Remodeling soil structure and efficient desalting saline-sodic land management technology model

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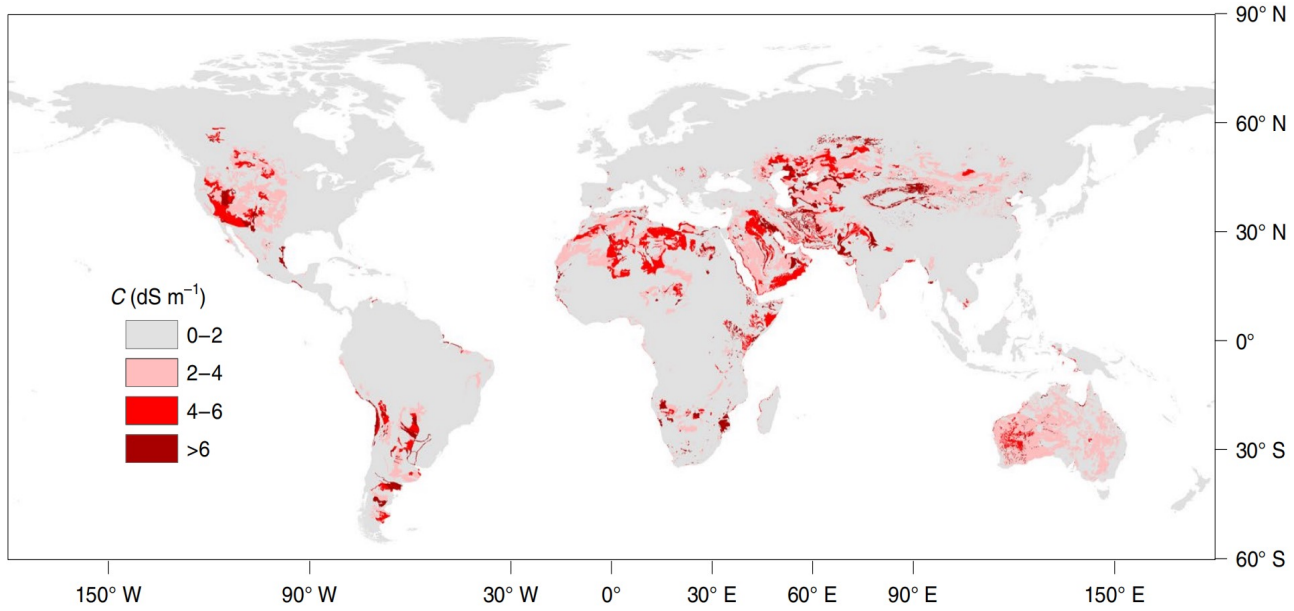
1. Background

- Soil salinity and sodicity are global issues, increasing at a rate of 1-2% annually
- Saline-sodic soils impact over 1,000 million hectares of land worldwide
- Soil salinization has become one of the major environmental and socioeconomic issues globally, which would be further exacerbated with climatic change

Distribution of saline-alkali land in the world



There are four typical types:

(1) Sodic soil, which is mainly composed of Na_2CO_3 and $NaHCO_3$

(2) **Coastal saline soil**, primarily containing NaCl

(3) **Mixed saline alkali soil**, with major components including NaCl, Na_2SO_4 and Na_2CO_3

(4) **Secondary salinization soil**, primarily made up of NaCl, Na_2SO_4 and $NaHCO_3$

Current saline-alkali soil remediation technology

Physical remediation

Hidden pipe salt, guest soil, lift the field, tectorial technology, straw cover

↓

Reduce the salt concentration in the topsoil layer

Chemical remediation

Organic acid, gypsum, aluminum sulfate, biochar, furfural residue, polymer

↓

Remove the Na^+ and desalinate

Plant remediation

Salt-tolerant crops: cotton, sunflower, rice, sugar beet, grass, etc

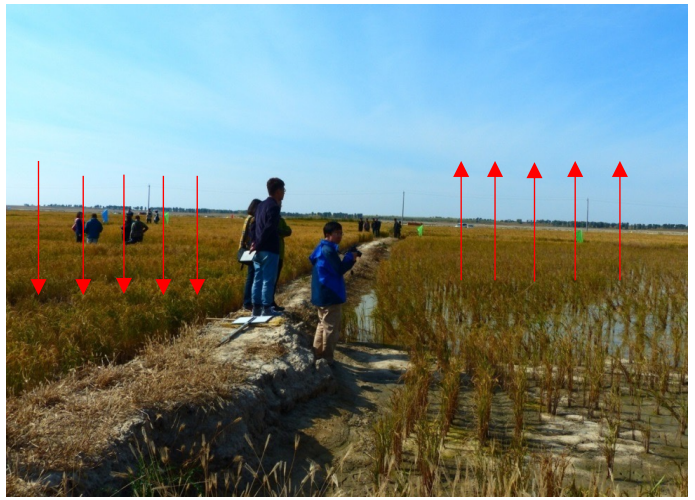
↓

Enrich salt and improve structure

Saline alkali areas generally suffer from water scarcity, and the key to effective management lies in the scientific use of water; **However, the management of saline-alkali land is an extremely complex systems engineering challenge and cannot be effectively addressed by just one or two technologies!**

Difficulties in saline-alkali land improvement

1. The soil exhibits poor structure, sticky
2. High salt content, high osmotic pressure
3. Low content of nutrient elements
4. **The low desalting efficiency caused by slow water infiltration rate is the most restricting factor**
5. **How to reduce surface water evaporation and improve soil permeability???**



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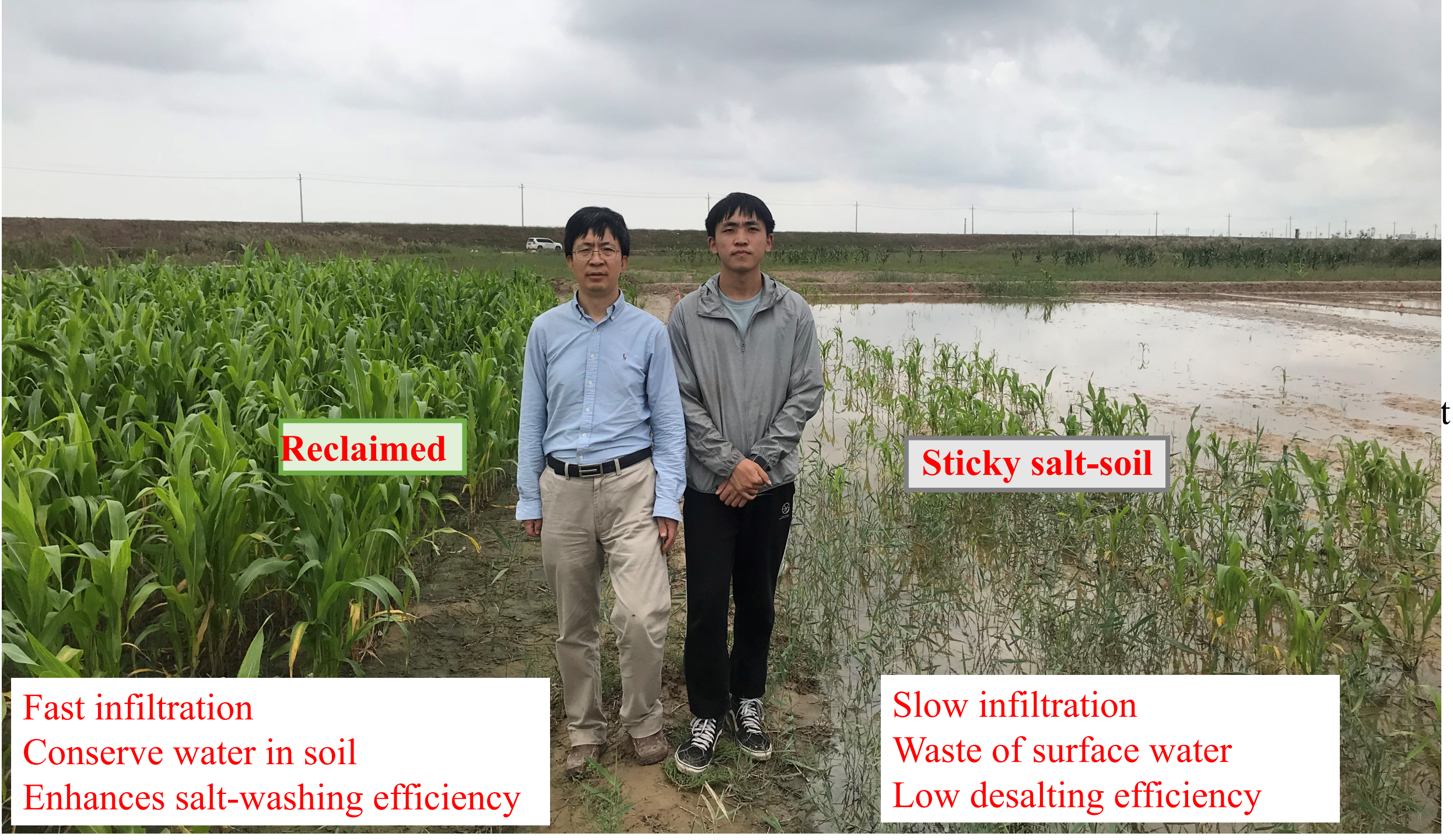
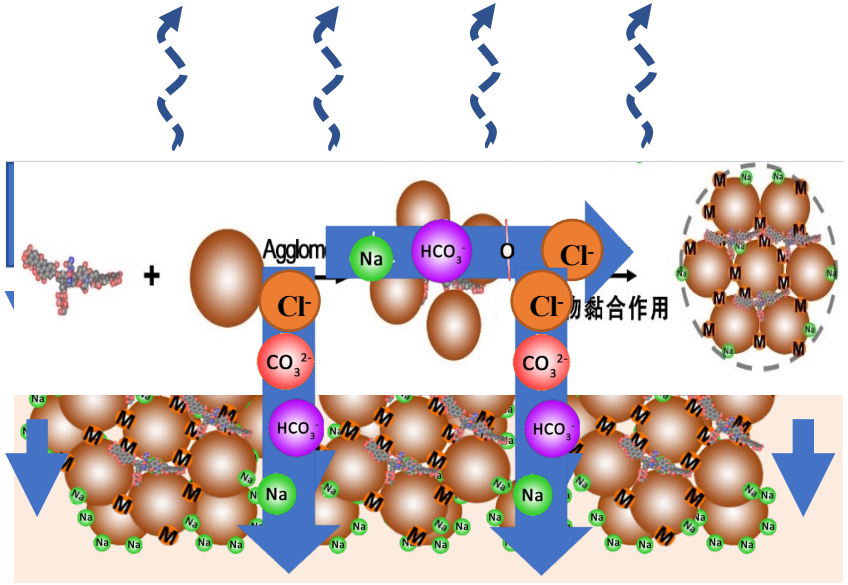
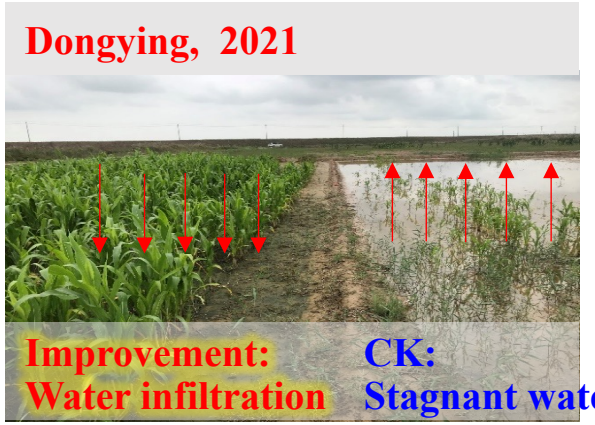
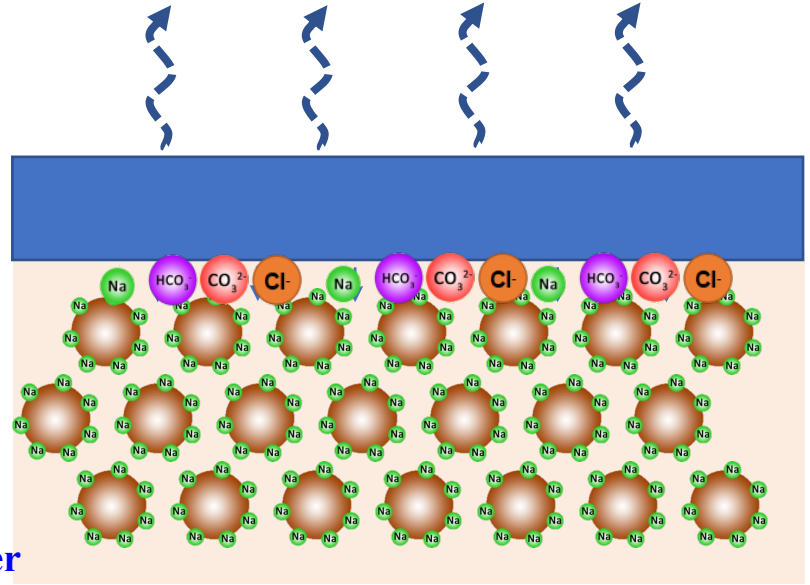

Reclaimed
Sticky salt-soil
Fast infiltration
Conserve water in soil
Enhances salt-washing efficiency
Slow infiltration
Waste of surface water
Low desalting efficiency

A series of new bio-based modified soil amendments have been developed to greatly improve the efficiency of desalting



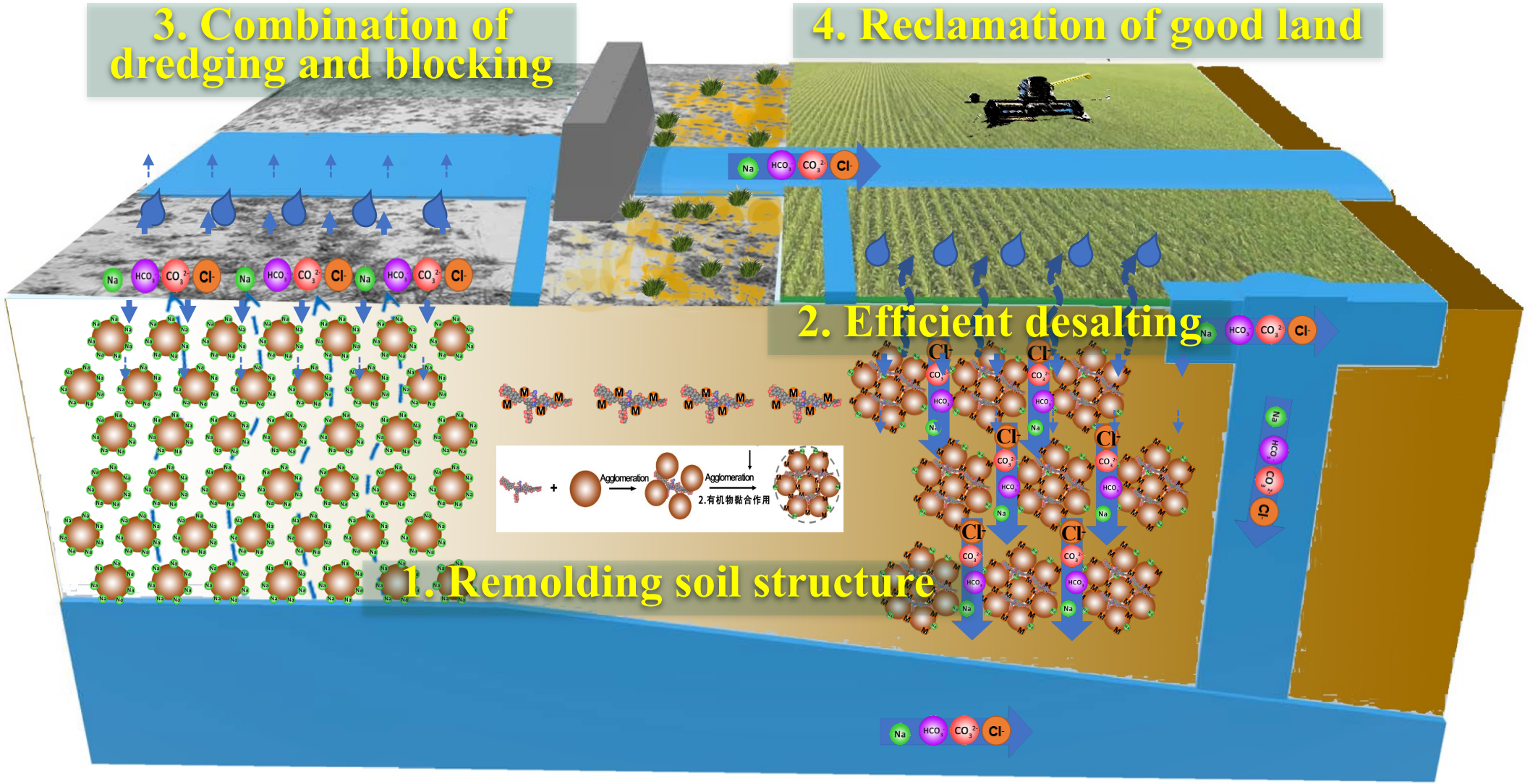




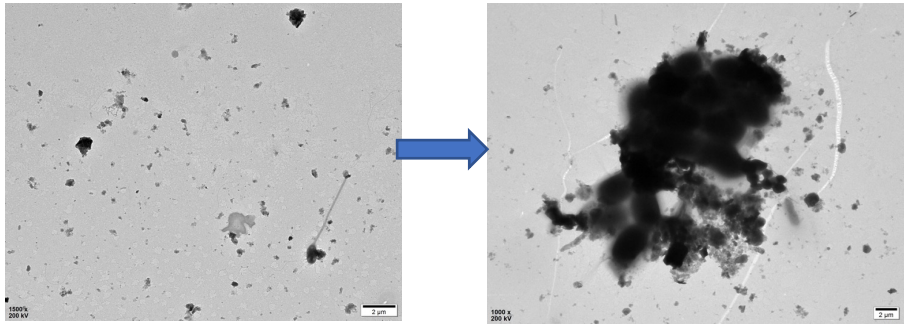
Soil aggregate was formed by the novel amendments, increased soil porosity, and improved the efficiency of salt washing by more than tenfold

Na^+ content is high, soil structure is poor, sticky, slow infiltration, salt is difficult to remove with water

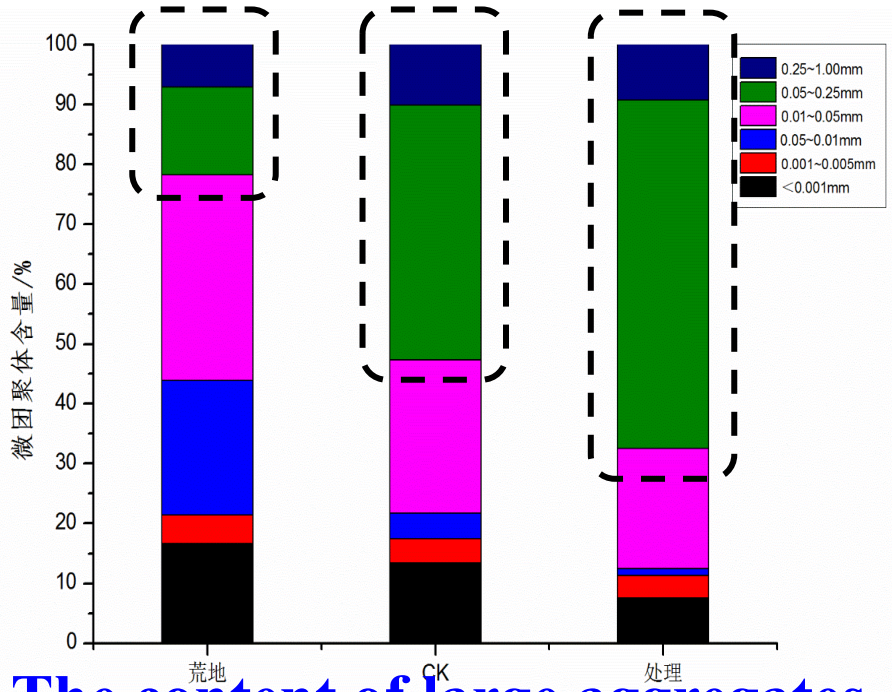
The system improvement of saline-alkali land includes: “Remolding the soil, efficient desalting, a combination of dredging and blocking, and reclamation of fertile land”



Soil structure remodeling → Soil permeability increases → Alkalinity and salinity decrease

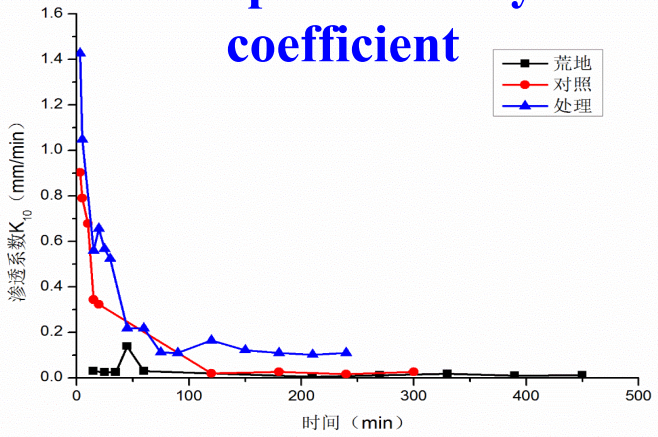


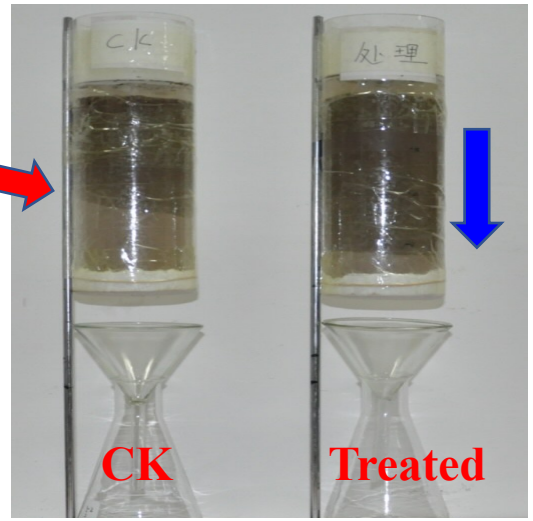
Soil colloid flocculation



The content of large aggregates increased

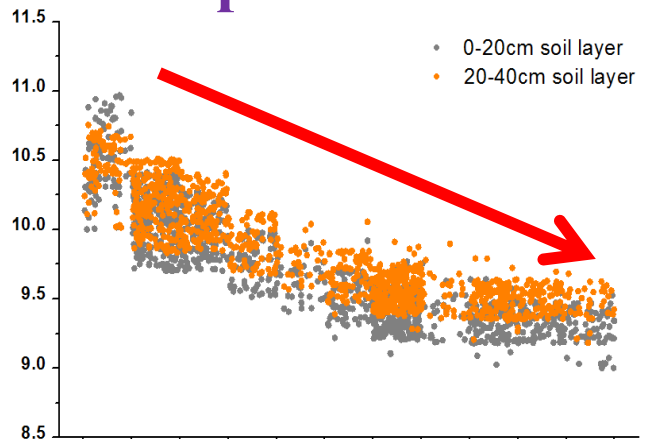
Soil permeability coefficient

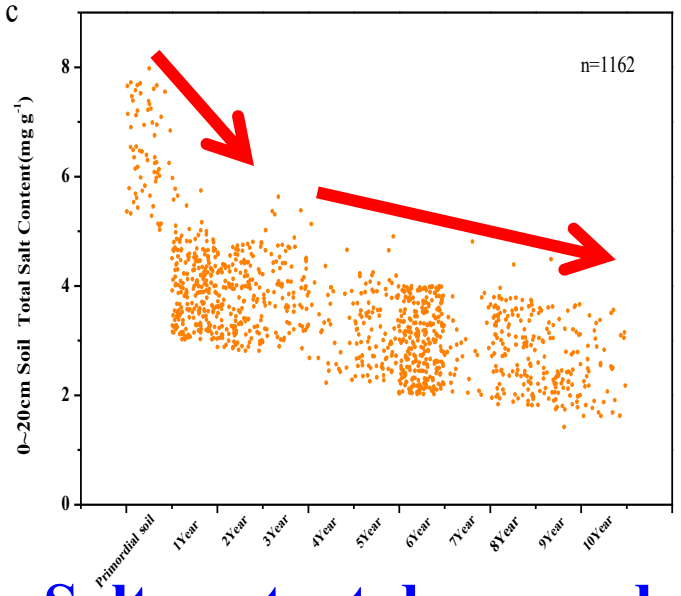




Infiltration rate increased

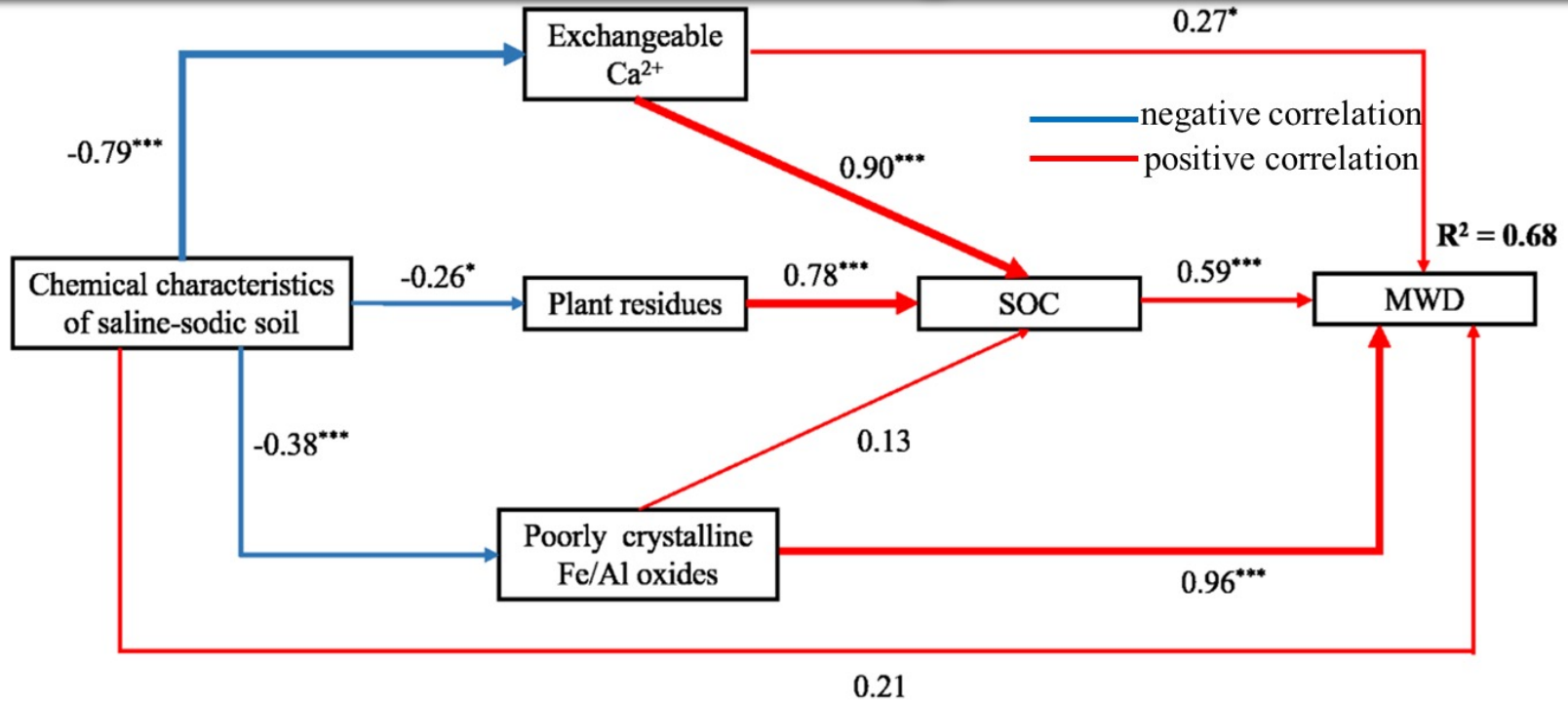
Soil pH decreased





Salt content decreased

Mechanism of aggregate formation and stability based on the "remodeling soil structure" improvement model



Feng, Land Degr. Dev., 2021

The formation of saline-alkali soil aggregates can be divided into two stages:

(1) **Exchangeable Ca^{2+}**, **amorphous Fe-Al oxide** and **organic matter** are factors that promote the formation of soil aggregates

(2) **Soil microbial exudates** enhance the formation of highly stable water-stable macroaggregates.

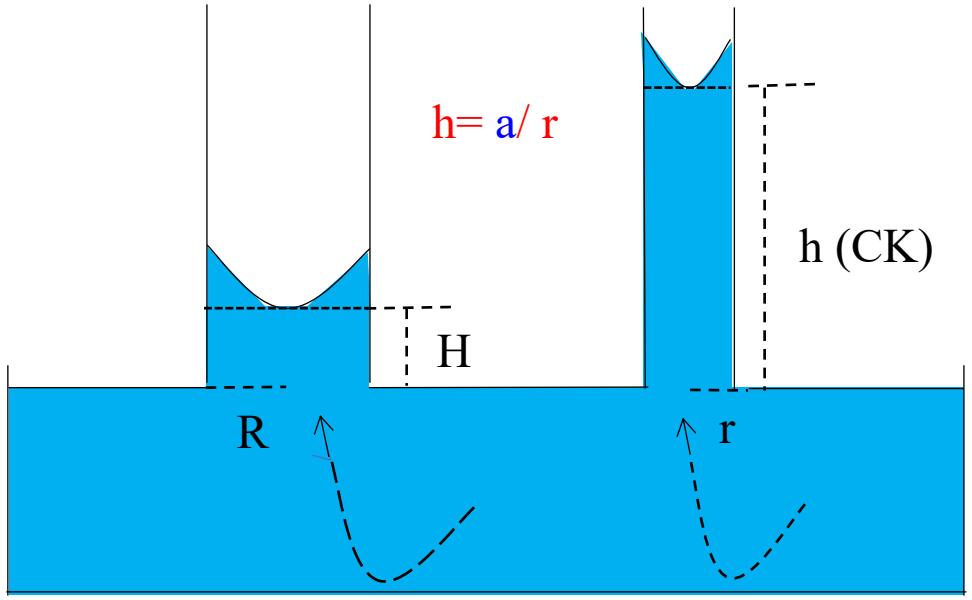
Comprehensive method to suppress soil salt return

Salt return rate under different treatments

Treatment	Base liquid change /mL	Water absorption rate /mL h^{-1}	Total salt accumulation /g kg^{-1}	Salt accumulation rate g kg^{-1} d^{-1}
Waste land	1395	3.63	*9.01*	0.56
Other technique	1830	4.77	8.93	0.56
Our reclamation	1850	4.82	5.56	0.35

1. Larger diameter, lessened capillary effect
2. Returned straw, root residues neutralization
3. Controlled the groundwater level

Soil capillary effect



$RCOOH+Na_2CO_3 \rightarrow RCOONa+NaHCO_3$

$RCOOH+NaHCO_3 \rightarrow RCOONa+CO_2+H_2O$

Wang, J. Agr. Sci. Agrotech, 2022

Response of soils microorganism to saline-sodic soils under long-term rice-based cropping system: increased diversity and abundance

Rebuild microbiological community

Ammonia-oxidizing archaea (Nitrososphaera)

↓ 1-2 years

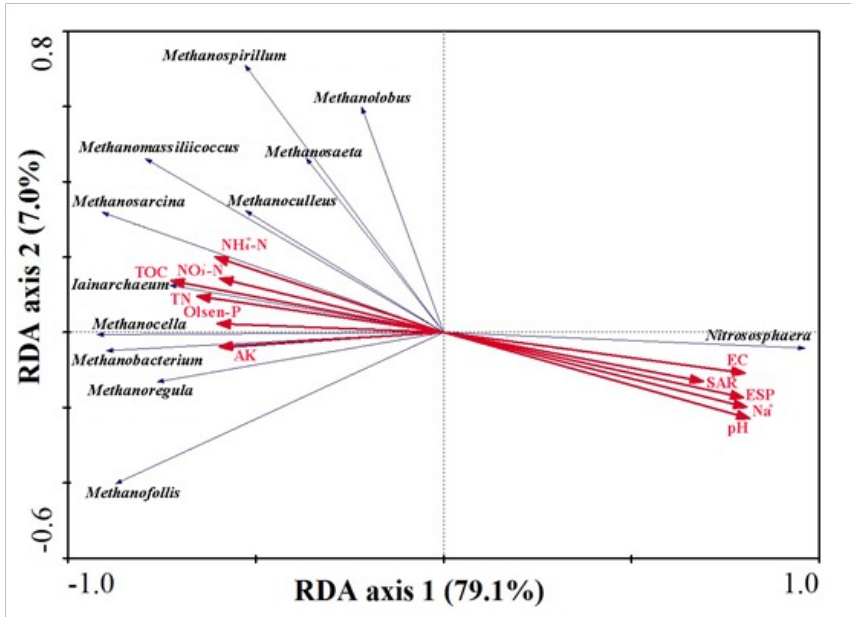
Anaerobic methanogenic archaea

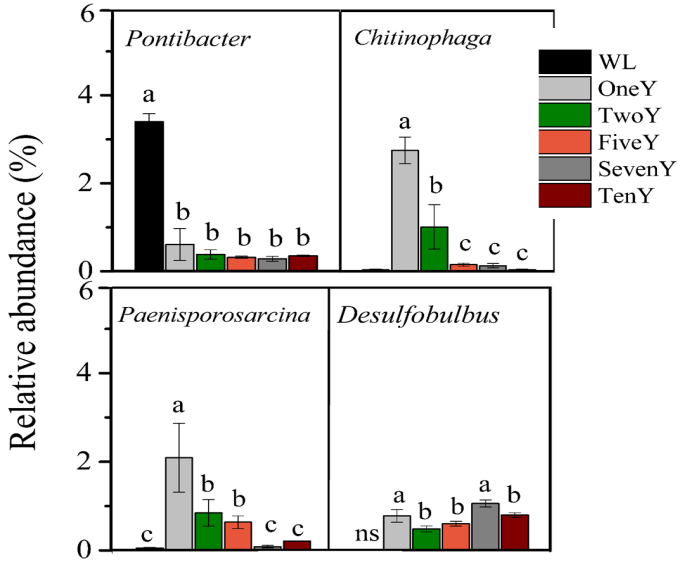
↓ 3-5 years

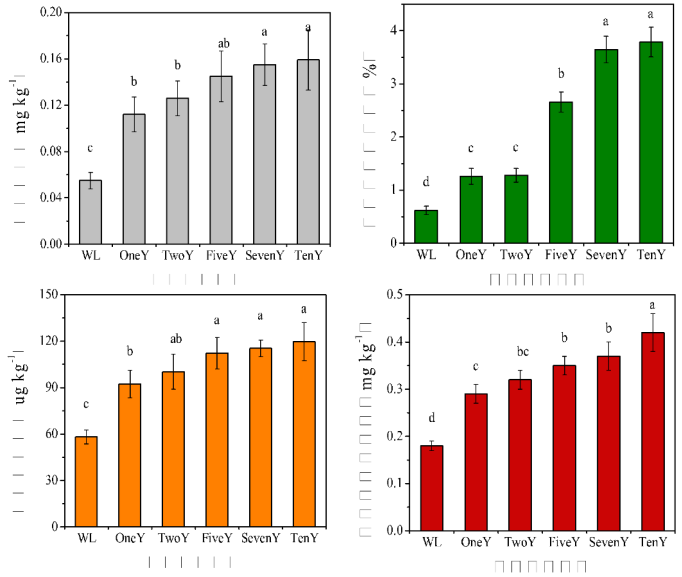
Aerobic archaea

↓ 6-10 years

Methanogenic archaea became stable



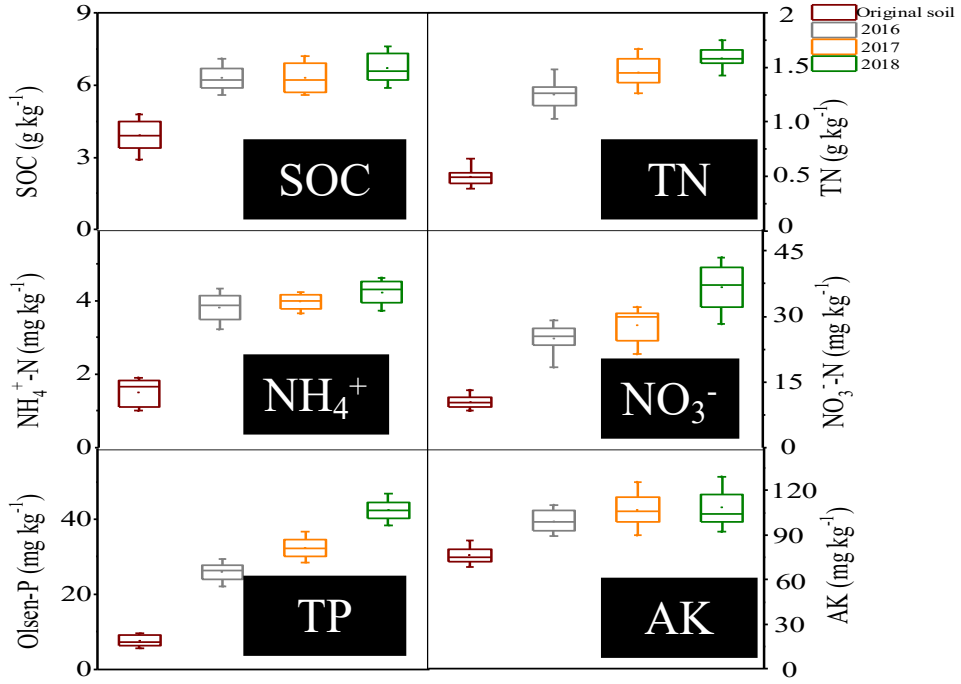


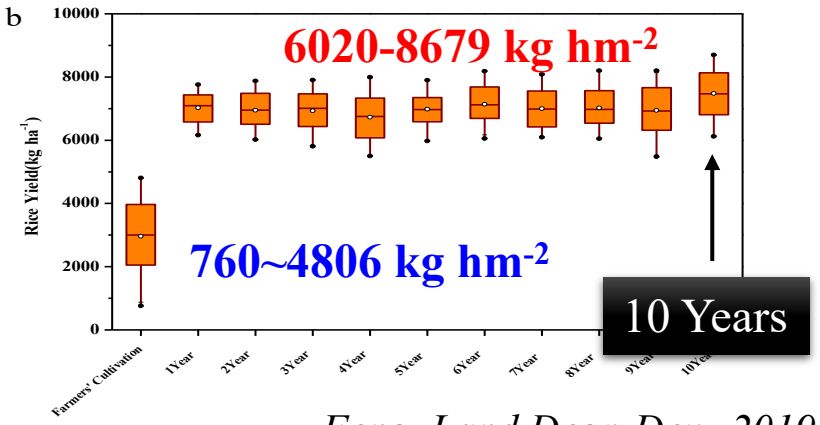


1. **Within the span of 1-5 years, the rates of soil carbon sequestration, cellulose decomposition, sulfur conversion, and humus decomposition continued to increase**
2. **After 5 years**, the increase has **stabilized**

Du, Arch. Agron. & Soil Sci., 2021

With just a single reclamation effort, soil productivity was restored





Feng, Land Degr. Dev., 2019

Du, Geoderma Regional, 2022

With the extension of the improvement time, soil nutrients, crop yield and the thickness of the soil ripening layer increased, and the effect of ripening the tillage layer was realized

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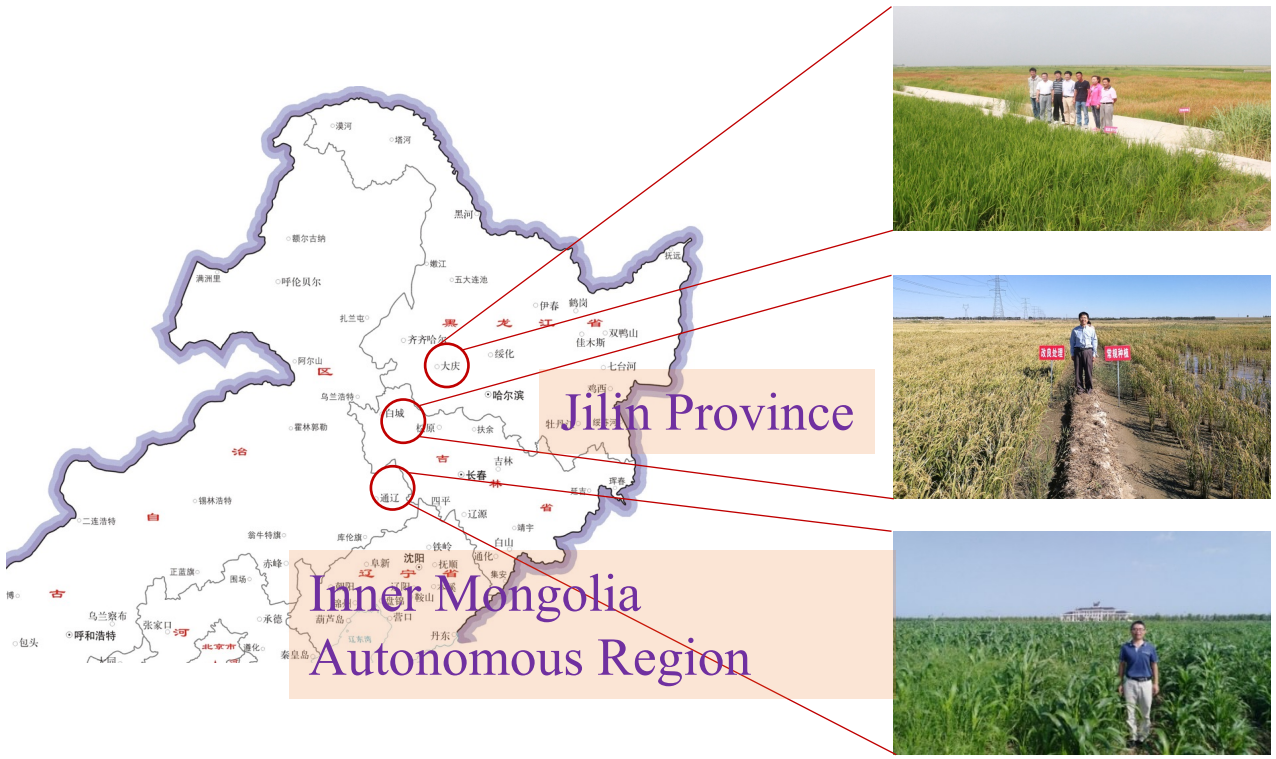
3. Demonstration Sites

- 133 test sites
- 315 soil profiles
- 100 plots fields
- 32,245 soil samples
- create database
- 36 demonstration bases

(1) Restoration of northeast songnen plains –sodic (mainly Na_2CO_3) type soils



Problem

Poor soil structure, sticky

Low water permeability

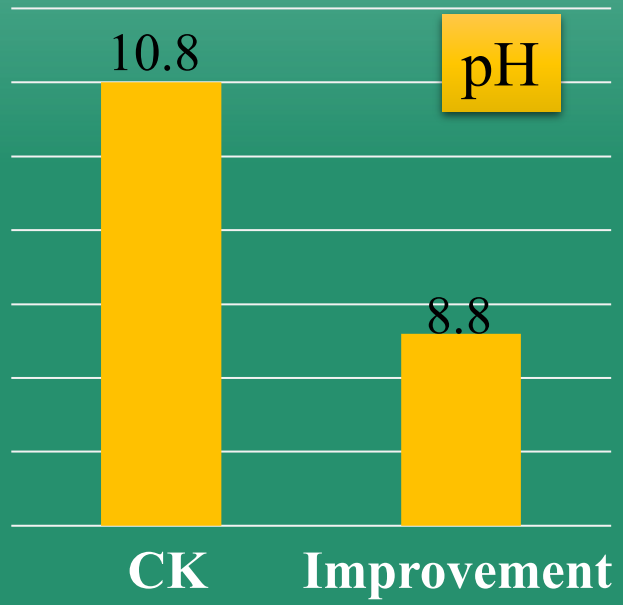
Surface salt removal is difficult

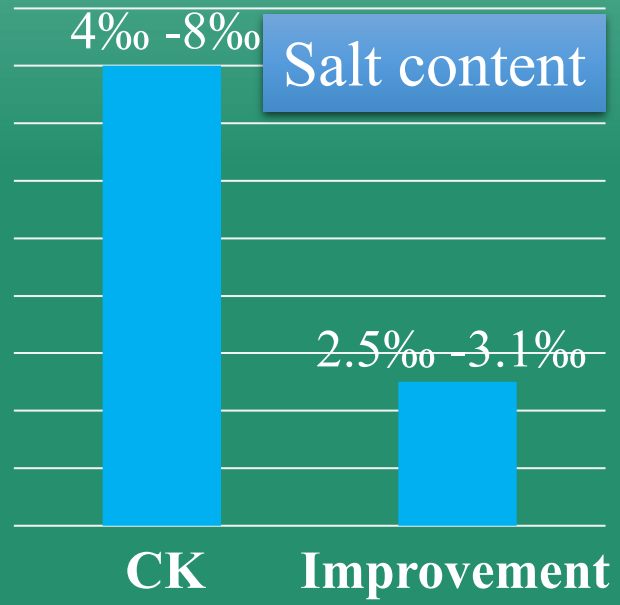
Crops are hard to grow

Strategy

Reshaping soil structure and removing soil salt quickly to achieve normal crop growth

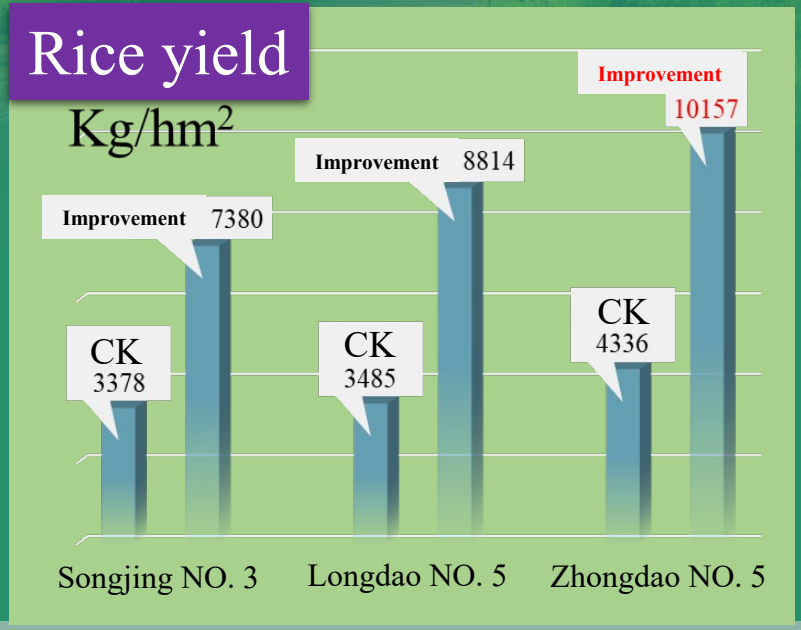
Typical case 1: Severe saline-alkali land reclamation project in Songyuan, Jilin Province

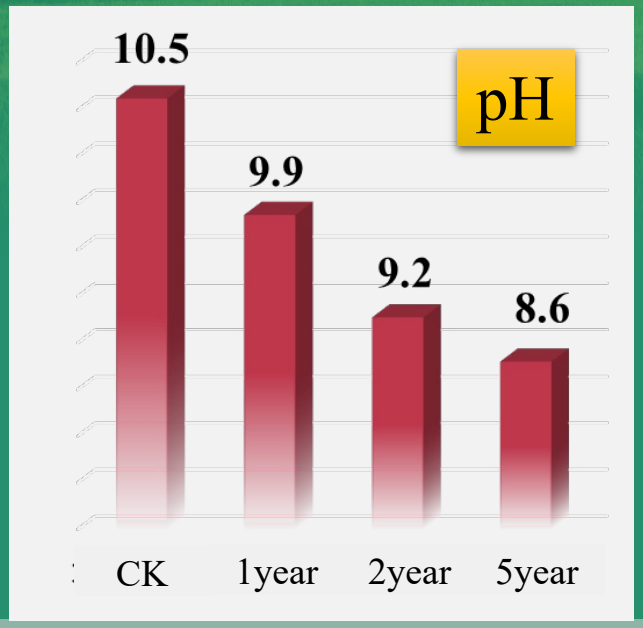


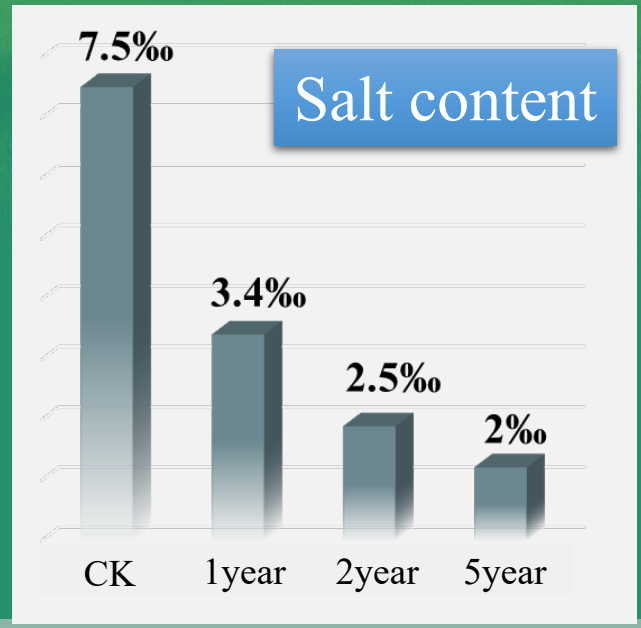


100 hectares of extremely sticky saline-alkali land were transformed into fertile land, with high yields achieved in the same year of reclamation

Typical case 2: Restoration of 300 hectares of extremely heavy saline-alkali wasteland in Da'an, Jilin Province

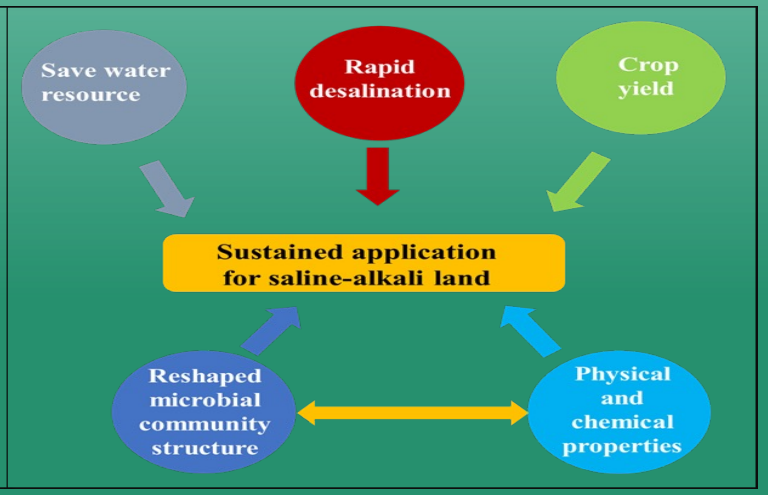






With just a year of reclamation, up to 8 years of stable, high yields were achieved

Typical case 3: Ecological restoration saline-alkali land with “rotate paddy field into upland model” in Daqing, Heilongjiang



To enhance water resource utilization, we created the "rotate paddy field into upland model." It involves reclaiming the land as a rice field for 1-2 years, swiftly removing salt from the topsoil, and subsequently transitioning the field to upland use

(2) Restoration of the eastern coastal - saline soils (mainly NaCl)

Dongying
Shandong Province

Hebei Province,
Tianjin, etc

Yancheng, Jiangsu

Problem

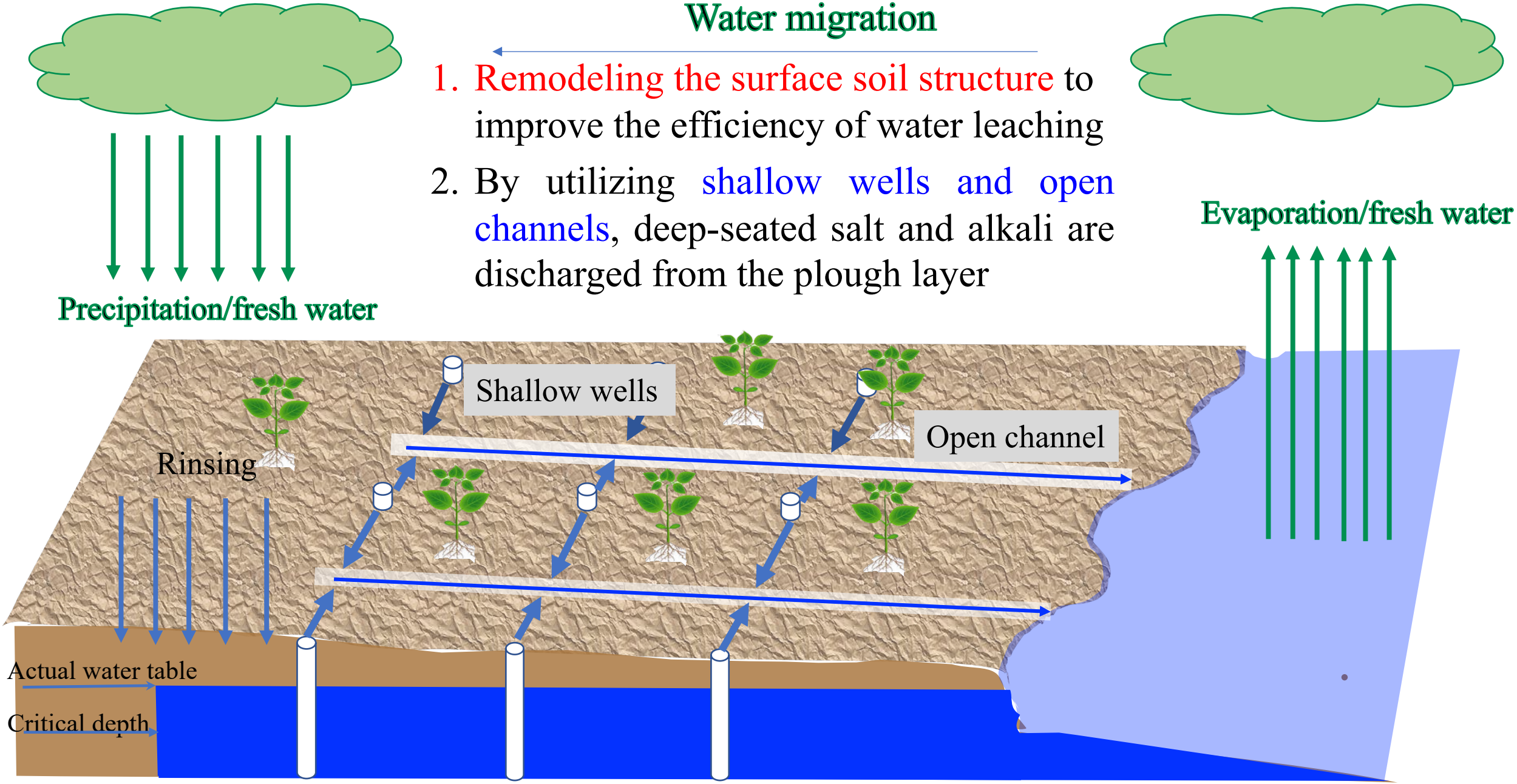
1. The water table is shallow and prone to seawater erosion
2. Saline-alkali soil has a poor structure and low water permeability

Strategy

1. Build embankments and gates to control the water table and prevent salt return (Step 1)
2. Reshape soil structure and enhance soil permeability (Step 2)

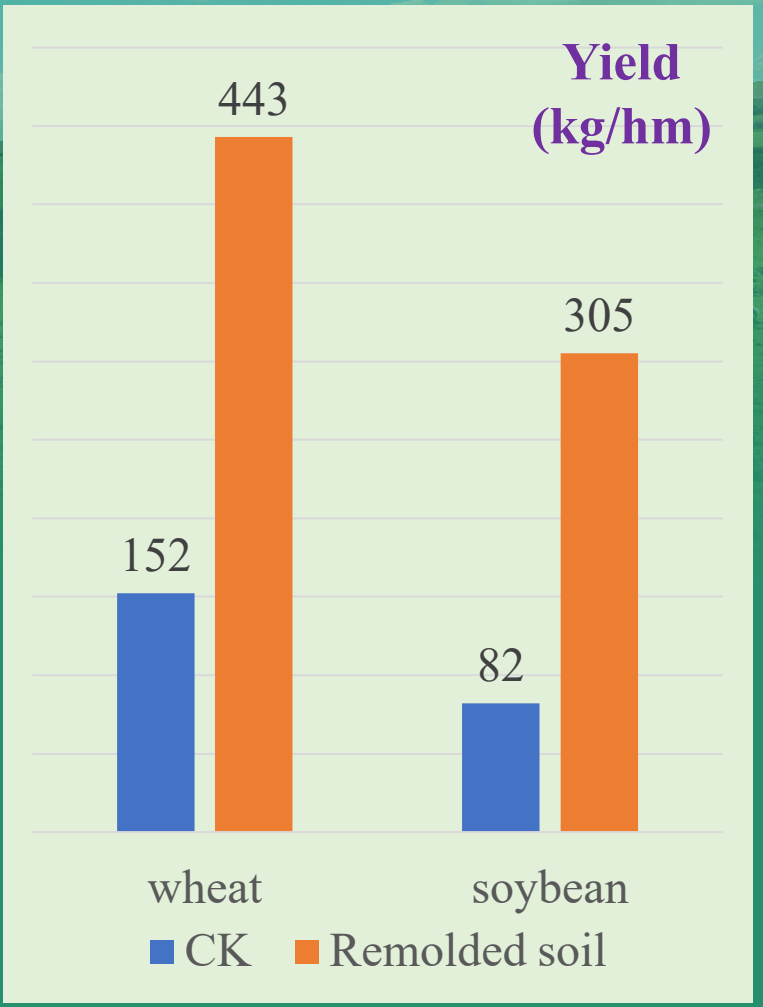
Water migration

1. Remodeling the surface soil structure to improve the efficiency of water leaching
2. By utilizing shallow wells and open channels, deep-seated salt and alkali are discharged from the plough layer

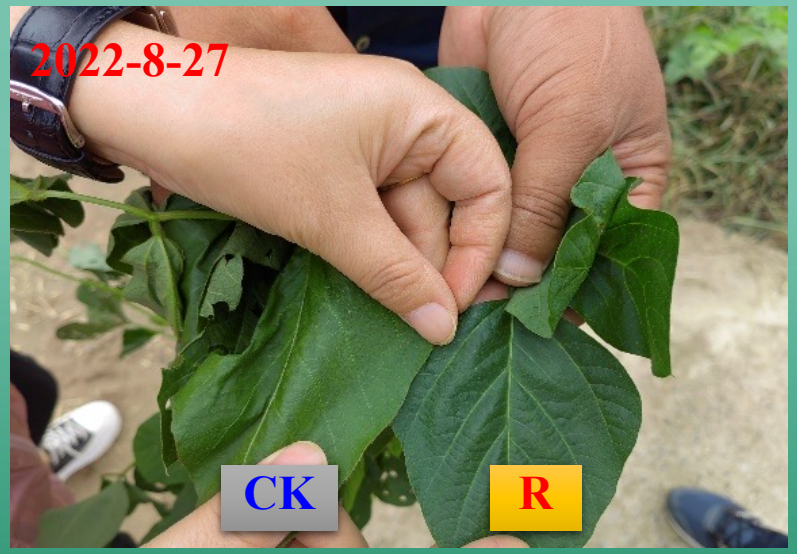


Typical case 1: Wheat/soybean planting in saline soil of Dongying, Shandong

Only one year reclamation, up to five season of stable high yield for both wheat and soybeans

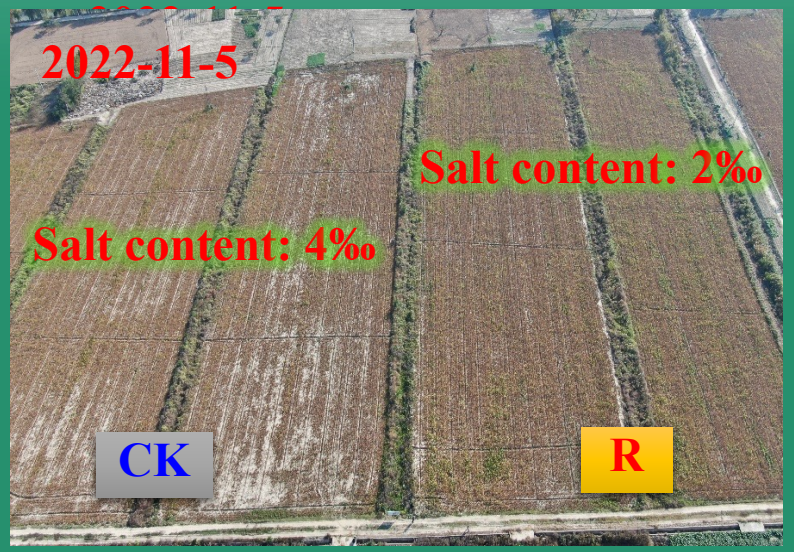


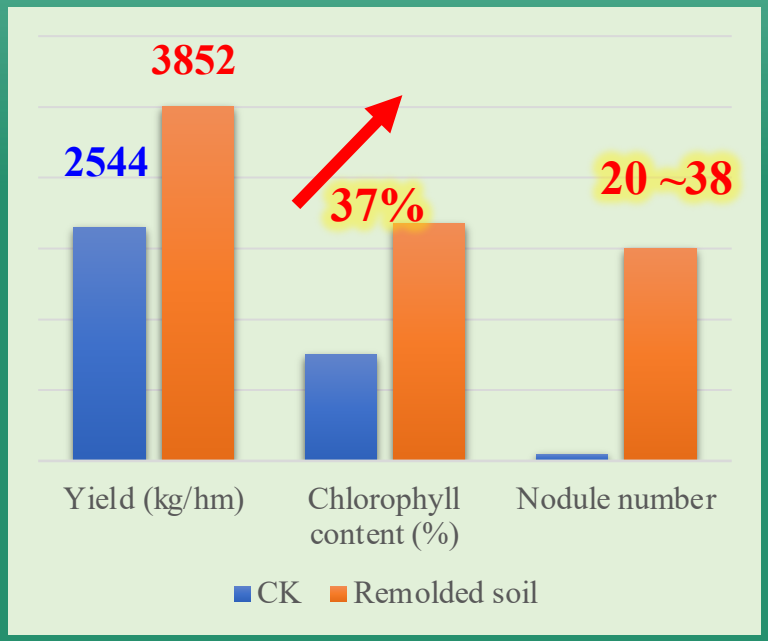
Typical case 2: Experimental demonstration of soybean yield increase in saline cultivated land in Yancheng, Jiangsu Province



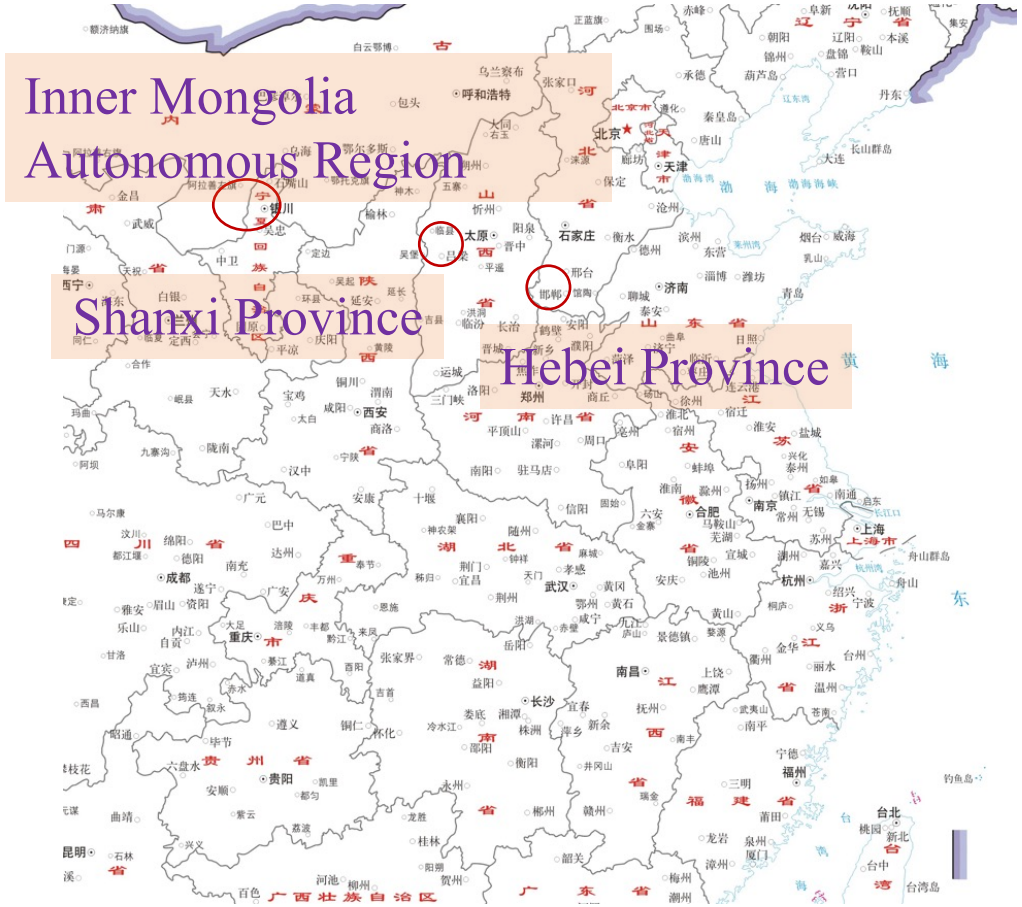
The yield of soybean in improved field increased by 51.4%

The number of every root nodules generally ranged between 20 and 38, while the soybean in control field had no root nodules





(3) Restoration of mixed saline-sodic type soils (mainly NaCl, Na_2SO_4 and Na_2CO_3)



Problem

1. Irrigation with mineralized water leads to salinization
2. Channel leakage raises the water table, resulting in saline soil zones

Strategy

1. Set up irrigation and drainage system, control the water table
2. Remolding soil structure and water saving drip irrigation

Typical case 1: The saline-alkali desertification land in Tongliao, Inner Mongolia turned into high-quality grassland after soil improvement

With just a year of reclamation, up to 7 years of stable high yield were achieved under rain-fed condition

2017-1-12

2017-6-19

2018-8-2

2019-7-31

2020-7-18

2021-7-19

2022-7-13

Classic Case 2: Ecological restoration of saline land in Bayannur, Inner Mongolia, with only 1 year reclamation, up to 7 years of stable high yield

After reclamation, the yield of sunflower was increased by 132%

Since then, the local rain-fed conditions have been used for continuous planting, and the soil index continues to improve, becoming an ecological fertile field

Classic case 3: Xinjiang Bazhou improved saline-alkali land to grow cotton

Remodeling soil and water saving drip irrigation of water soluble conditioner, the cotton grew well

(4) Restoration of secondary salinization

Classic case 1: In the restoration of secondary salinization sticky soil, the waterlogging resistance of chili peppers was improved

Heavy rain caused **waterlogging** and death of chili peppers in unimproved secondary salinization soil, while those in improved soil experienced no water accumulation and grew well

Classic case 2: Solving of “peach chlorisis” caused by Fe fixation in saline alkali soil in Dangshan, Anhui Province

We addressed the problem of "peach chlorosis" caused by Fe fixation in saline alkali soil

After reclamation, the salt content in the soil decreased by 72%, iron was activated, and the improved peach chlorophyll increased by 51.1%, the yield increased by 23%

Conclusions

- We have created the systemic technical model of "**reshaping soil, efficient desalting, combining dredging and cultivating good farmland**" for ecological restoration of saline-alkali land.
- **(1) A series of new bio-based soil amendments have been developed, which can promote the formation of soil aggregate structure, increase soil permeability, and greatly improve the infiltration and desalination efficiency.**
- (2) **Adopt the "combination of dredging and blocking" strategy was adopted to manage groundwater, prevent brine evapotranspiration, and export regional salt.**
- Experiments and demonstrations on various types of salt and alkali have been conducted over many years in saline-alkali areas. The results showed that **soil salt and alkali content decreased and soil structure improved year by year. Crops achieved higher yields after only one year's restoration.**
- **Under continuous farming conditions, the yield and biomass increased year by year, and the restoration effect was very stable in all regions without recurrence.**


Let’s work together, make a
beautiful and sustainable world!
Thanks!
Before