WAGENINGEN UNIVERSITY
ENVIRONMENTAL SCIENCES

Modelling of soil sodicity development due to capillary upflow of saline groundwater in the stochastic ecohydrological framework

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Introduction

The occurrence of salt affected soil is a main hazard to agriculture especially in the semi-arid regions. The effective management of salt affected soil requires adequate understanding, not only of how water and, hence, salt are transported in the root zone, but also how water, salt, and composition of salt interact with each other in groundwater dependent ecosystems. Groundwater uptake can be an important source of water, salt and composition of salt in semi-arid areas and therefore capillary pressure induced upward water flow may cause root zone salinization and then as a result soil sodication.

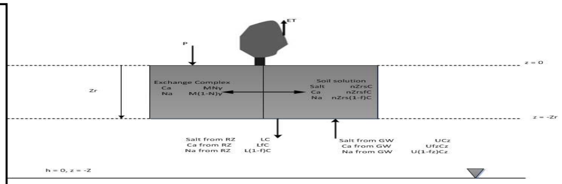

Fig.1 Conceptual model for salt uptake from groundwater by vegetation in semi-arid regions.

Objectives

- To develop a relatively simple model that emphasizes some dependencies only, to assess as transparent as possible, to what degree periodic salinity may cause soil sodicity which is quantified by exchangeable sodium percentage (ESP).
- Determining the effects of different soil cation exchange capacity (CEC) on the development of soil ESP under different groundwater depths and climates
- Determining the effects of different root zone thickness on the development of root zone ESP for a range of climates and groundwater depths. The effects include how fast steady state approaches, how the critical groundwater depth (where salt concentration and ESP is maximum) switches and quantification of salinity and sodicity.
- In all illustrations, the soil is sandy clay loam and vegetation is trees.

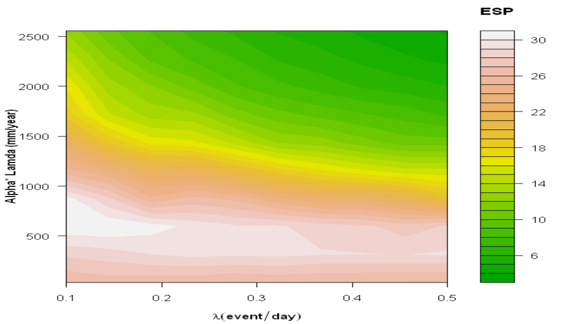

Fig.2 Contours of soil ESP as a function of rainfall (αλ) and rainfall frequency (λ). The groundwater depth (Z) is 150 cm, and root zone thickness (Z_r) of 30 cm.

Conclusions

- Changes in rainfall frequency affect capillary flux and therefore also root zone salinity and sodicity (Fig. 2).
- If salinity reached steady state, sodicity may still grow as a function of time due to buffering by exchange (Fig. 3).
- Development of soil sodicity (ESP) is inversely related to CEC, because with growing CEC more calcium needs to leach and more sodium is required via capillary upflow from groundwater to attain an equilibrium ESP (Fig. 3).
- Since capillary flux decreases if Z-Zr increases (keeping Z constant) , salt concentration and root zone ESP approach steady state faster due to less exchange between Na and Ca for larger Z-Zr as compared to smaller Z-Zr in dry and wet climates (Fig. 4).

Materials and Methods

In order to assess the effect of salinity on soil sodicity, we combined the mass balance equations for water, salt, and calcium assuming Poisson-distributed daily rainfall and brackish/saline groundwater.

Water balance equation

$$n.Zr.\frac{ds}{dt} = P - ET(s) + U(Z,s) - L(s)$$

Where n is porosity, Zr is root zone thickness in cm, s is the relative saturation, ET is evapotranspiration in cm/day, U is capillary upflow in cm/day, L is leaching flux in cm/day. The rainfall (P) input is generated assuming a Poisson distribution of rainfall events and exponentially distributed rainfall depths.

Salt balance equation

$$\frac{d}{dt}(n.Zr.s.C) = U.C_Z - L.C_{Zr}$$

Where C is salt concentration in mol_c/L, C_z is groundwater salt concentration in mol_c/L, C_{Zr} is salt concentration of root zone in mol_c/L.

Calcium balance equation

$$\frac{dT}{dt} = nZrCs\frac{df_{Zr}}{dt} + nZrf_{Zr}s\frac{dC}{dt} + nZrf_{Zr}C\frac{ds}{dt} + M\gamma\frac{dN}{dt} = Uf_ZC_Z - Lf_{Zr}C$$

Where f_{Zr} is calcium fraction in root zone, N is calcium fraction in exchangeable complex, and f_z is the calcium fraction in groundwater.

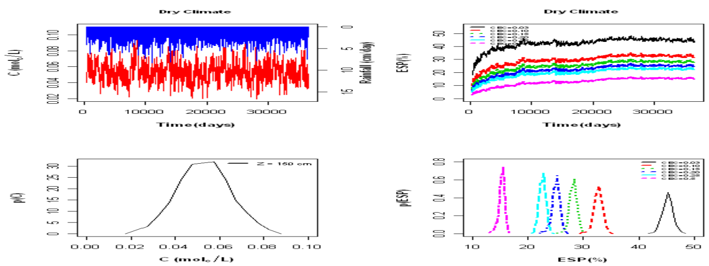

Fig.3 Temporal development of soil salinity (C), pdf of C, soil ESP, and corresponding pdf of ESP for six different CEC ($molc/Kg_{Soil}$) under dry climate (blue colour). The root zone thickness is 50 cm, and groundwater depth (Z) is 150 cm.

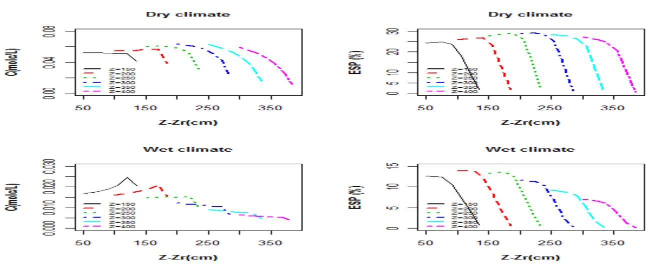

Fig.4 The average salt concentration and soil ESP as a function of Z-Zr under different root zone thickness and groundwater depths for dry and wet climate.

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