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Coupled Effects of Halophytes and Soil Texture on Water and Salt Movement in Unsaturated Saline Soils

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Outline

1. Research background and the significance

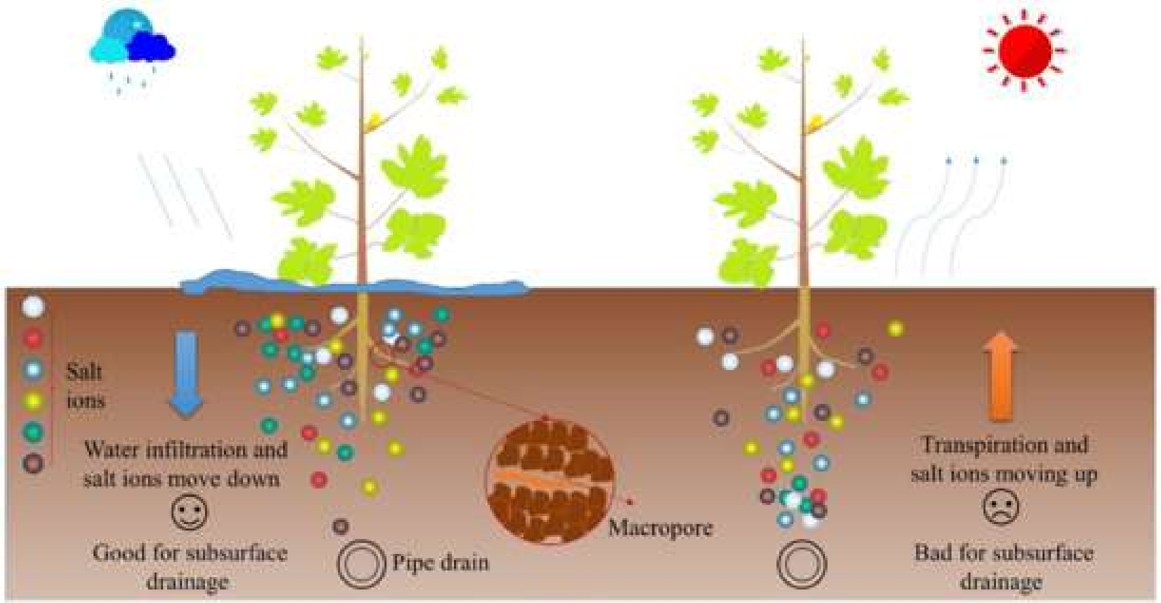
Soil salinity is a global ecological and socioeconomic problem.

Representing countries worldwide with salinity problems
(Shahid et.,al 2018)

- **High salt concentrations in soil due to evaporation, transpiration, and unreasonable human activities.**
- **Impacts 831 million ha of land worldwide (FAO 2016).**
- **Costs over $25 billion annually (Qadir et al., 2014).**
- **Breaks plants and lowers agriculture, degrading land (Qadir et al., 2014), causing famine and poverty.**

1. Research background and the significance

The movement of soluble salts in the soil profile is an important process for soil salt accumulation. Understanding this process is the first prerequisite for improving saline land.



Precipitation, evaporation, transpiration, and soil permeability affect the salt movement in saline soil *(Fang et al., 2022)*

- **Convection, upwelling water from evaporation and transpiration, diffusion, and the flow barrier affect salt getting to the soil surface.**
- **Soil texture and hydraulic properties affect water-salt retention, flow, and drainage.**

1. Research background and the significance

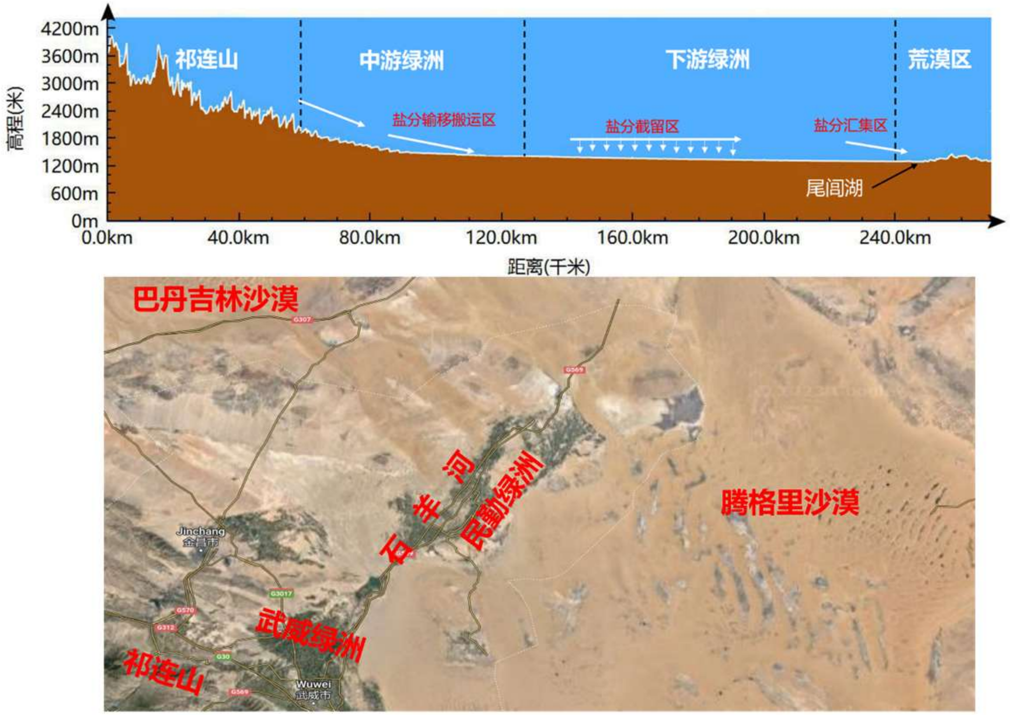
Halophytes are extensively used to improve salt-affected land by affecting soluble salt transport and accumulation.

Halophytes species planted in salt affect soil
(Kearl et al.,2019)

- **Halophytes can survive in salt-contaminated environments and tolerate salinity concentrations of more than >1M of NaCl.**
- **In Chile, A. Nummularia found to increase hydraulic conductivity and reduced bulk density (Silva et al.,2016)**
- **S. salsa reclaimed saline soil in northwest China, with a salt extraction potential of 3.75 to 3.91 T ha-1 year-1 (Wang et al.,2020).**

1. Research background and the significance

Minqin Oasis is a typical region affected severely by salinization and owns many kinds of unused Halophytes. Improve and use the salt-affected land needs understanding the coupled effects of halophytes and soil texture on water and salt movement in soils.

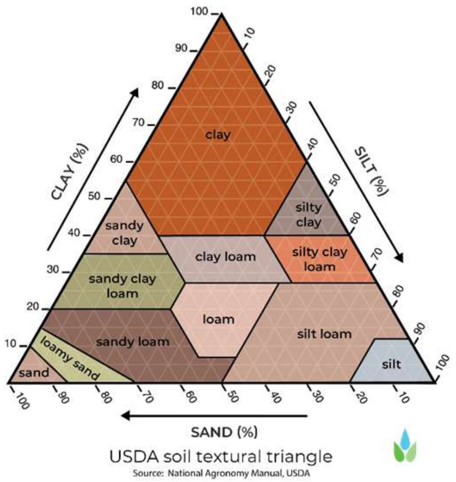


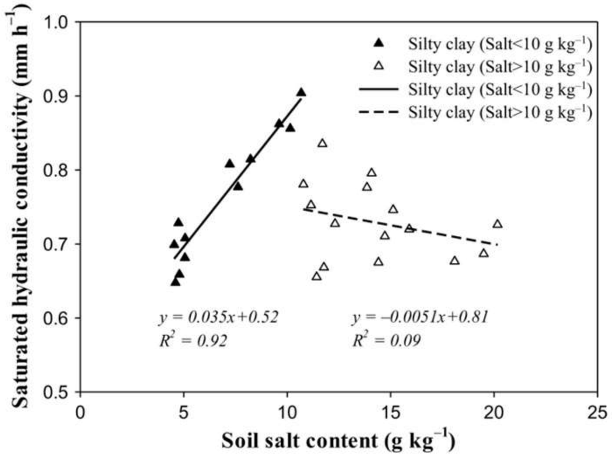
Water and salt movement
in the watershed scale of the Shiyang River

Native Halophytes in the salt-affected land
of the north Minqin Oasis

2. Literatures review

The effect of soil texture on water-salt movement in the saline soil.





(Tang et al., 2021)

Saturated hydraulic conductivity for different soil salinities of the silty clay samples

Hydraulic characters of different textures saturated soil

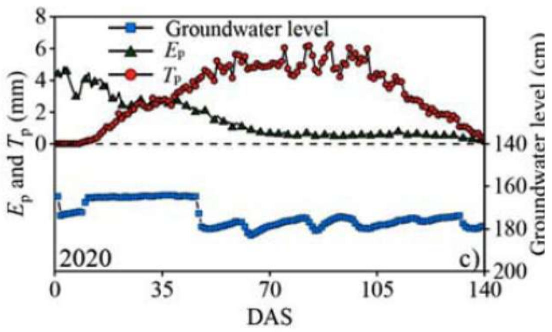
Soil Texture	$\overline{b}$	$\overline{\psi_s}$	$\overline{\theta_s}$	$\overline{K_s}$
Sand	4.05	12.2	0.395	1520.64
Loamy sand	4.38	9.0	0.410	1350.72
Sandy loam	4.90	21.8	0.435	299.52
Silt loam	5.3	78.6	0.485	62.21
Loam	5.39	47.8	0.451	60.05
Sandy clay loam	7.12	29.9	0.420	54.43
Silty clay loam	7.75	35.6	0.477	14.69
Clay loam	8.52	63.0	0.476	21.17
Sandy clay	10.4	15.3	0.426	18.72
Silty clay	10.4	49.0	0.492	8.93
Clay	11.4	40.5	0.482	11.09

https://docs.vandersat.com/data_products/soil_water_content/soil_water_content.html

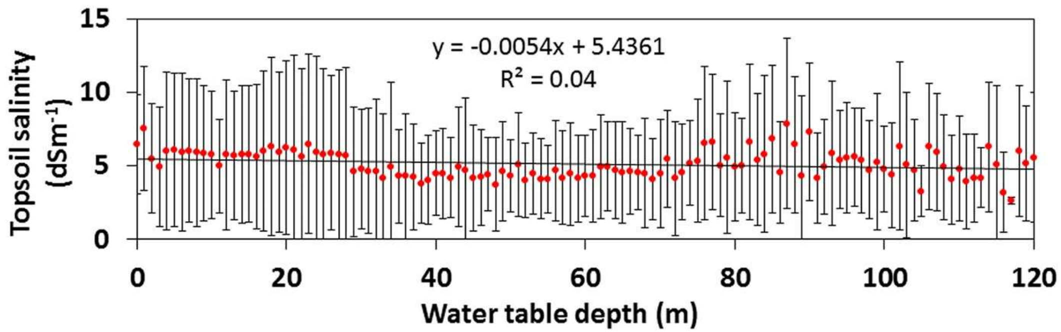
- **Soils with high permeability may cause salts to wash away more than soils with low permeability, which causes salts to accumulate.**
- **Clay soils with a fine texture may hold more salt than sandy soil, causing salt accumulation.**
- **However, salt content plays an uncertain influence in the migration process.**

2. Literatures review

The effect of groundwater table on water-salt movement in the saline soil.

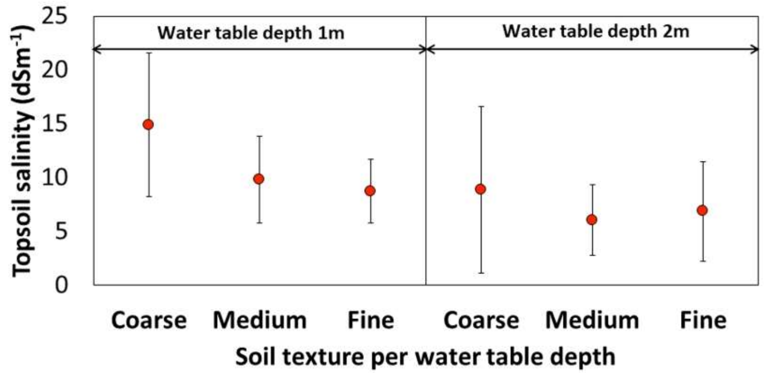


Evaporation, transpiration, and groundwater table during the crop growing season *Zhang et al., 2023*



The average topsoil (0–30 cm) salinity obtained from the model *Salomé et al., 2020*

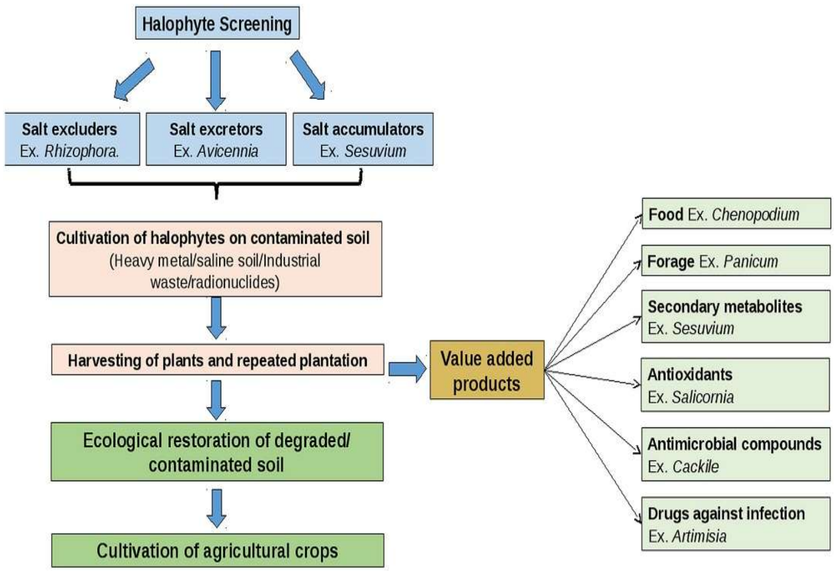
- **The distance between the groundwater table and the soil surface affects capillary rise under evaporation and transpiration.**
- **Deeper groundwater tables allow for better leaching of excess salts downward, preventing salt buildup in the root zone.**
- **However, soil texture and plants bring uncertain influence.**



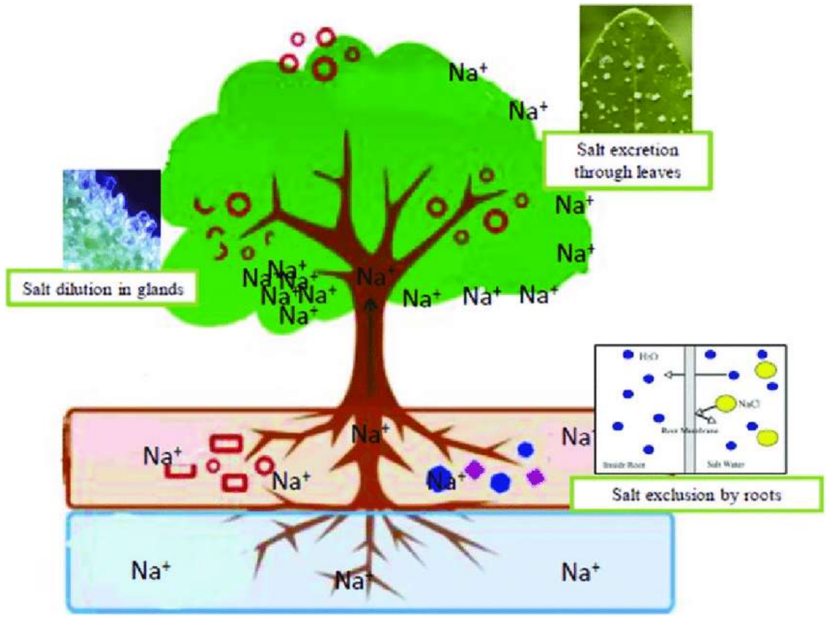
The average topsoil salinity (0–30 cm) as a function of soil texture under water table depths of 1 and 2 m

2. Literatures review

The effect of halophytes on water-salt movement in the saline soil.



A wide range of applications of major halophytes, *(Nikalje et al., 2017)*

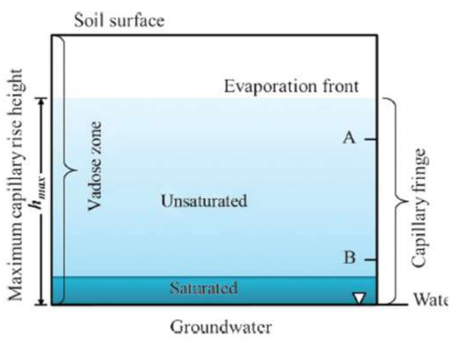


Salt movement in soil and plant system *Banyal et. ,2019*

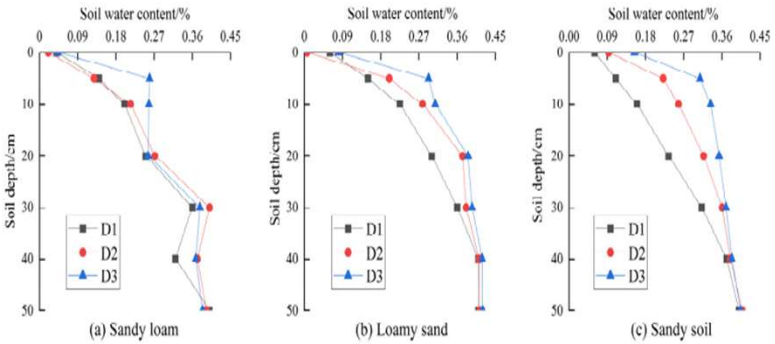
- **Halophytes affect saline soil in different mechanisms such as salt exclusion, salt dilution and salt excretion, However, these mechanisms varied with halophytes and soil type is still elusive.**

2. Literatures review

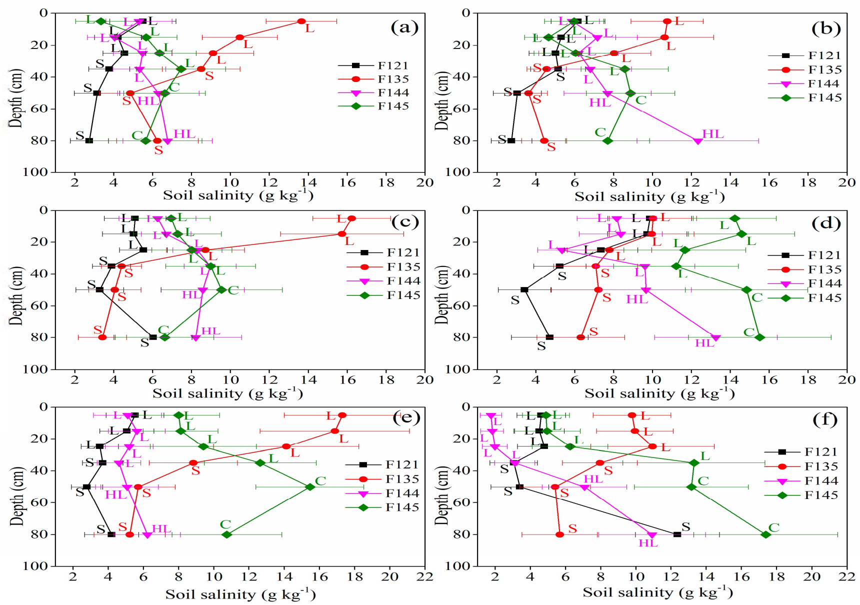
The relationship among *soil texture*, *groundwater table*, and *halophytes shrubs* and *their combined effect* on water-salt movement in the saline soil, but lack of research.



A soil profile with the presence of a water table *(Li et al.,2013)*



Distribution characteristics of water in different textured soils,(Wang et al.,2023)

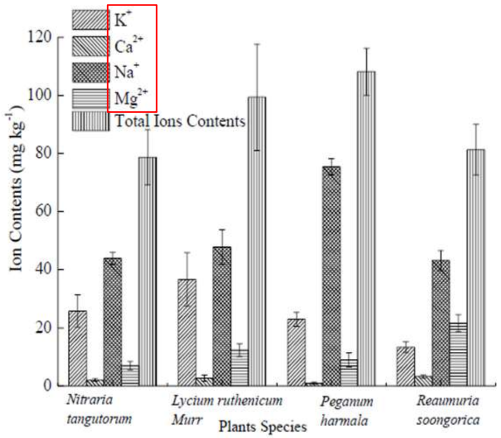


Distribution of soil salinity and soil texture at different soil depths in the cotton cropland (Guan et al.,2019).

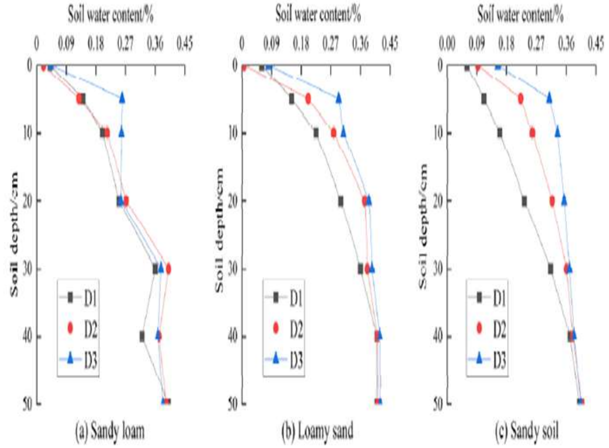
- **As deep layer salt rises via capillary rise, ground water and leached soil layer control crop soil salinity.**

2. Literatures review

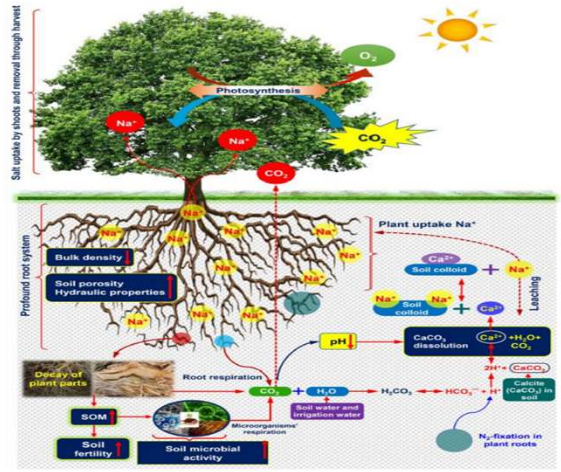
Lack the research of salt movement in soil in Minqin, despite it is very important in improving the saline land.



Ions and their amount in dominant plants in Minqin oasis *(Chen et al.,2019)*



Distribution characteristics of water in different textured soils *(Wang et al., 2023)*

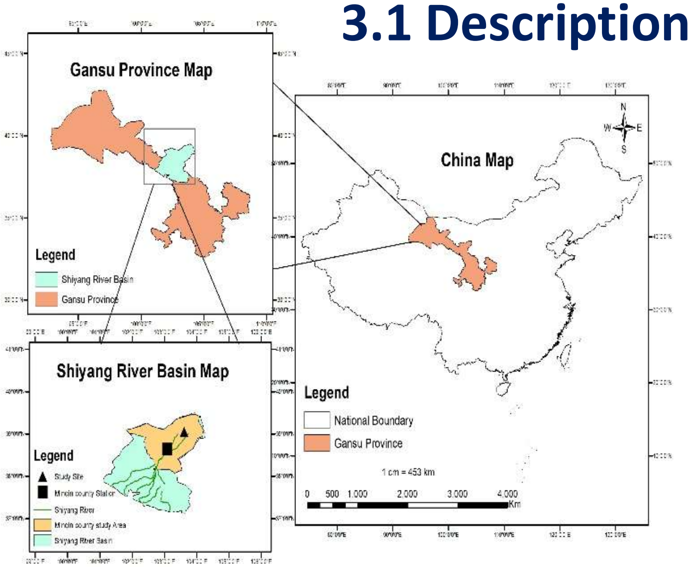


Sketch of halophyte plants in soil profile with salt affected soil, (*Rahman et al.,2021*)

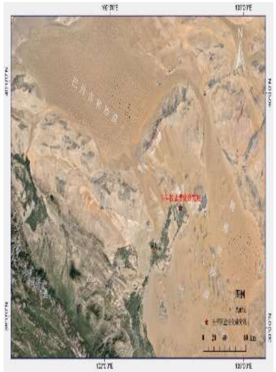
- **How and how much does high sodium salt salute and move in the soil?**
- **How does the change ground water table influence the salt move in the soil?**
- **How does the soil interbedded with sand and clay affect salt movement in saline soil?**
- **How does local halophytes influence salt move by absorbing Na+ in soil?**

3. Research methods

3.1 Description of the study area



The study area is located at Drylands Salinization Research Station



The typical landscape of the study area

Nitraria tangutorum plant

Tamarix ramosissima plant

- **Location:** 103˚ 61’72’’E and 39˚46’31’’N
- **Climate type:** Typical continental desert climate
- **AT:** 8.9◦C; **P:** 113.2 mm;
- **ET0:**1383.0 mm, **Evap**: 2644mm
- **Groundwater table** : 2.5–9.5 m
- **Soil type:** sandy, loam, and silty loam soil
- **Halophytes:** *Nitraria tangutorum and Tamarix ramosissima are dominant plants*

3. Research methods

3.2 Experimental design

- Treatment: 9, Soil types: 3, Plant shrubs type: 3, Repetition: 4, Total plots: 36

Note: SLS : **Sandy loam soil**, SS : **Sand soil,** SiLS : **Silt loam soil** , NT : **Nitraria tangutorum**, NP : **Non plant**,
TR: **Tamarix ramosissima**,
R1: **representative replication,**
R **representative sensors.**, DP: **Data logger with solar panel**
IP: **Irrigation pipe**.
Sand loam **and** sand soil **with pH:8.433 and 8.837 and** Silt loam soil **pH 8.413.**

3. Research methods

3.2 Experimental design

- **Field plot were filled gravels and soil with help of caterpillar machine, farmers, shovels and meter tape.**

a) Sketch view of the plot b) Empty field plot , c) Gravels size d) Caterpillar machine with gravel

- **Plastic sieve were laid underground water table followed by gravels** and **sand loam** and **sand, silt loam soil filled into the field plots**.

a) and b) Black plastic sieve and gravel laid in a tank, c) Farmer and machine filling plot and d) filled plots with soils

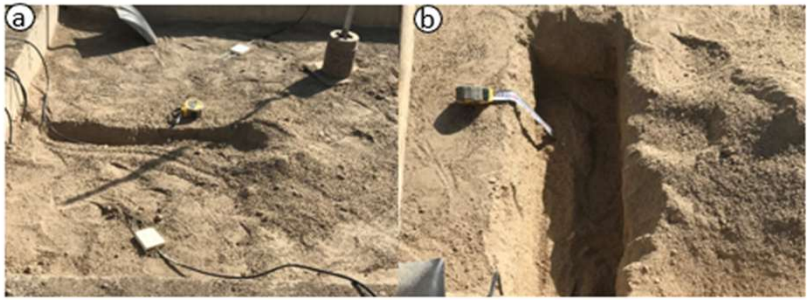
3. Research methods

3.2 Experimental design

- **Bulk density were measured at each field plots by using soil core method and dried in oven dry at 105 degree celicius for 24 hr.**

a) Core rings and knife b and c) Soil sampling design in a tank and d) Oven dry with soil core.

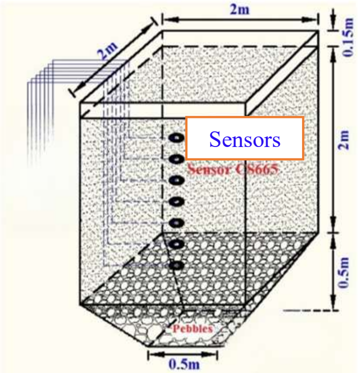
- **The CS655 sensors were installed at different position depth of selected field plot to measure SWC and EC in long run.**



a) CS655 sensors in field plot b) Meter tape to measure soil profile depth in a field plot

3. Research methods

3.2 Experimental design



A sketch view of a field plot

Note: SLS NP: **Sandy loam soil Non plant** SLS NT: **Sandy loam soil Nitraria tangutorum**: Sand soil, SLS TR: **Sandy loam soil Tamarix ramosissima**

Water meter

Data collections at the field

- Irrigation: Fresh water, 3weeks
- Instruments: CS655 sensors buried at depth: 5cm, 15cm,30cm, 40cm, 60cm, 100cm,160cm,180cm, and 200 cm
- Data collection: Soil water content (SVWC), soil electric conductivity (EC).
- Data time collection: 10 min from datalogger to the Computer

3. Research methods

3.2 Experimental design

- Field plots were irrigated with fresh water
- Seedling of NT and TR shrub plant were planted in the field experiment plot of sand loam and sand soils and silt loam soils.
- At start of the field experiment plots were covered with plastic mulch after planting to reduce evaporation of water.
- Field capacity (FC) was measured before planting.

After Irrigation of Field experimental plots

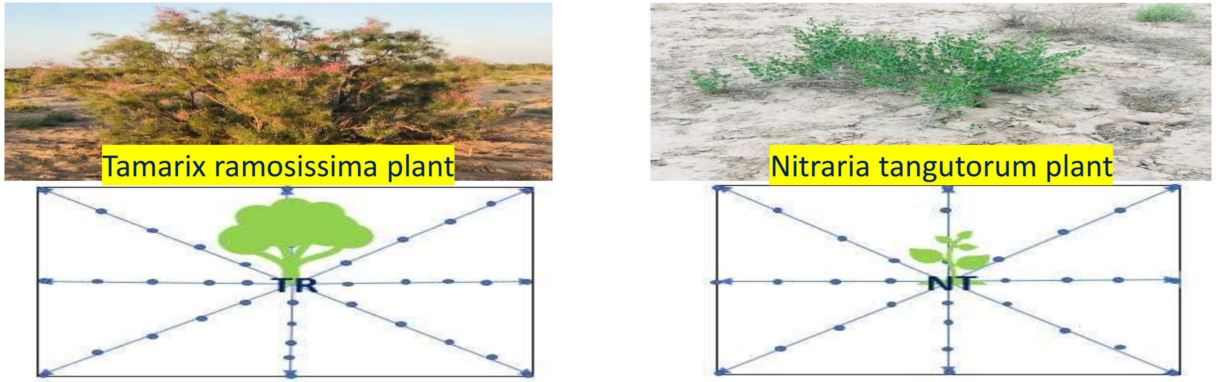
Nitraria tangutorum shrub plant

Tamarix ramosissima shrub plant

Field experiment plots of sand loam and sand soil and silt loam soil.

3. Research methods

3.3 Field observation experiment design



Quadrant sketch showing eight directions of before and after rainfall, from the center of TR and NT plant at different space and different soil profile depth

- **Two halophytes shrubs of Nitraria tangutorum bobrov and Tamarix ramosissima Lebed were selected at field community of shrub plant in arid and semi-arid land regions.**
- **Soil samples were obtained using soil hand auger before rainfall and after rainfall during period**
- **Depth: 0-20 cm, 20-40 cm,40-60 cm,60-80 cm,80-100 cm, 100-120 cm,120-140 cm,140-160 cm,160-180 cm,180-200 cm depth for tamarix ramosissima and Depth: 0-20 cm, 20-40 cm,40-60 cm,60-80 cm,80-100 cm of Nitraria tanguturom at different distance and axis 50cm, 100cm, 150cm.**
- **Soil moisture/water content were determined by using core method in the oven dry and Soil electrical conductivity of the soil was measured by soil electrical conductivity meter**
- **Soil structure will also be analyzed.**

3. Research methods

3.3 Field observation experiment design

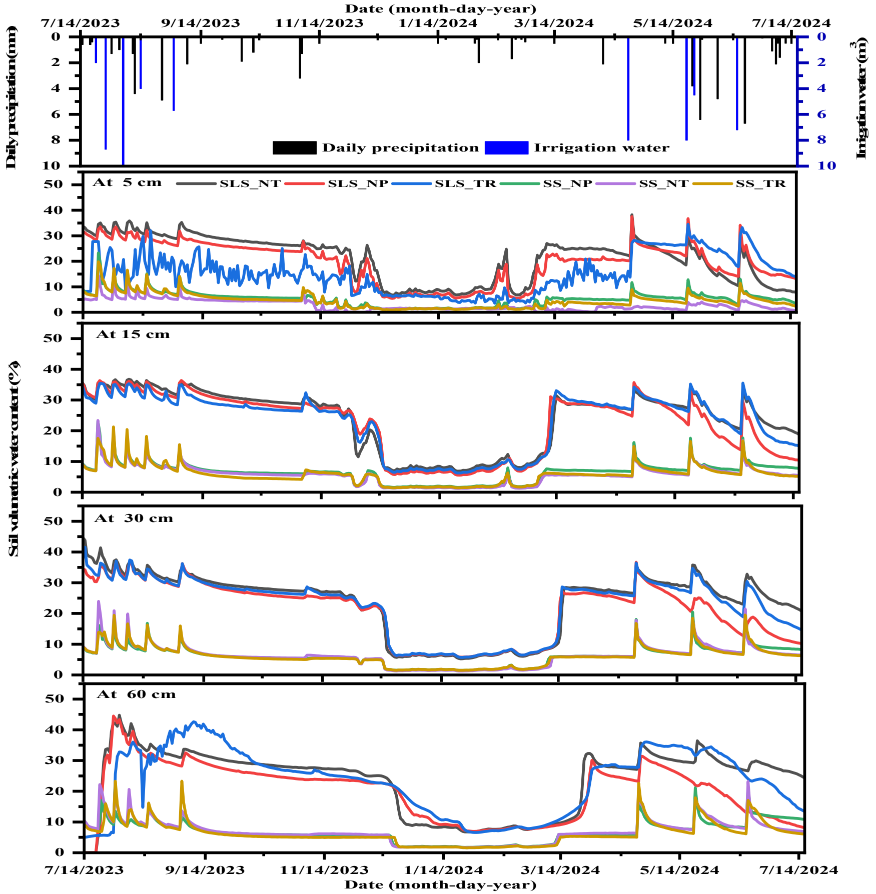
Soil samples preparation and measuring of soil volumetric water content, Soil EC

- Soil samples were obtained **before rainfall, after rainfall in three replicate during period** (25.06.2024-3.7.2024 and 25.9.2024-8.10.2024) respectively using **soil auger.** Plant width and height were measured.
- **Depth:** 0-20 cm, 20-40 cm,40-60 cm,60-80 cm,80-100 cm, 100-120 cm,120-140 cm,140-160 cm,160-180 cm,180-200 cm depth for tamarix ramosissima and **Depth:** 0-20 cm, 20-40 cm,40-60 cm,60-80 cm,80-100 cm of Nitraria tanguturom at different distance and axis **50cm, 100cm, 150cm.**
- Soil volumetric water content by oven dry and Soil EC by EC meter were determined in laboratory and Soil particles size/soil texture are being measured in Lab using MalvinHyDro3000.

4. Results

4.1 Field plot experiment

a) Soil Volumetric water content (SVWC) pattern change at different depth



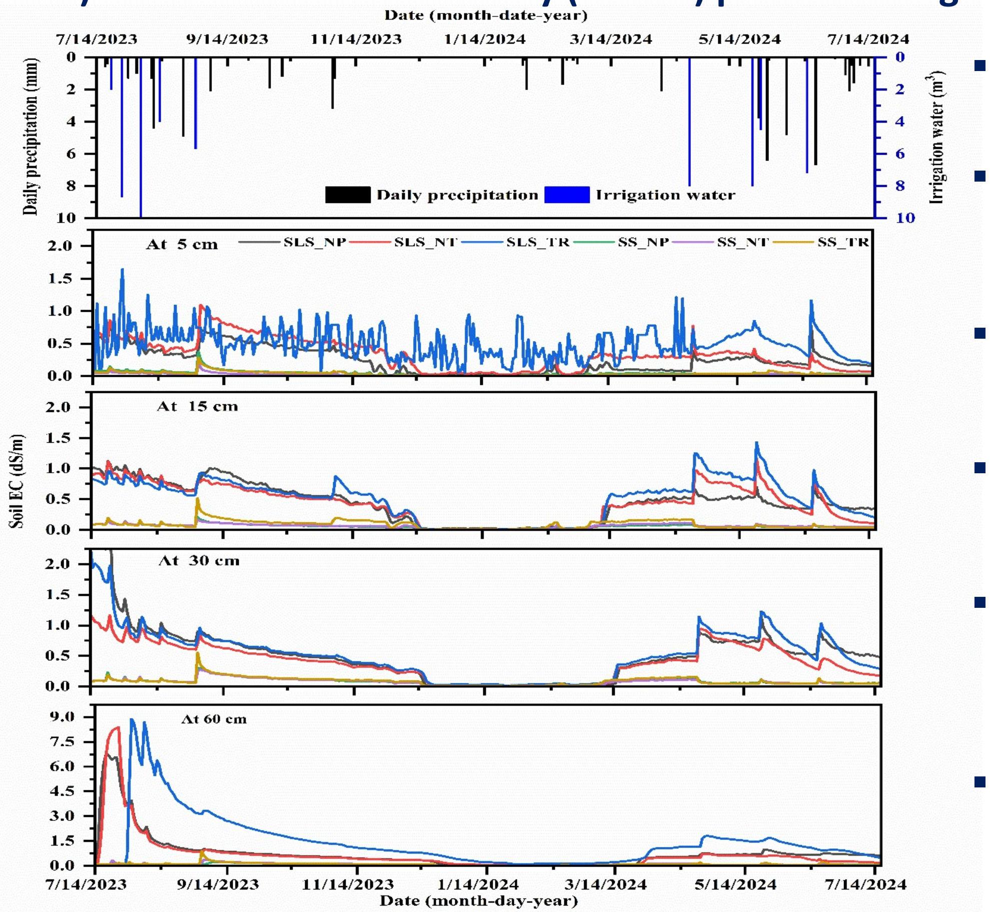
- **The average of daily of the installed sensors in six treatments were for one year (7.2023/7.2024) were obtained.**
- **Note: SLS NP, NT, TR: Sand loam soil non plant, with Nitraria tantrums, with Tamarix ramosissima, SS NP, NT, TR: Sand soil non plant, with *Nitraria tangutorum*, with *Tamarix ramosissima*.**
- **At 5 cm, SVWC both precipitation and irrigation, in SSNP, SSTR is lower due large pores water move fast while SLS NP, SLS NT TR maintain is higher SVWC. and 15 cm depth Initial Soil WC in both irrigation and precipitation SS TR is lower at zero irrigation while SLSNT, SLSTR, decreases due to root distribution growth of NT and TR.**

- **At 30cm depth, Initial SVWC is lower both zero Irrigation and Precipitation, SS NP,TR is lower due moremacropes water move fast while SLS NP, SLS NT TR maintain is higher SVWC. However as monthly increases all SM decrease due to no irrigation and precipitation in late Dec.2023 to March.2024).**
- **At 60cm, Initial SVWC both irrigation and precipitation , SS NP,TR is lower due moremacropes water move fast while SLS NP, SLS NT, SLS TR maintain is higher SVWC.**

4. Results

4.1 Field plot experiment

b) Soil electrical conductivity (Soil EC) pattern change at different depth



- The average of daily of the installed sensors in six treatments were for one year (7.2023/7.2024) were obtained.
- Note: SLS NP, NT, TR: Sand loam soil non plant, with Nitraria tangutorum, with Tamarix ramosissima, SS NP, NT, TR: Sand soil non plant, with Nitraria tangutorum, with Tamarix ramosissima.
- At 5 cm depth, Initial Soil EC in both irrigation and precipitation SS TR is lower at zero irrigation while SLSNT, SLSTR, decreases due to growth of SLS NT and SLS TR.
- At 15 cm depth, Initial Soil EC in both irrigation and precipitation SS TR is lower at zero irrigation while SLSNT, SLSTR, decreases due to root distribution growth of NT and TR.
- At 30cm depth, Initial Soil EC in both irrigation and precipitation SS TR is lower at zero irrigation while SLSNT, SLSTR, decreases due to growth of SLS NT and SLS TR.
- At 60 cm, Initial Soil EC in both irrigation and precipitation SS TR is lower at zero irrigation, while SLSNT, SLSTR, decrease fast due to root absorption and distribution growth in SLS NT and SLS TR.

4. Results

4.2 Field observation experiment

a) Average Soil volumetric water content (SWC) and Electrical conductivity (SEC) pattern changes of Nitraria tangutorum

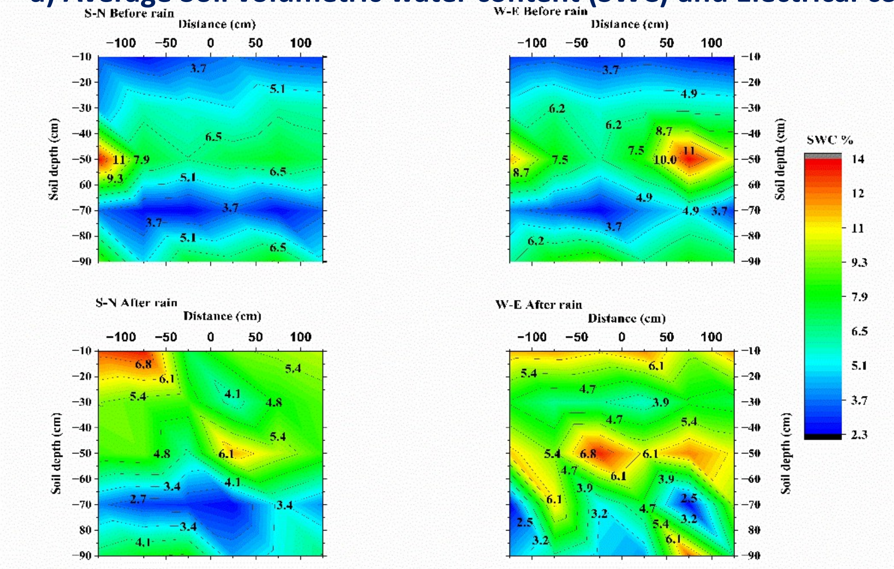


Figure 1. Soil water content (SWC) of Nitraria tanguturum shrub at different direction

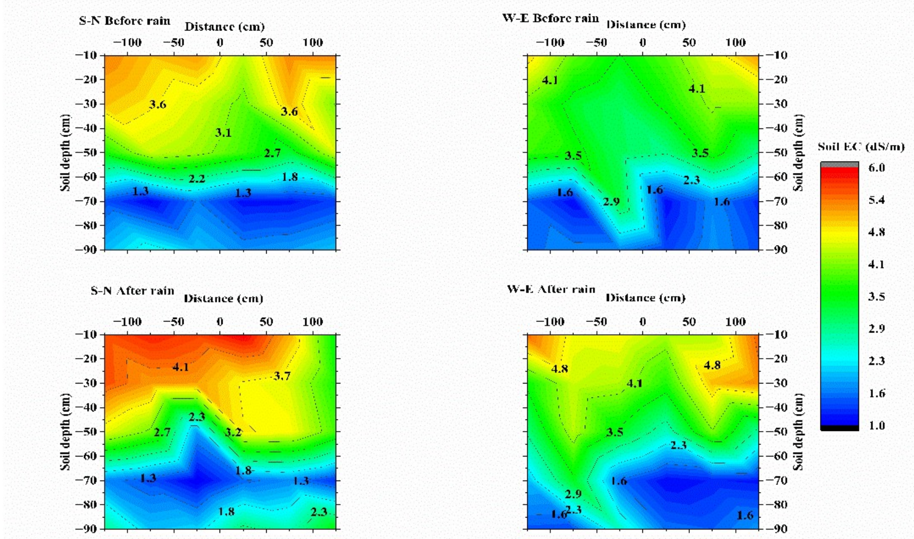


Figure 2. Soil Electrical conductivity (SEC) of Nitraria tangutorum shrub at different direction

- Note: S-N, south north W-E: west-east directions axis. Soil volumetric water content (SWC) patterns changes at different distance of the halophytes of Nitraria and Tamarix shrubs were obtained before and after rainfall.
- SWC is highly distributed in middle layer (40-60cm) compare to deep soil layer in Nitraria before rain compare to after rain and SWC decreases in middle and move unto topsoil this is attributed to capillary rise and evaporation into soil (Fig 1).
- SEC was higher in all distance in upper soil layer between 30-60 cm depth then decrease as move deep soil layer, furthermore, after rainfall, nitraria shrubs showed slight increase of soil EC at 20-30 cm depth indicating influence of rainfall in salt migration in Nitraria(Fig.2).

4. Results

4.2 Field observation experiment

b) Average Soil volumetric water content (SWC) and Electrical conductivity (SEC) pattern changes of Tamarix ramosissima.

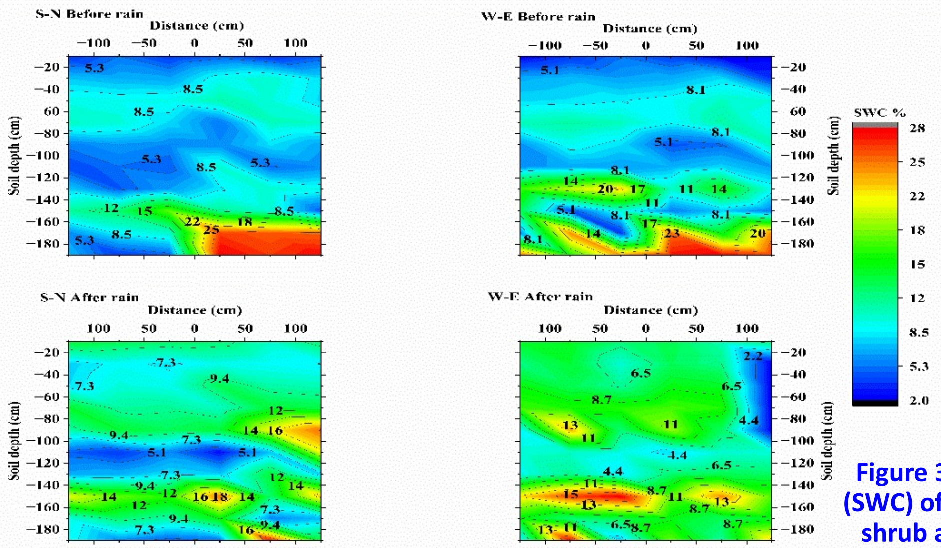


Figure 3 . Soil water content (SWC) of Tamarix ramosissima shrub at different direction

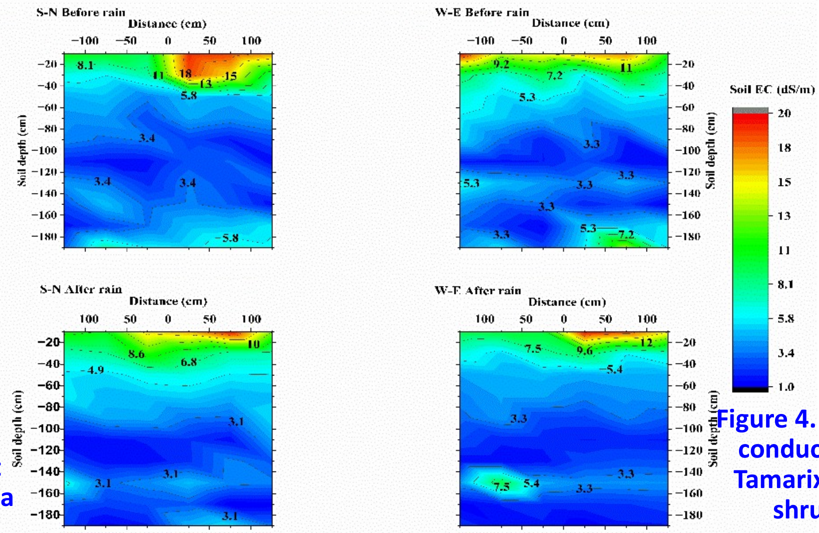


Figure 4. Soil Electrical conductivity (SEC) of Tamarix ramosissima shrub at different directions

- Note: S-N, south-north W-E: west-east direction axis. Average soil electrical conductivity patterns changes at different distance of the halophytes of Tamarix shrubs were obtained before and after rainfall.
- **SWC** is highly distributed in deep soil layer(160-180cm) compare to upper soil layer in Tamarix ramosisima before and after rainfall (Fig 3) as it has deep roots to absorb water for its survive mode in arid-semi arid land.
- SEC was higher in upper layer of Tamarix at 20-40 cm depth then SEC decrease as move deep soil layer however after rainfall, Tamarix also showed slight decrease of SEC thus could indicate influence of rainfall in salt leaching. It is also revealed that SEC is most found in the top soil layer of the soil surface (Fig 4) S-N after rain.

5. Conclusions

- ✓ This study highlights that soil type and halophyte traits jointly shape water-salt dynamics in the vadose zone of arid ecosystems.
- ✓ Sandy loam promotes higher water and salt retention than sand, while increasing sand content enhances soil porosity, limiting salt accumulation in surface layers.
- ✓ *Nitraria tangutorum*, with a broad canopy and shallow roots, effectively intercepts rainfall and maintains surface soil moisture, whereas *Tamarix ramosissima* facilitates deeper infiltration and salt leaching.
- ✓ Incorporating shallow-rooted, high-canopy halophytes into shelterbelt design can reduce soil evaporation and surface salinity, supporting vegetation stability and long-term ecological resilience in oasis systems.

Thank you!