Modeling Irrigation Systems in Semi-Arid Regions: Current Status & Emerging Needs for SWAT

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Irrigated Stream-Aquifer Systems

- Irrigation Water
- Salts, N, P
- Soil Salinity

- Water Table
- Seepage
- NO$_3$
- FeS$_2$
- Shale Bedrock
- SO$_4$

- Canal
- Salts, N, P
- Pumps
- Alluvial Aquifer
Motivation

Simulate water flow and solute transport in irrigated watersheds, under varying management scenarios.

- Effect of high water tables on crop yield (waterlogging; soil salinity)
- Effect of high water tables on municipal infrastructure
- Water rights: Effect of groundwater pumping on nearby streams
- Irrigation groundwater return flows to streams
- Nutrient leaching: effect on groundwater quality, loadings to streams
- Groundwater salinity: effect on groundwater quality, loading to streams
Outline

1. Irrigation Patterns
2. Salinity (Soil, Groundwater, Loading to Streams)
3. Tile Drains ("Drainsheds")
4. Water Rights: Groundwater vs. Surface Water
Irrigation Patterns

Lower Arkansas River Basin

- Irrigation: Canals (earthen)
- Irrigation: Groundwater Pumping
- Canal seepage
Irrigation Patterns

Lower Arkansas River Basin

- Irrigation: Canals (earthen)
- Irrigation: Groundwater Pumping
- Canal seepage

Salinity

Tile Drains

Water Rights
Salinity

Semi-arid agricultural areas:

- Excessive irrigation
- Seepage from earthen canals
- Inefficient drainage systems
  - Evaporative concentration

  High soil salinity
  High groundwater salinity

  Reduction in crop yield
Salinity

Lower Arkansas River Basin

Irrigation Patterns

Salinity

Tile Drains

Water Rights
Salinity

Lower Arkansas River Basin
Salinity

Lower Arkansas River Basin

Irrigation Patterns

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Salinity

Lower Arkansas River Basin

Groundwater Salinity

No. of Samples

$C_{TDS}$ (mg/L)

2 values greater than 20000
Estimated Maximum to Prevent Crop Loss ~ 900 mg/L

Freshwater Limit (WHO)
Salinity

Assess Impact of BMPs on Salinity

- Soil Salinity
- Groundwater Salinity
- Salt loads to River

Modeling: Groundwater Flow and Transport Model

MODFLOW

+ RT3D

1. Sulfur Cycling
2. Major Ion Chemistry
3. Precipitation-Dissolution
Assess Impact of BMPs on Salinity

- Soil Salinity
- Groundwater Salinity
- Salt loads to River

**Modeling:** Groundwater Flow and Transport Model

SO$_4$ Groundwater concentration
Salinity

Assess Impact of BMPs on Salinity

- Soil Salinity
- Groundwater Salinity
- Salt loads to River

Modeling: Groundwater Flow and Transport Model

**SWAT** (SWAT-MODFLOW) **Salinity Module**
Tile Drains

Loading of: **Salt**
**Nutrients** (N,P)
**Trace Metals** (Se, U)
Tile Drains

Modeling

MODFLOW Conduit Flow Package

MT3D CFP (Solute Transport)

→ SWAT capabilities for Tile Drain Flow
Water Rights

The use of water in many of the states in the western U.S. is governed by the doctrine of Prior Appropriation. (also known as the "Colorado Doctrine" of water law)

Allocation of Water = “First in Time, First in Right”

South Platte River Basin
By 1965: 10,000 wells drilled in South Platte Basin
- 2003 (drought): 3,000 not allowed to pump
- May 7, 2006: 440 wells shutdown
Water Rights

Augmentation Plans

1. Pump Groundwater
2. Estimate Stream Depletion
3. Add recharge water to mimic return flows to stream

(Adapted from USGS)
Water Rights

South Platte River

Stream Depletion

Irrigation Patterns

Salinity

Tile Drains

Water Rights
Water Rights

Recharge Ponds

Irrigation Patterns

Salinity

Tile Drains

Water Rights
Water Rights

Augmentation Plans

Pump Groundwater → Estimate Stream Depletion → Add recharge water to mimic return flows to stream

MODELING

Glover Model (1D Analytical)

MODFLOW

SWAT (SWAT-MODFLOW)

Irrigation Patterns

Salinity

Tile Drains

Water Rights
Summary

To use SWAT in Irrigated Stream-Aquifer Systems:

1. Irrigation Patterns
2. Salinity (Soil, Groundwater, Loading to Streams)
3. Tile Drains (“Drainsheds”)
4. Water Rights: Groundwater vs. Surface Water

- SWAT+ (object connections)
- SWAT-MODFLOW-RT3D
Questions