Salinization in semi-arid irrigated regions of Argentina

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- Salinization process
- Salinization in Argentina
- Hydrological modelling using SIMGRO
- Model application: Mendoza region
- Conclusions
Hydrological processes at the soil surface

- Rainfall
- Infiltration
- Evaporation
- Percolation
- Capillary rise
- Leaching Drainage
- Soil surface
- Root zone
- Water table
- Saturated (groundwater) zone
- Unsaturated (Vadose) zone
- Irrigation
Why does soils get saline

1  2  3

Vineyard affected by salts  no problems
### Salinised soils in the world

<table>
<thead>
<tr>
<th>Region</th>
<th>Area (mln ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>69.5</td>
</tr>
<tr>
<td>Near and Middle East</td>
<td>53.1</td>
</tr>
<tr>
<td>Asia and Far East</td>
<td>19.5</td>
</tr>
<tr>
<td>Latin America</td>
<td>59.4</td>
</tr>
<tr>
<td>Australia</td>
<td>84.7</td>
</tr>
<tr>
<td>North America</td>
<td>16.0</td>
</tr>
<tr>
<td>Europe</td>
<td>20.7</td>
</tr>
</tbody>
</table>

**Irrigated area worldwide**: 275.0

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### Salinity

Salinity is measured in electric conductivity of a saturated extract of the soil sample expressed as:

EC – Electrical Conductivity (dS/m)

(deci Siemens per meter)

- Fresh water: EC < 0.5 dS/m
- Saline soil: EC 4 – 8 often results in yield depression (less crop production)
- Some crops like barley are salt tolerant (EC < 12-16)
Salinity movement in the soil

Salinization (salt accumulation) can take place both at relatively shallow and deep groundwater tables.

How to estimate salinity (1)

• Make a water balance of the water flows
  Assign an EC to each flow
How to estimate salinity (2)

Make use of a hydrological model

EC is regarded as a conservative matter (as a tracer)

Requirements for a modelling approach

- Physically based (a white box)
  - Not a conceptual or lumped model (a grey box)
- Simulate processes as accurately as possible
- Not too much input data
- Modular set-up
- Applicable practical problems and hydrological research
Hydrological model: SWAT (not yet) or SIMGRO (yes)

For irrigated systems:
- Sub region border
- Irrigation from groundwater
- Surface drainage
- Sub surface drainage
- Irrigation system
- Soil use
- Root zone
- Capillary rise or deep percolation
- 1st aquifer
- Aquitard (less permeable layer)
- 2nd aquifer
- Hydrological base
- Prescribed flux or level
- Node point in finite element grid
Discretisation

Model area
Subcatchment
Nodes

Subcatchments: Surface water
Nodes: Groundwater

Unsaturated zone

Area with specific land use

\[ P_n + P_s \]

\[ E \]

\[ V; V_{eq} \]

\[ Q_c \]

Root zone
Subsoil
Groundwater level
Sub-soil salinity transport (SIMGRO model)

Interaction surface water - groundwater
SIMGRO/AlterrAqua

GIS-application:

AlterrAqua

Digital input data

Presentation of input data

Results

Calculation with SIMGRO

Presentation of results:
- Groundwater levels and river flows
- Evapotranspiration (potential and actual)
- Etc.

Example input data

Watercourses
Subcatchments
DTM
Sewer catchments
Culverts
Weirs
Land-use
Topographic data
### Some case studies carried out with Simgro model to support policy making

<table>
<thead>
<tr>
<th>Country</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poland</td>
<td>Biebrza wetland</td>
<td>Management tool for analysis of measures to ensure a sustainable situation of this wetland</td>
</tr>
<tr>
<td>Brazil</td>
<td>Pantanal-Taquari</td>
<td>Determine the impact of climate change and land use changes</td>
</tr>
<tr>
<td>Lithuania</td>
<td>Dovine Basin</td>
<td>To support the design of an integrated restoration and management plan</td>
</tr>
<tr>
<td>South Africa</td>
<td>Limpopo and Letaba</td>
<td>Small holder farming. Effect of upstream water use on downstream nature areas</td>
</tr>
</tbody>
</table>

### Argentina

Irrigated area in Argentina 1.35 mln ha (4.1% of country)

20% of irrigated land is in Prov. of Mendoza

- 70% irrigated with surface water
- 21% sprinkler irrigation
- 9% drip irrigation
Mendoza Province

MENDOZA RIVER IRRIGATED AREA

Irrigation water is allocated according to area with water rights

Problems
- water shortage (dry years)
- supplementary groundwater use
- over-irrigation (wet years)
- high water tables
- soil salinization
- crop productivity reduction
- environmental degradation
Irrigation network

Sometimes quite complex

Irrigation by flooding
<table>
<thead>
<tr>
<th>Irrigation of crops</th>
</tr>
</thead>
</table>

**MENDOZA RIVER BASIN**

Salinity modelling

Andes

Potrerillos new reservoir

Mendoza city

Mendoza irrigated system

Mendoza river

Saline soils
Question to be addressed by INA-CRA

1. What will be the consequences in the irrigated area of Mendoza River because of the construction of Portrerillos dam in the Andes mountains

2. Will the salinity level increase

Consequence of building the dam

1. Sediments are trapped in the dam
2. The irrigation water will be clear (no sediments)
3. Unlined canals will have less sediments on the bottom, thus the canals are more permeable and water can percolate to the groundwater
4. Groundwater levels become higher
5. More capillary rise
6. Consequence higher salinity
Objectives of study

To analyse basin behaviour because of construction Potrerillos storage dam:

• Hydrology (surface water and groundwater)
• Salt balance (soil & water)

• SIMGRO model calibration in the area irrigated by Mendoza river
• Performance indicators are used to quantify & qualify the irrigation and drainage water use
• Give present situation and after dam constructed

Construction Porterillos dam
Portrerillos dam

Before and after construction of the dam

Before:

After:
Irrigation canals

Tertiary and drainage canal
Irrigated area of Mendoza River

Image land-use

Areas irrigated by Mendoza and Tunuyan River
False color (red means irrigated land)          Zones

Modelling area was based on the irrigated areas (area 3400 km²)
Irrigation and drainage canals plus natural streams

- Irrigation System
- Superficial Drainage System
- Drainage System
- River
- Natural Stream
- Project Area

References

Model Simgro

Components:
- Nodes: 3685
- Distance: 1000 m * 1000 m
- Elements: 6986
- Subregions: 124
- 3 aquifers and 2 aquitards

Land use:
- grapes & fruit trees
- olives
- summer vegetables
- winter vegetables
- grass
- fallow
- urban area
Finite element network and the irrigation canals

Network has 3685 nodal points; approx. 1000 m apart.

SERIES DE SUELOS

I - Compuertas Maipú
II - Ciudad - Agrelo - Rodeo
III - Corralitos - Barcala
IV - El Sauce - Jocolí
V - Lavalle
VI - Tres Porteñas

Groundwater pumping wells in the area

Soil type: mean basic infiltration 1.3 – 7.3 mm.h⁻¹
Performance indicators

- To evaluate changes and feasibility of mitigation measures
- Performance indicators should include water delivery, water use efficiency, maintenance, irrigation sustainability, environmental aspects, socio-economics and management.

Performance indicators used

- Relative evapotranspiration (RET): *ratio between actual and potential evapotranspiration. It reflects to what an extent the potential evapotranspiration is met, and influences crop yield.*

  \[ D_F = \frac{ET_{actual}}{P + V_c} \]

  - *ET*<sub>actual</sub>: actual evapotranspiration by irrigated crops
  - *P*: precipitation
  - *V<sub>c</sub>*: volume of irrigation by surface- and groundwater

- Depleted fraction (DF): *relates water balance parameters for an irrigated area with each other in such a way that the manager knows the rate of change of groundwater level.*
MODEL CALIBRATION

The model was calibrated using groundwater levels, evapotranspiration, and salinity for 94/95 growing season.

Groundwater depth at node 2391
Simulated and measured soil electrical conductivity (salinity) at grape root zone subregion 408 (growing season 90-95).

Simulated and measured soil electrical conductivity (salinity) at root zone in different irrigated crops (growing season 90-95).
RESULTS OF PERFORMANCE INDICATORS

Relative evapotranspiration (RET) of agricultural technologies

Rate of change of groundwater table as a function of depleted fraction

\[ y = -0.2371x + 0.1418 \]
SCENARIO ANALYSIS

S0: present situation - S1: new scenario (more infiltration from the river bed and irrigation canals)

SCENARIO ANALYSIS

Relative evapotranspiration of agricultural land

S0: present situation and S1: new scenario
Conclusions and recommendations

- SIMGRO can be used in situations where changing conditions affect the hydrological system
- Irrigation practices can be simulated for a number of years with changing meteorological conditions and irrigation depths
- The increase of infiltration losses in the riverbed and canals will result in a rise of the groundwater table
- In the lower part of the basin a significant increment in salinity can be expected
- Future modelling must reveal an improved water distribution scheme using the performance indicators as a reference