movement of soil salt

4. Conclusion

The horizontal migration of soil salinity in the water storage mode is mainly the interannual circular migration from the far end of the pool to the end of the near pool and then to the end of the far pool. The horizontal migration of soil salt in the drainage mode is mainly the single movement from the end of the far pool to the end of the near pool. Migrate towards the two ends, superimposing a small amount of the middle part to move towards both ends. The reason for this result may be that the soil background value, irrigation amount, and crop planting amount of the water storage mode and the drainage mode are consistent. That is, the downward movement of soil salt in the theoretical state is consistent with the drainage mode. The difference in the upward migration of salinity due to water supply (storage and drainage) is neglected because it is relatively weak. The movement of salt in the horizontal direction mainly depends on the lateral movement of water-soil flow [8,9]. Soil flow refers to the lateral flow of water at the interface of the soil surface or layered soil, which mainly occurs at the discontinuous interface of different layers of soil or organic matter. When the infiltration capacity of the lower soil is less than that of the upper soil, the infiltration water flow is blocked and accumulated on the interface, forming a saturated zone and lateral hydraulic slope, and the infiltration water flow is blocked and accumulated on the discontinuous interface to form a temporary saturated zone and a soil flow occurs. Under the condition of water storage, due to the existence of the reservoir, the potential energy of the soil flow generated by irrigation or precipitation is mainly a unidirectional flow from the far end of the pond to the near end of the pond. However, when no external water enters the test area, the soil The body moisture is gradually reduced by evaporation and crop absorption, and the water in the reservoir gradually enters the lower layer of the soil to produce a countercurrent flow. In this way, in the irrigation runoff and the soil near the end of the reservoir, evaporation, the water in the reservoir will flow into the soil. Under the action of soil flow, a cyclic system is formed, which drives the interannual circulation of the salinity from the far pool end to the near pool end and then to the far pool end, which is consistent with the research theory of Feng Chen et al. [10]. Under drainage conditions, the potential energy of soil flow generated by irrigation or precipitation is mainly a unidirectional flow from the far end of the pond to the end of the inlet pond. Due to timely drainage, there is no reverse flow from the pond to the soil. Therefore, the salt transport is mainly The one-way movement from the far end of the pool to the near end is the main one.

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