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Salinization sources and management strategies in South Africa

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Highlights

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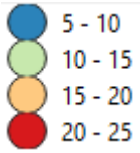
- The Crocodile River in South Africa is impaired by salinization issues.
- Salinization measured by riverine chloride concentrations is highly dependent on both point sources and diffuse sources from irrigation farming. For source characterization, the distinct functionalities between concentration and discharge from these two types of sources were employed.
- Irrigation is triggered when the soil water content is below a threshold. Two irrigation strategies were compared in terms of their impacts on salinization: a) irrigation to field capacity, and b) irrigation with a constant amount. The former method needed less water in total, and because the water source contained dissolved salts, gave less salinization problems.

Average observed chloride conc 1999-2008 (mg/l)



Crocodile River catchment

Acknowledgement: This work received funding from bilateral project (NV). Bartosova et al. Source to Sea: Tracing Causes of Water Quality Problems and Evaluating Potential Mitigation.

Crocodile River and HYPE

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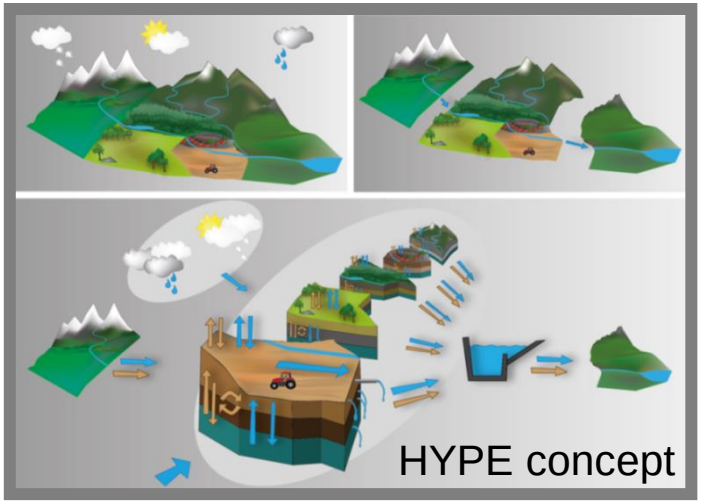
- Water quality in South Africa is declining, and salinization is caused by industrial effluents, mining, poor treatment of sewage, irrigation farming etc. [1]

- The Crocodile River in the northeastern part of the country has a catchment area of 10 400 km^2. It has extensive agriculture with production of sugar cane and other crops, involving large irrigated areas. [2]

- HYPE is a catchment-based model that simulates rainfall-runoff as well as water quality processes. Recently, an application was developed based on HYPE that covers almost the entire globe, World Wide HYPE [3]

- In this work, a salinization routine was developed in HYPE, whereby salt components follow all main natural hydrological pathways as well as irrigation using groundwater or river flow as a water source. The routine was applied to the Crocodile River, with characterization of sources and evaluation of mitigation strategies.



[1] Griffin et al. 2014. Critical Analysis of Environmental Water Quality in South Africa: Historic and Current Trends. Report to the Water Comission. Rhodes University.

[2] Slaughter et al. 2015. Development and application of a simple South African water quality model for management of rivers and reservoirs under current and future development and climate change scenarios. Water Research Comission Report No K5/2237/5

3. Arheimer et al. 2019. Global catchment modelling using World-Wide HYPE (WWH), open data and stepwise parameter estimation. Hydrol. Earth Syst. Sci. Discuss.

http://hypeweb.smhi.se/

Sources of salt (here, chloride shown)

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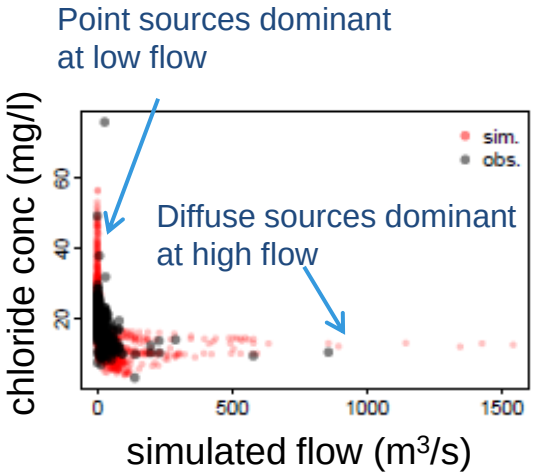
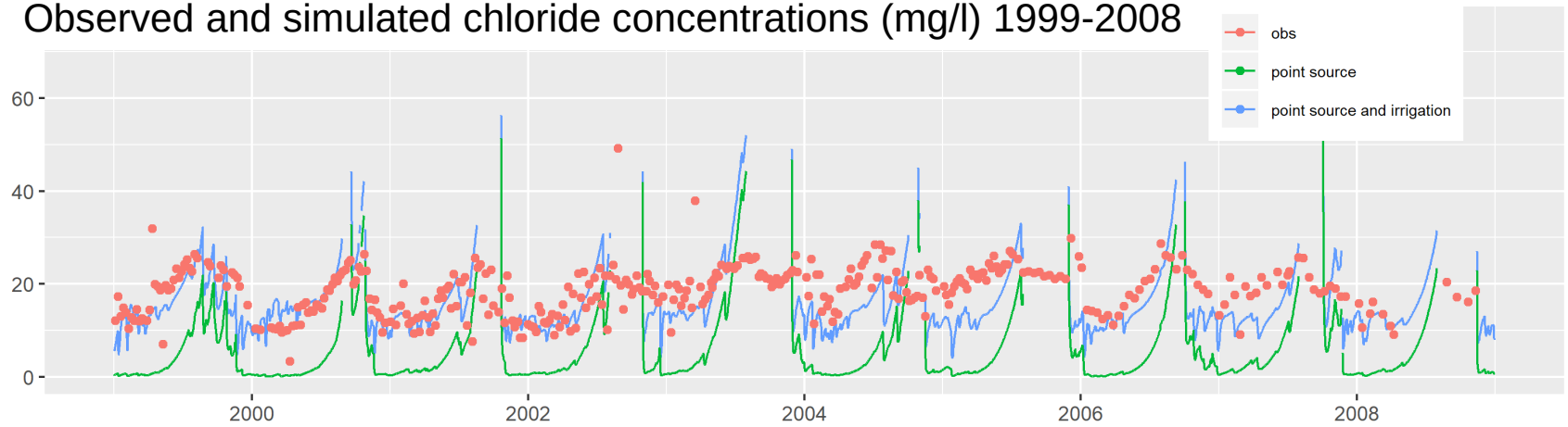
- Point sources as well as diffuse sources from irrigation farming must be calibrated due to lack of input.
- Sources were adjusted as follows:
  - Diffuse sources from irrigation farming dominate at high flows and are needed to reach the observed values around 10-15 mg/l at these conditions (fig below). They were adjusted by modifying the solubility limit.
  - Point sources from urban areas were added to provide sufficient increase in salt concentrations during low-flow conditions.
- The modified solubility limit in the model is lower than the literature value, accounting for subscale behavior not represented in the model (e.g. patches of salt rather than equal distribution)



Observed and simulated chloride concentrations (mg/l) 1999-2008

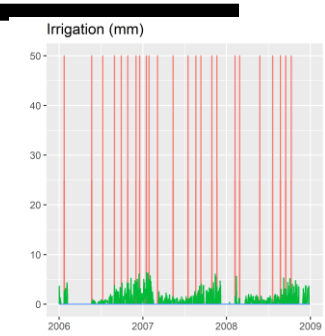


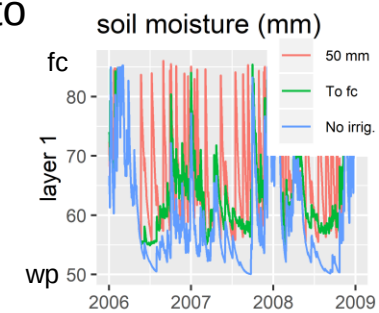
Management strategies

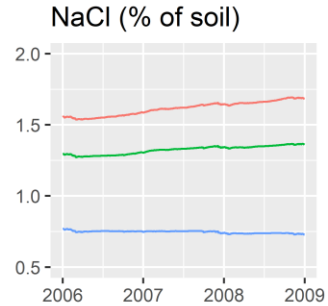
Experiment:

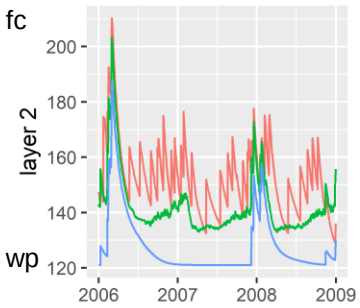
- Two irrigation strategies were compared to see the impact on salinization.
- Lowest water need mid Feb to late March (sugar cane)
- Simulation starts 1989 with 1 % NaCl mineral in the soil
- Irrigation water has concentration at the solubility limit to amplify the effects
- Irrigation is triggered by soil moisture below a critical (dynamic) threshold in soil layer 1 or 2 (root zone).

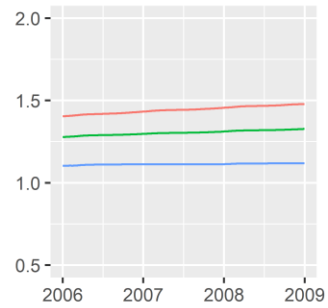
wp=wilting point
fc=field capacity

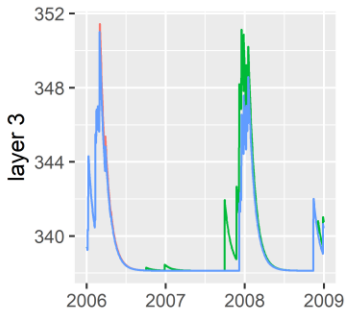


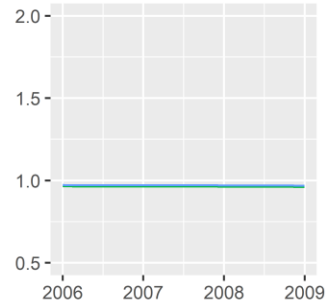












Results:

- NaCl is not depleted from the soil, i.e. soil water concentrations are at equilibrium
- No irrigation (blue): Overall reduction of NaCl due to rain.
- Irrigation to ”weighted” field capacity (green): Increased NaCl due to evaporation of irrigation water.
- Irrigation with 50 mm (red): More NaCl forms because 60 % more irrigation water was applied with this less optimized approach.