A Salinity Chemistry and Transport Module for SWAT

Ryan Bailey
Saman Tavakoli-Kivi
Xiaolu Wei

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Outline

1. The Salinity Problem
2. Development of Salinity Transport Module for SWAT
3. Application to Arkansas River Basin, Colorado
4. Future Work
The Salinity Problem

Salinity in Agricultural Groundwater Systems

Semi-Arid / Arid Agricultural Areas:

- Excessive irrigation
- Seepage from earthen canals
- Inefficient drainage systems
- Consequent evaporative concentration

High soil salinity
High groundwater salinity
Reduction in crop yield

The Salinity Problem

Salinity in Agricultural Groundwater Systems

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ucanr.edu/sites/Salinity/Salinity_Management/
The Salinity Problem

Salinity in Agricultural Groundwater Systems

Global Salt-Affected Soils

Wicke et al. (2011) *Energy and Environmental Science*

- 230 million ha of irrigated land \(\rightarrow\) 20-25% severe salinity
- Salt-affected area increases by 1-1.5 million ha / year
- 27-28% of irrigated land \(\rightarrow\) decline in crop productivity
The Salinity Problem

Watershed Salt Transport

(Salt = SO₄, Ca, Mg, Na, K, Cl, CO₃, HCO₃)

Objectives

1. Develop Salinity transport module for SWAT
2. Test model in an irrigated watershed
3. Assess Salinity and Crop Yield under changes in climate, land use, and water management strategies
Salinity Module for SWAT

Start

Read Inputs

Year Loop

Day Loop

Subbasins

Water and nutrient calculations for each subbasin

HRUs

Water and nutrient calculations for each HRU in the subbasin

Rainfall/runoff hydrology

Groundwater hydrology

Chemical equilibrium salt_chem

Irrigation loading salt_irrig

Nutrient soil leaching salt_lch

Crop growth soil salinity stress

Nutrient groundwater transport salt_gw

Lag nutrients and salt in surface runoff surfstor

Lag nutrients and salt in groundwater flow substor

Route Water

Route water, sediment, nutrients, and salt watqual through the stream network

Mass calculations salt_balance

End

• Initial soil / groundwater salt ion conc.
• Initial salt mineral content (%)
• Plant salt tolerance parameters

Threshold: the EC of soil saturated extract (ECe) when yield starts decrease.
Slope: % of yield decrease when ECe increased by 1 dS/m.

(Salt = SO₄, Ca, Mg, Na, K, Cl, CO₃, HCO₃)

1. CaSO₄
2. NaCl
3. CaCO₃
4. MgCO₃
5. MgSO₄
Application to Irrigated Regions

Lower Arkansas River Valley, Colorado

Colorado, USA
Application to Irrigated Regions

Lower Arkansas River Valley, Colorado

Colorado, USA
Application to Irrigated Regions

Lower Arkansas River Valley, Colorado

Colorado, USA

54,723 Soil Samples
Application to Irrigated Regions

Lower Arkansas River Valley, Colorado, USA
Application to Irrigated Region

- Relates total applied irrigation water to the volume diverted from the river, according to water rights
- Includes seepage from earthen irrigation canals to the shallow aquifer
- 1999-2009 simulation period
- Tested against streamflow at 5 gages (3 in River, 2 tributaries)

Application to Irrigated Region

Cultivated Field = HRU
Application to Irrigated Region

SWAT Model (Salinity)

- Initial gw salt ion conc. / salt mineral $\rightarrow$ based on field data / NRCS soil survey
- Initial soil water ion conc. / salt mineral $\rightarrow$ based on field data / NRCS soil survey
- Chemical equilibrium parameters $\rightarrow$ based on literature
- Mass loading of Salt ions (kg/day) at inlet $\rightarrow$ Gage data (flow, EC)
Application to Irrigated Region

Results
Arkansas River Concentration

- **SO$_4$ (mg/L)**
- **Cl (mg/L)**
- **TDS (mg/L)**
Results
Arkansas River Concentration

![Graphs showing concentration results for different substances over time.]

**SO₄** (mg/L)
- SWAT: Red line
- Observed: Black dots

**Cl** (mg/L)
- SWAT: Blue line
- Observed: Black dots

**TDS** (mg/L)
- SWAT: Green line
- Observed: Black dots

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**Application to Irrigated Region**

SWAT Model
Application to Irrigated Region

Results
Timpas Creek Concentration

- **SO$_4$ (mg/L)**
  - Timeline from 07/24/1998 to 11/18/2010
  - SWAT model results in red
  - Observed data as black dots

- **Cl (mg/L)**
  - Timeline from 07/24/1998 to 11/18/2010
  - SWAT model results in blue
  - Observed data as black dots

- **TDS (mg/L)**
  - Timeline from 07/24/1998 to 11/18/2010
  - SWAT model results in green
  - Observed data as black dots
Application to Irrigated Region

Results

Groundwater Concentration

SO$_4$ (mg/L)
Application to Irrigated Region

Results
Groundwater Concentration

TDS (mg/L)

SWAT Model

Relative Frequency

TDS concentration (mg/L)
Application to Irrigated Region

Results
Mass Balance Components (total salt)

- GW Irrigation: 10
- SW Irrigation: 35
- Runoff: 5
- Lateral Flow: 1
- Soil Profile: 61
- Aquifer: 830
- Dissolution: 28
- Perc.: 103
- Upflux: 45
- GW Loading: 94
- River: 351

Graph showing time series data for Loading (kg/ha) from 01/01/2006 to 01/01/2009.
Future Work

- Further Calibration and Testing of Model
- Further assessment of salinity stress on crop yield
- Assess Salt Transport and Crop Yield under changes in climate, land use, and water management strategies