A modelling-based Optimization framework for reclamation leaching practices

Issam Khaddam, Stefan Werisch and Niels Schuetze

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Outlines:

- Introduction
- Background
- Materials & Methods
- Results
- Conclusions
**Introduction:**

Fig. 1. Global distribution of precipitation (http://12.000.scripts.mit.edu/mission2017/solutions/engineering-solutions/rainwater-harvesting-techniques/).

Fig. 2. Global distribution of salt-affected soils (GAEZ. Rome, Italy: FAO, 2012. Internet resource).
Salinity Reclamation

- Scraping: appropriate for small areas, temporary solution.
- Flushing: temporary.
- Leaching: by rain or/and irrigation. It needs good drainage conditions.

\[
LR = \frac{EC_{iw}}{5 \cdot EC_e - EC_{iw}} \quad \text{(Rhoades 1974; and Rhoades and Merrill 1976)}
\]

- LR: the minimum leaching requirement.
- \(EC_{iw}\): salinity of the applied irrigation water in dS/m.
- \(EC_e\): average soil salinity (soil saturation extract) tolerated by the crop in dS/m.

Objective:

Develop a transient-state based approach, which considers the 2D distribution of salts
HYDRUS-2D (Šimůnek et al., 1999):

- A numerical modeling software for simulating water flow, solute and heat transport.
- Richards equation for water flow:
  \[
  \frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x} \left[ K(h) \frac{\partial h}{\partial x} \right] + \frac{\partial}{\partial z} \left[ K(h) \frac{\partial h}{\partial z} + K(h) \right] - S(h)
  \]
- The general advection-dispersion equation for solute transport:
  \[
  \frac{\partial \theta c}{\partial t} = \nabla \cdot (\theta D \nabla c - q c)
  \]

θ: soil volumetric water content [L³L⁻³].

τ: time [T].

x, z: horizontal and vertical coordinates [L].

K(h): unsaturated hydraulic conductivity function.

h: the soil water pressure head [L].

S(h): a sink term represents the plant root water uptake.

c: the solution concentration [ML⁻³].

D: the dispersion tensor [L²T⁻¹].

q: the Darcy-Buckingham water flux vector [LT⁻¹].
Preliminary study:

- Synthetic initial conditions- different soil textures- different irrigation (leaching) types.

Fig. 3. Initial salt concentrations.
Optimization Framework:

- **System 1 (surface)**
- **System 2**
- **Redistribution**

**AMALGAM**

- **2D HYDRUS base projects**
  - Sprinkler + SDI
  - Sprinkler + SI
  - SI + SDI

- **Definition of optimization parameters**
  - Sprinkler Flux/time
  - SDI Flux/time
  - SI Flux/time

- **Run HYDRUS 2D**

- **Read & save results**

- **Calculate OF₁, OF₂**

- **Find final optimal solutions**

- **Optimal solutions for individual projects (Pareto fronts)**

- **Final optimal solutions**

- **Objective function OF₁**: The overall applied water.
- **OF₂**: The final EC near field capacity.

Fig. 4. Optimization Framework.
Conceptual Setup:

- Potential evaporation: 0.0375 cm/h (9mm/d).
- Drip-line distance: 5-10-15-20 cm.
- Operation time (h):
  - Sprinkler: [0.1-110] loam, [0.1-240] silt.
  - SI: [0.1-130] loam, [0.1-360] silt.
  - SDI: [0.1-130] loam, [0.1-360] silt.
- Sprinkler flux (cm/h): [0.025-1.025] loam, [0.025-0.275] silt.
- Dripper flux (cm/h): [0.1-20] loam, [0.1-10] silt.

Fig. 5. Conceptual structure.

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Results:

Loam

Silt

Fig. 6. OFs and Pareto optimal solutions for loam (left) and silt (right).
Results:

Fig. 7. Optimal parameters combinations

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Conclusions:

- Numerical modelling is a powerful tool to perform transient-state analyses.
- The proposed approach evaluates LR considering:
  - Time
  - 2D temporal evolution of salts concentration
  - Hydraulic particularity of soil textures
- The framework is flexible to optimize more parameters or/and OFs.
THANKS FOR YOUR ATTENTION