The Study the Effects of Irrigation Water Quality and Leaching on Soil Salinity at Greenhouse Scale using Monitoring-Modelling Techniques

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Outline

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- Problem Statement
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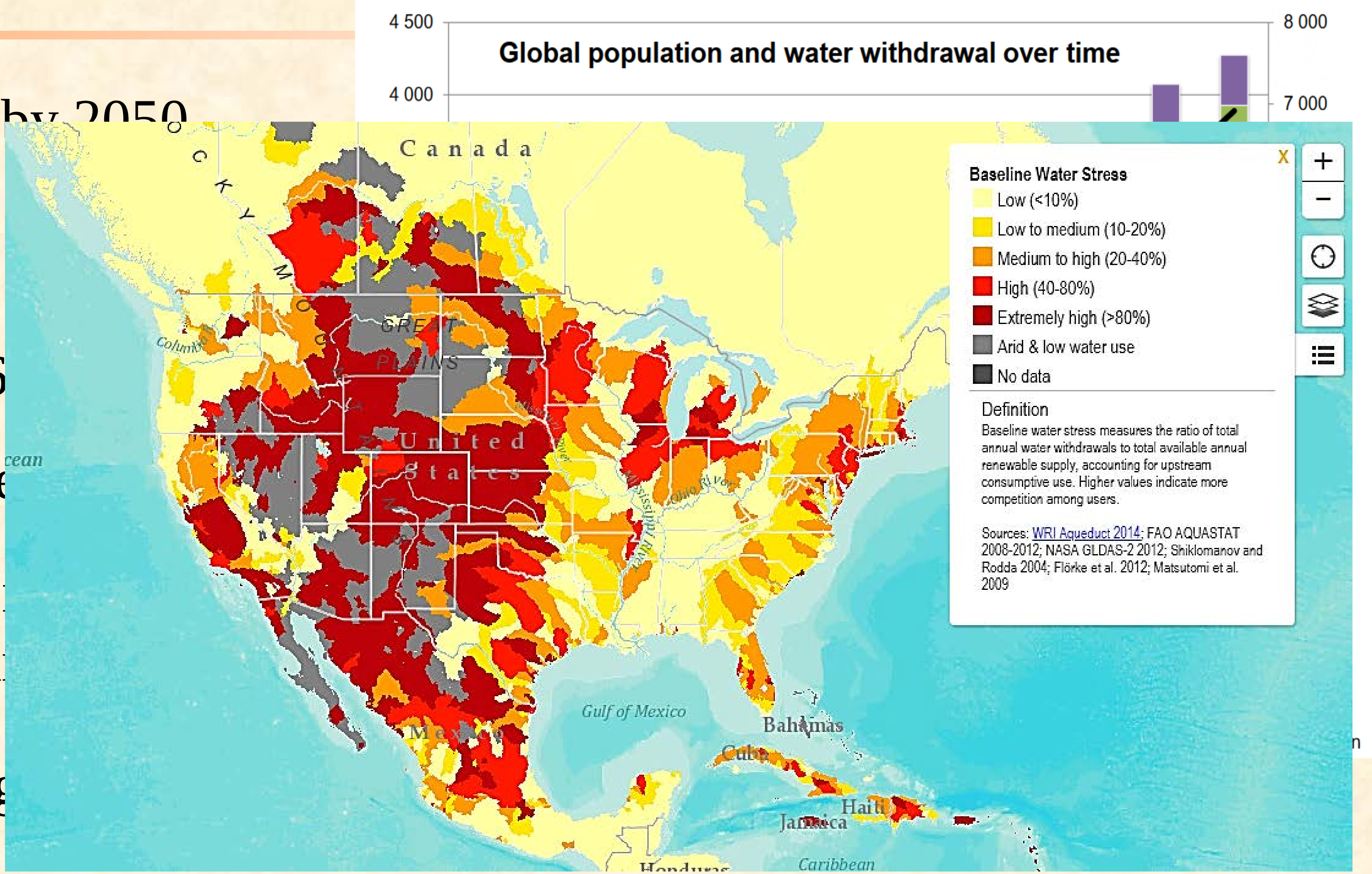
Problem Background

- Global population 10 billion by 2050
- Food, intensified agriculture,
- Irrigation water withdrawal 6
- Freshwater withdrawals triple
- Annual increase in freshwater
  64 billion cubic meters a year
- Water shortage main challeng



https://www.un.org/development/desa/publications/world-population-prospects-the-2017-revision.html
http://www.fao.org/nr/water/aquastat/water_use/index.stm
http://www.wri.org/applications/maps/aqueduct-atlas/#x=-105.12&y=24.76&s=ws!20!28!c&t=waterrisk&w=def&g=0&i=BWS-16!WSV-4!SV-2!HFO-4!DRO-4!STOR-8!GW-8!WRI-4!ECOS-2!MC-4!WCG-8!ECOV-2!&tr=ind-1!prj-1&l=4&b=terrain&m=single-BWS

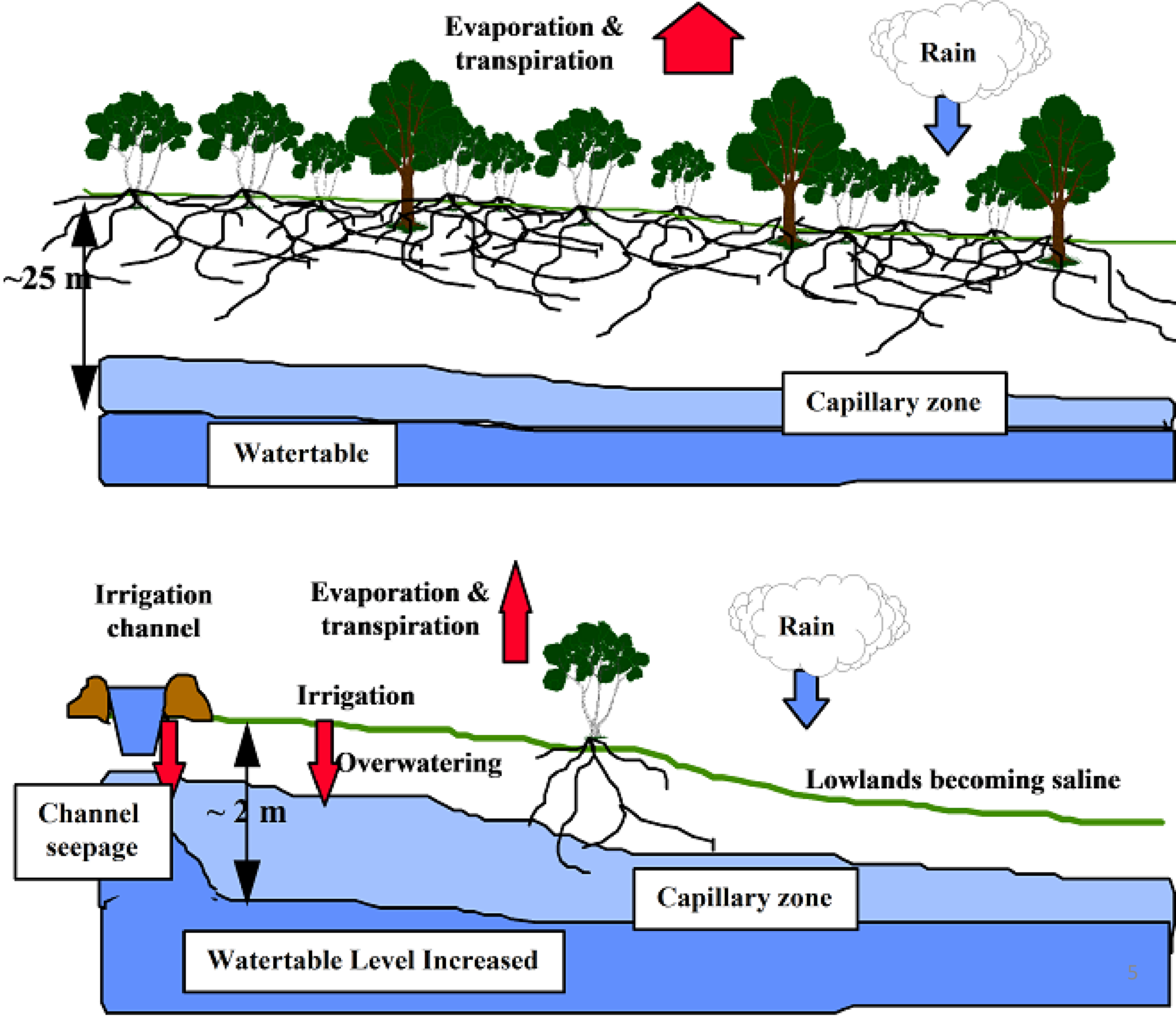
Salinization of Irrigated Lands

- Land degradation: second agricultural production problem,
- Salinization as chemical soil degradation.
- Salt-spoiled soils worldwide: 20% of all irrigated lands,
- Annual lost cropland area,
- Annual costs $27 billion in lost crop value.

https://pursuit.unimelb.edu.au/articles/fighting-the-white-cancer-threatening-global-food-security
http://www.djfarmer.co.za/farms/senwane/news/irrigated_land/irrigated_land.html

Causes of salinity:

- Poor drainage condition,
- Rise of groundwater level,
- Over-irrigation
- Improper management of irrigation facilities,
- Unsuitable quality of irrigation water.

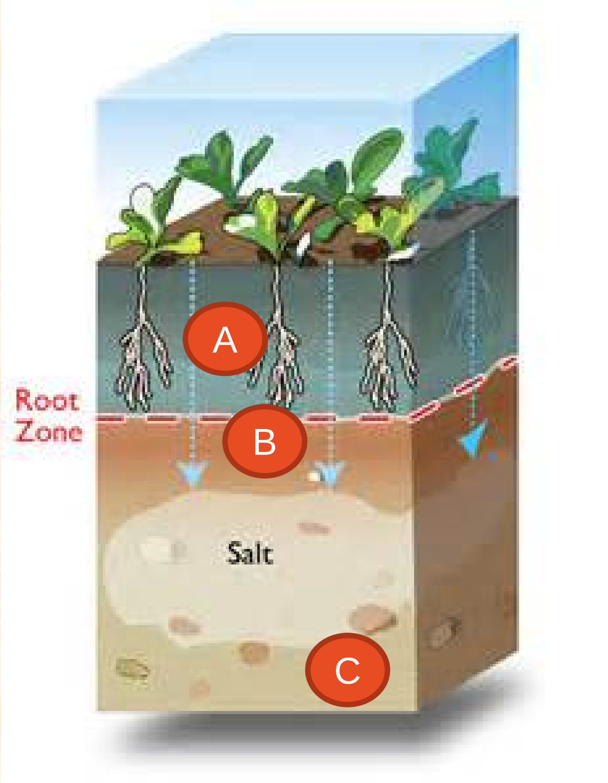


https://pursuit.unimelb.edu.au/articles/fighting-the-white-cancer-threatening-global-food-security

Salinity Control

Fast to develop and slow to reclaim. Prevention is the key.

- High quality irrigation water
- Lowering groundwater table
- Management Practices:
  - Scraping
    - Mechanically remove salt from soil surface
    - Salt disposal problems
  - Flushing
    - Wash salts from soil surface
    - Little salt can be washed
  - Leaching
    - The most effective procedure for removing salts from the root zone



Problem Statement

- Concerning the crucial role of irrigation in intensified agriculture on one hand and its contribution to salinization and thus declines in the crop productivity on the other hand, there are challenges in controlling salinization while maintaining the irrigated agricultural productivity.

- Different aspects of this problem have been investigated in the past. However, there is a lack of solutions that can be applied in different regions with variable agro-climatological conditions.

- This research is focused on this knowledge gap and attempts to investigate different strategies to cope with soil salinization in irrigated agriculture.

Goal and Objectives

Objectives

To study the effects of irrigation water quality and leaching on soil salinity at greenhouse scale using monitoring-modelling techniques

Material and Method

1. Experimental soil column study

Treatments	Treatment Explanation	EC (dS m^{-1})	Leaching application
CTRL	Control with tap water	0.5	no
EC3N	slightly saline water	3	no
EC6L	moderately saline water	6	yes
EC6N	moderately saline water	6	no
EC9L	highly saline water	9	yes
EC9N	highly saline water	9	no

Soil column experimental setup.

Material and Method

2. HYDRUS model

Input
Soil Properties
Water Flow conditions
Solute Transport Conditions
Root water and solute Uptake Parameters
Time Variable Boundary Conditions
Profile Information
Crop Root Distribution

HYDRUS →

Output
RRWU
Soil Saturation
Solute Concentration
Water fluxes
Solute Fluxes
Soil Profile Characteristics
Time Variable Properties

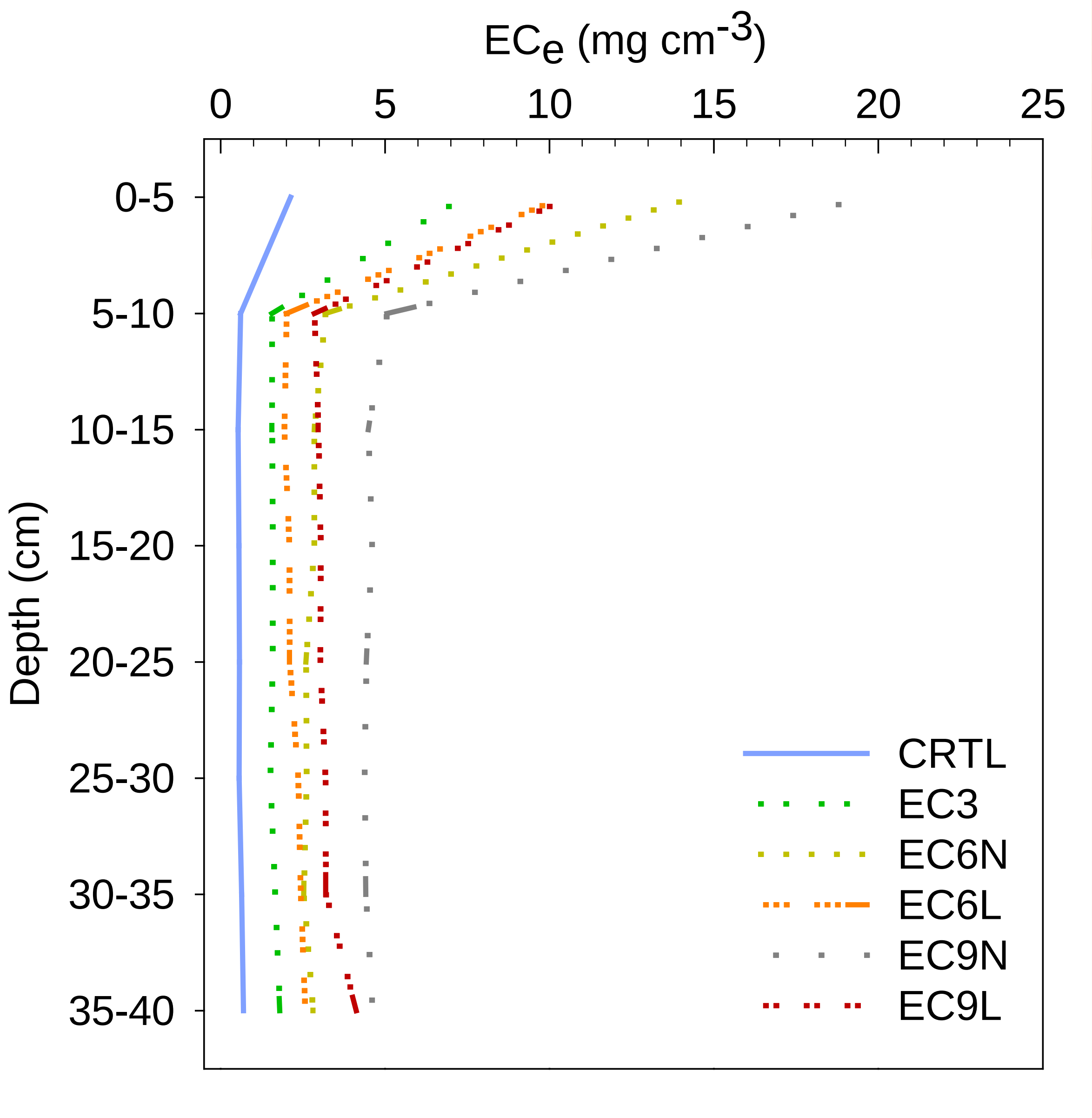
Governing Equations

- Water Flow Richards Equation → partially saturated medium → $$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x}\left[K\left(\frac{\partial h}{\partial x} + \cos\alpha\right)\right] - S$$
- Solute Transport or Dirichlet type; concentration → specify given concentrations at the input surface

Results

1.Greenhouse study:

- Max salinity at surface,
- Soil salinity increased by irrigation salinity,
- Leaching application was able to reduce salinity in all treatments,
- Depths greater than 10 cm were within salinity tolerance of Bermudagrass.

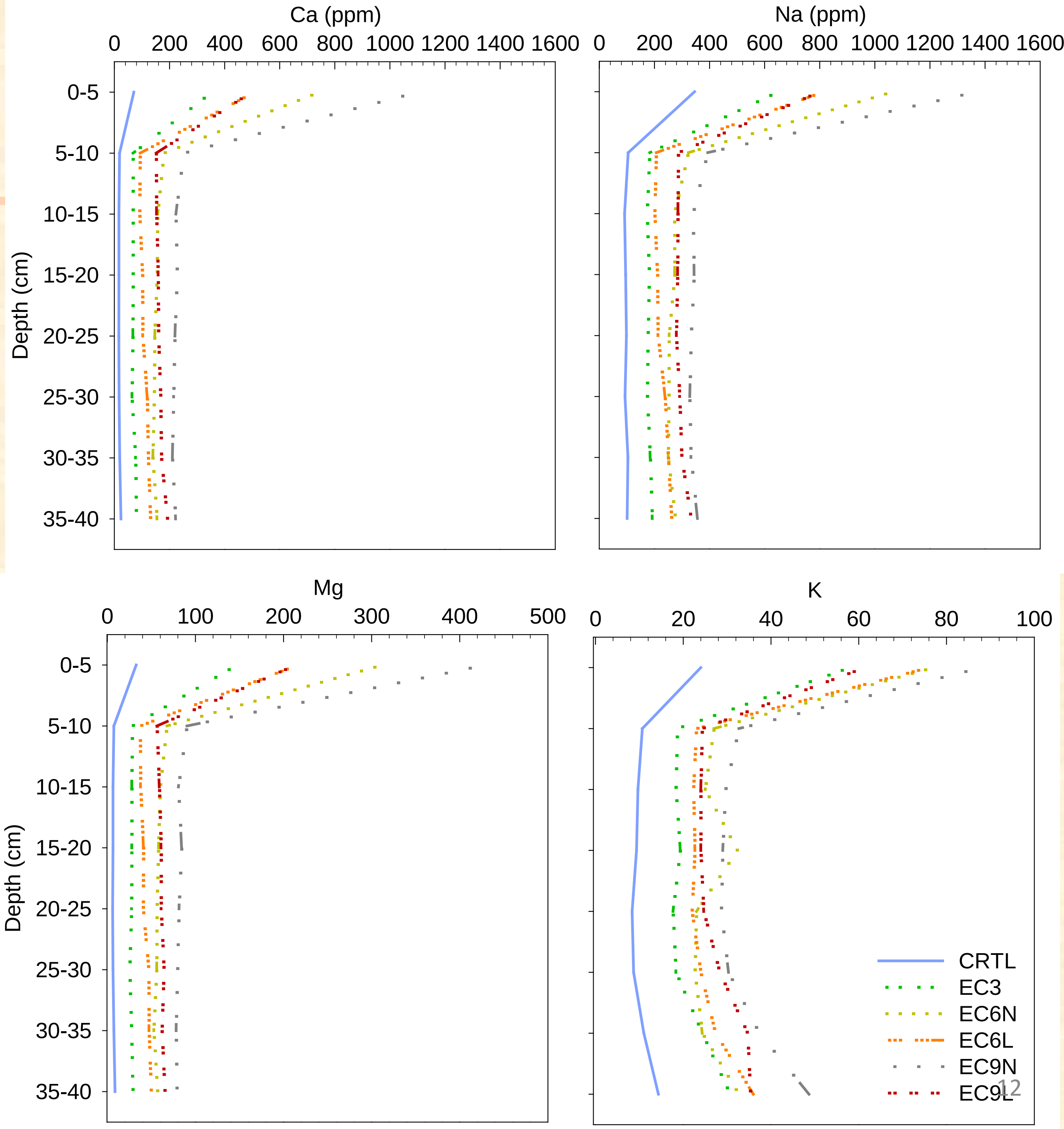


Results

1.Greenhouse study:

Distribution of major ions of Ca, Mg, Na and K for various treatments of saline water irrigation:

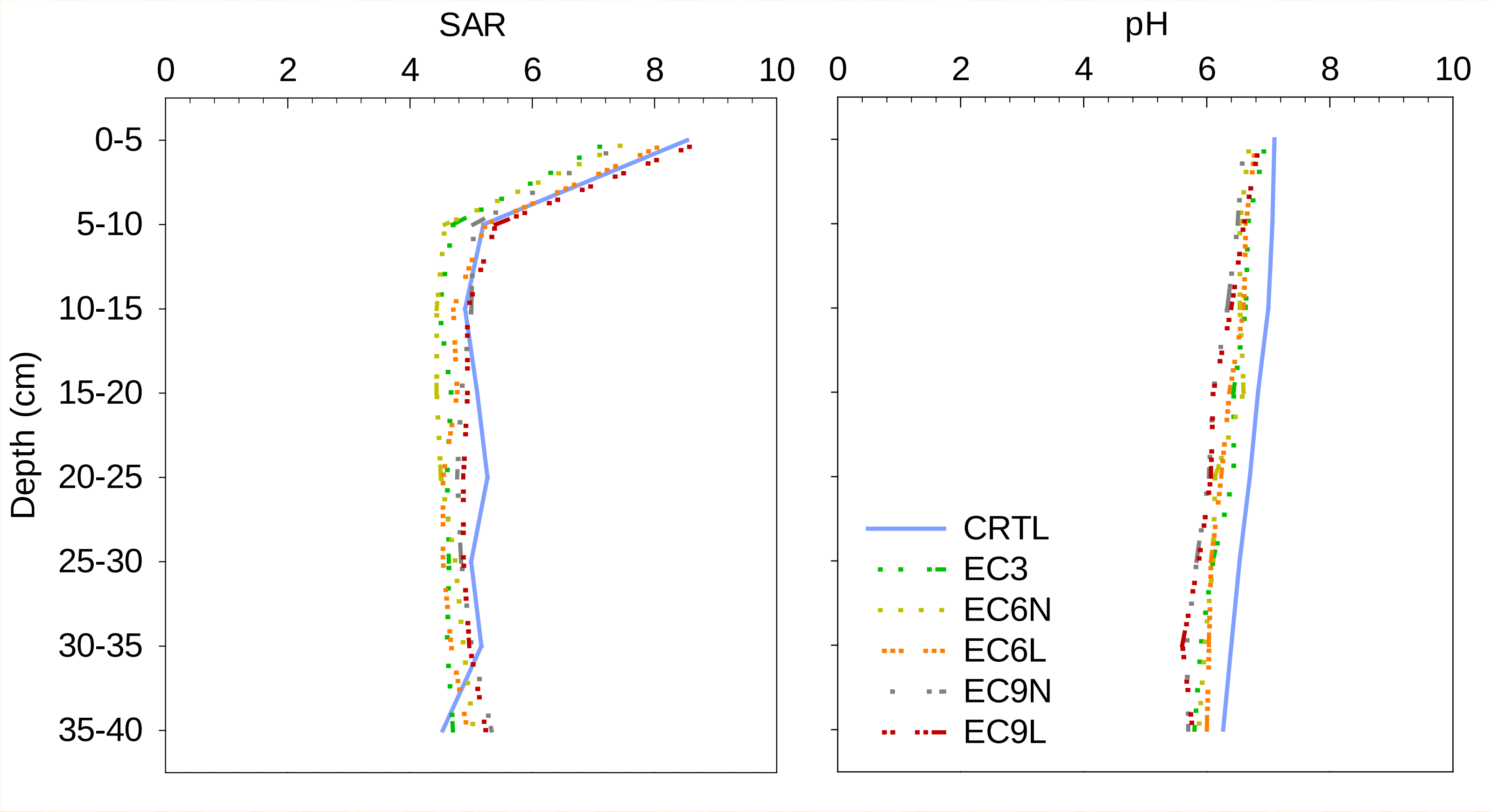
CTRL (0.47), 3, 6, and 9 dS m^{-1} with leaching (L) and without leaching (N).



Results

1. Greenhouse study:

Distribution of pH and SAR for various treatments of saline water irrigation with CRTL, EC3, EC6, and EC9 with leaching (L) and without leaching (N).



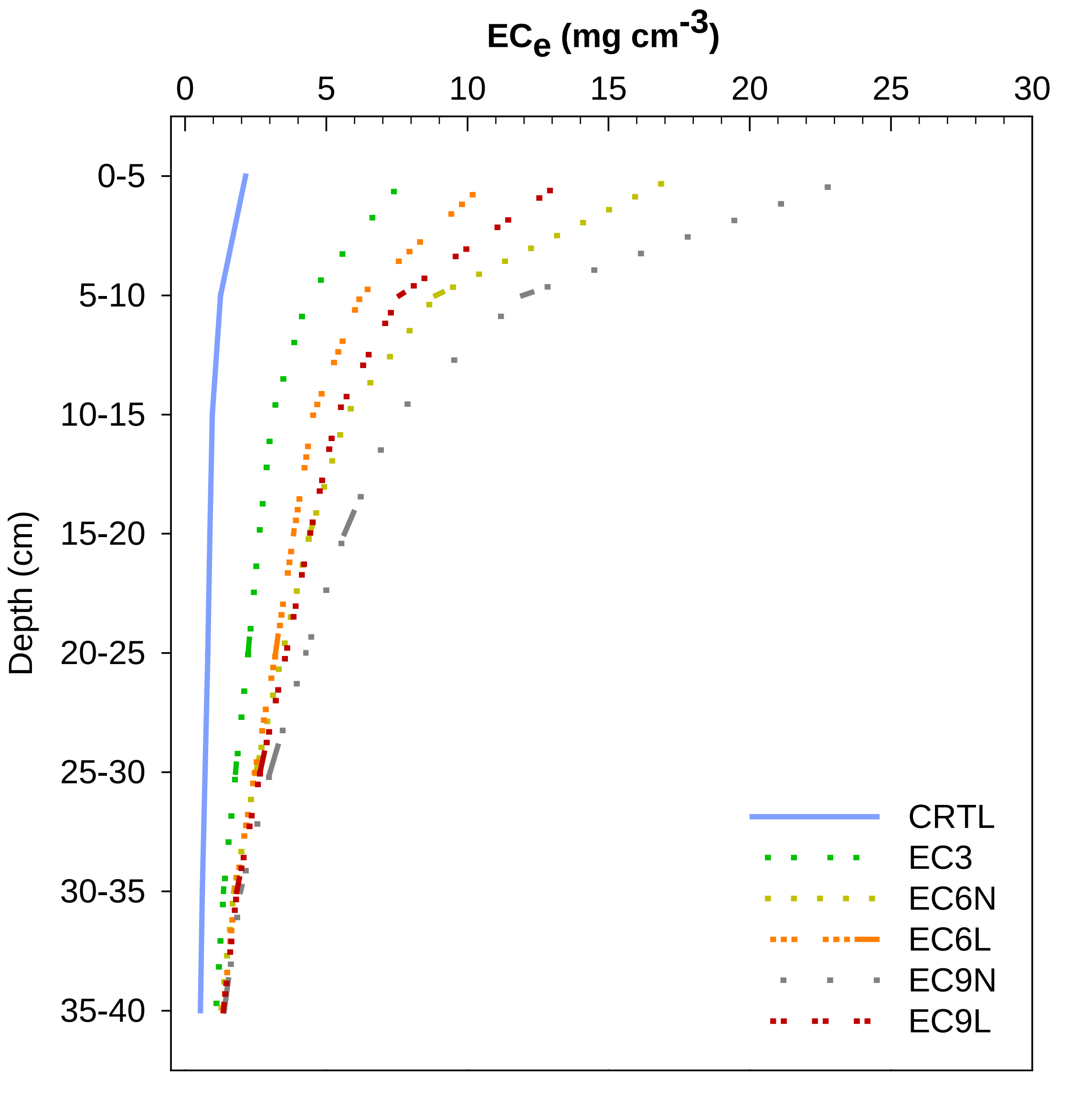
Results

2. HYDRUS model:

- Same trend of irrigation salinity effects,
- Over-estimations, but acceptable performance,
- Previous studies RMSE varied between

0.012 dS m^{-1} (Mguidiche et al., 2014) to 3.73 dS m^{-1} (Yurtseven , 2013).

Treatment	MBE	RMSE	MAE	r	NSE
CTRL	0.25	0.39	0.31	0.88	0.62
EC3N	0.89	1.56	1.21	0.87	0.58
EC 6L	1.31	2.46	1.90	0.83	0.47
EC 6N	1.80	3.30	2.57	0.91	0.53
EC 9N	1.16	3.11	2.62	0.80	0.00
EC 9L	1.22	4.26	3.48	0.90	0.54



Conclusions

- Soil salinity increases by irrigation water salinity,
- Maximum salinity at the surface,
- Leaching application offsets salt accumulations,
- HYDRUS performance is acceptable in simulating soil salinity profile as impacted by low quality of irrigation water.

Broader Impacts of Projects

- Potential utilization saline irrigation water with leaching application,
- Performance of HYDRUS 1-D in predicting soil and solute interactions was acceptable,
- Great starting point for selecting BMPs that suit local conditions before actual experiments,

Selected References

Berezniak, A., Ben-Gal, A., Mishael, Y., & Nachshon, U. (2017). Manipulation of Soil Texture to Remove Salts from a Drip-Irrigated Root Zone. *Vadose Zone Journal*.

Crescimanno, G., & Garofalo, P. (2006). Management of irrigation with saline water in cracking clay soils. Soil Science Society of America Journal, 70(5), 1774-1787.

Corwin, D. L., Rhoades, J. D., & Šimůnek, J. (2007). Leaching requirement for soil salinity control: Steady-state versus transient models. *Agricultural Water Management*, *90*(3), 165-180.

Fujimaki, H., Ando, Y., Cui, Y., & Inoue, M. (2008). Parameter estimation of a root water uptake model under salinity stress. Vadose Zone Journal, 7(1), 31-38.

Liang, Y., Si, J., Nikolic, M., Peng, Y., Chen, W., & Jiang, Y. (2005). Organic manure stimulates biological activity and barley growth in soil subject to secondary salinization. *Soil Biology and Biochemistry*, *37*(6), 1185-1195.

Maas, E. V., & Hoffman, G. J. (1977). Crop salt tolerance–current assessment. Journal of the irrigation and drainage division, 103(2), 115-134.

Wicke, B., Smeets, E., Dornburg, V., Vashev, B., Gaiser, T., Turkenburg, W., & Faaij, A. (2011). The global technical and economic potential of bioenergy from salt-affected soils. Energy & Environmental Science, 4(8), 2669-2681.

Wang, X., Liu, G., Yang, J., Huang, G., & Yao, R. (2017). Evaluating the effects of irrigation water salinity on water movement, crop yield and water use efficiency by means of a coupled hydrologic/crop growth model. Agricultural Water Management, 185, 13-26.