Land Use Management: A Dryland Salinity Mitigation Measure (Western Cape, South Africa)

International Interdisciplinary Conference on Land Use and Water Quality
Reducing the Effects of Agriculture
The Hague, the Netherlands (10 June 2013 – 13 June 2013)

R.D.H. Bugan¹⁺², M. Fink³, T. Steudel³, B. Pfenning³, C. Fischer³, J. Helmschrot³, N.Z. Jovanovic¹, W.P. De Clercq²

¹ Council for Scientific and Industrial Research (CSIR), Stellenbosch (South Africa)
² Department of Soil Science, Stellenbosch University (South Africa)
³ Department of Geoinformatics, Hydrology and Modelling, Friedrich-Schiller-University Jena (Germany)
Background and Motivation

Min = 12.7 mS/m  
Average = 102.3 mS/m  
Max = 737 mS/m

Min = 4 mS/m  
Average = 813 mS/m  
Max = 1 780 mS/m

Min = 6.5 mS/m  
Average = 21.4 mS/m  
Max = 111.8 mS/m

Min = 0.5 mS/m  
Average = 10.8 mS/m  
Max = 42.6 mS/m

- The increase in salinity is a combination of naturally saline geology as well as land use change
- Land use change has resulted in DRYLAND SALINIZATION!
Aims of the Investigation

- To simulate the hydrology and salinity fluxes in the Sandspruit catchment with the JAMS/J2000 – NaCl semi-distributed hydrosalinity model
  - Model Parameterisation
  - Model Calibration (Manual and Automatic)

- Identify land use/management scenarios that would minimise the impacts of dryland salinisation on water resources in the Sandspruit catchment.
Description of the Sandspruit Catchment

- The Sandspruit river is a seasonal tributary of the Berg River
- It is located approximately 80 km north-east of Cape Town
- Land use is dominated by wheat cultivation (3 year land rotation)
- Man-made anti-erosion contours are evident throughout the catchment
- Semi-Arid climate (precipitation = 400 - 450 mm a⁻¹)
- Catchment actual evapotranspiration amounts to approximately 94% of precipitation
- Large quantities of soluble inorganic salts are stored in the regolith
Model Description

JAMS/J2000

- Simulates the water balance in large catchments.
- Hydrological Response Unit concept (overlay land use, geology and soils)
- Input Data: precipitation, temperature, wind speed, relative humidity, solar radiation and sunshine hours

JAMS/J2000 – NaCl

- Salinity modelling capability adopted from SWAT
- Additional land use and land management options (SWAT)
- Incorporates the effects of contour banks on the catchment hydrology
Model Set-Up

- The model was run for the period 2006 – 2011
- 2006 – 2008 = model initialisation
- 2009 – 2010 = model calibration
  - Manual calibration
  - Automatic calibration (OPTAS)
- 2011 = model validation
Model Results

Model Initialisation

Model Calibration
- Runoff Coefficient = 0.07 (2009) and 0.03 (2010)

Model Validation
- Data Errors
- Low Runoff Coefficient (0.006)
Dominance of Interflow from the shallow soil layers confirmed with other hydrograph separation techniques
The simulated and observed catchment precipitation was generally of the same order of magnitude.

Simulated catchment actual evapotranspiration ranged between 84 – 95% of the simulated precipitation.

Discrepancies in the magnitude were observed between the annual simulated and observed runoff in 2010 and 2011 which may be a function of the low runoff coefficient and errors in the observed dataset.

There was a good correlation between the annual simulated and observed salt output in 2009.
Scenario Simulations

- Recharge control has been identified as the dominant approach to mitigate the impacts of and control dryland salinisation, i.e. land use change from annual agricultural cropping systems to perennial vegetation

- Reduces groundwater recharge/infiltration and the subsequent mobilisation of stored salts

- Hydrological models have been the main tool with which to evaluate the effects of land use change scenarios

- A scenario may represent a land use option, a land management change or an engineering solution

- Each scenario is modelled over a fixed period of climatic data, with the differences between each being used to quantify the impacts of the scenario on the water balance, catchment hydrology and salinity

<table>
<thead>
<tr>
<th>Crop Name</th>
<th>Classification</th>
<th>Rooting Depth (m)</th>
<th>Maximum Canopy Height (m)</th>
<th>Optimal Temp. for Plant Growth (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed Forest</td>
<td>Tree</td>
<td>2</td>
<td>24</td>
<td>15</td>
</tr>
<tr>
<td>Evergreen Forest</td>
<td>Tree</td>
<td>2.5</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>Range Brush</td>
<td>Tree</td>
<td>2</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>Pasture</td>
<td>Perennial Vegetation</td>
<td>0.8</td>
<td>0.9</td>
<td>21</td>
</tr>
</tbody>
</table>
Increased Infiltration
Retention
Groundwater Recharge
Interflow
Salt Output

LEGEND
Et  Evapotranspiration
E   Evaporation
Cr  Capillary rise of soil water and groundwater
I   Infiltration and percolation
Sr  Surface runoff
Int Interflow
Gwf Groundwater flow
St  Salt transport and delivery
Sd  Salt discharge and output
Sa  Salt accumulation
Sg  Salt generation by weathering
--  Groundwater level

Flügel (1995)
Scenario 1: Simulating the effects of alternative land use/vegetation types in riparian zones
Scenario 2: Simulating the effects of alternative land use/vegetation types along contour banks
Scenario 3: Simulating the effects of alternative land use/vegetation types in areas which exhibit a high salt storage in the regolith zone
Scenario Simulation Results (Actual ET)

- The sensitivity of JAMS/J2000-NaCl is evident
  - different crop types (with rooting depth being the dominant factor)
  - different spatial distribution of the crops
- The shallower rooted crop types exhibited higher annual evapotranspiration rates (reduced annual runoff) when compared to deeper rooted species
  - Model does not have functionality to incorporate root water uptake from both shallow and deep soil layers
Scenario Simulation Results (Salt Output)

- The deeper root species exert a greater influence, i.e. reduction, on the catchment salt balance
- These crop types abstract water from the soil horizons where salt mobilization dominantly occurs
- The Evergreen Forest exerts the greater influence on the catchment water and salt balance. This species is most effective in minimising salt mobilisation when the lower more saline parts of the catchment are re-vegetated (Scenario 3)
  - 70% reduction in the catchment salt output in 2009
Conclusions

- The sensitivity of JAMS/J2000-NaCl semi-distributed hydrological model to different land uses and different spatial distributions of vegetation is evident.

- Of the vegetation types tested an Evergreen Forestry species (2.5 m rooting depth) exerted the greatest influence on the simulated hydrosalinity balance.

- This species was most effective in minimising salt leaching when the lower more saline parts of the Sandspruit catchment were re-vegetated (Scenario 3).

- This investigation provides evidence of the potential to use deep rooted perennial species to mitigate the impacts of dryland salinity.

- The importance of quantifying the spatially distributed catchment salt storage has been highlighted.

The landscape in the Sandspruit Catchment
Thank you for your attention!

Acknowledgements

- National Research Foundation (South Africa)
- Water Research Commission (South Africa)
- Federal Ministry of Education and Research (BMBF, Germany)
- Department of Water Affairs (South Africa)