SWAT+ Future Developments

Strasbourg 2024

My Plans

- I plan to retire from USDA at end of calendar year and work part time with Texas A&M. Continue in model support role.
- Nancy will continue with A&M and go part time in the future
- January 1, 2025 - Nancy and I will go into support mode

Community Model

- We need 1 person with overall understanding and responsibility for model development and support
- With current software development tools (GitHub), multiple developers can efficiently collaborate
- Other key developers need to commit time for model support

Future Role in Model Support

- Taci Ugraskan – ARS Support Scientist. Expertise in GIS, picked up SWAT fortran code quickly and is currently working with users, running national scale SWIFT model, starting on documentation.

Software Support

- Olaf David – Setting up GitHub. Working on making SWAT+ a true community model. Archive, compare and merge, document, automate output comparison with previous versions. Will require time and good communication between model developers.

Future Roles in SWAT+ Development

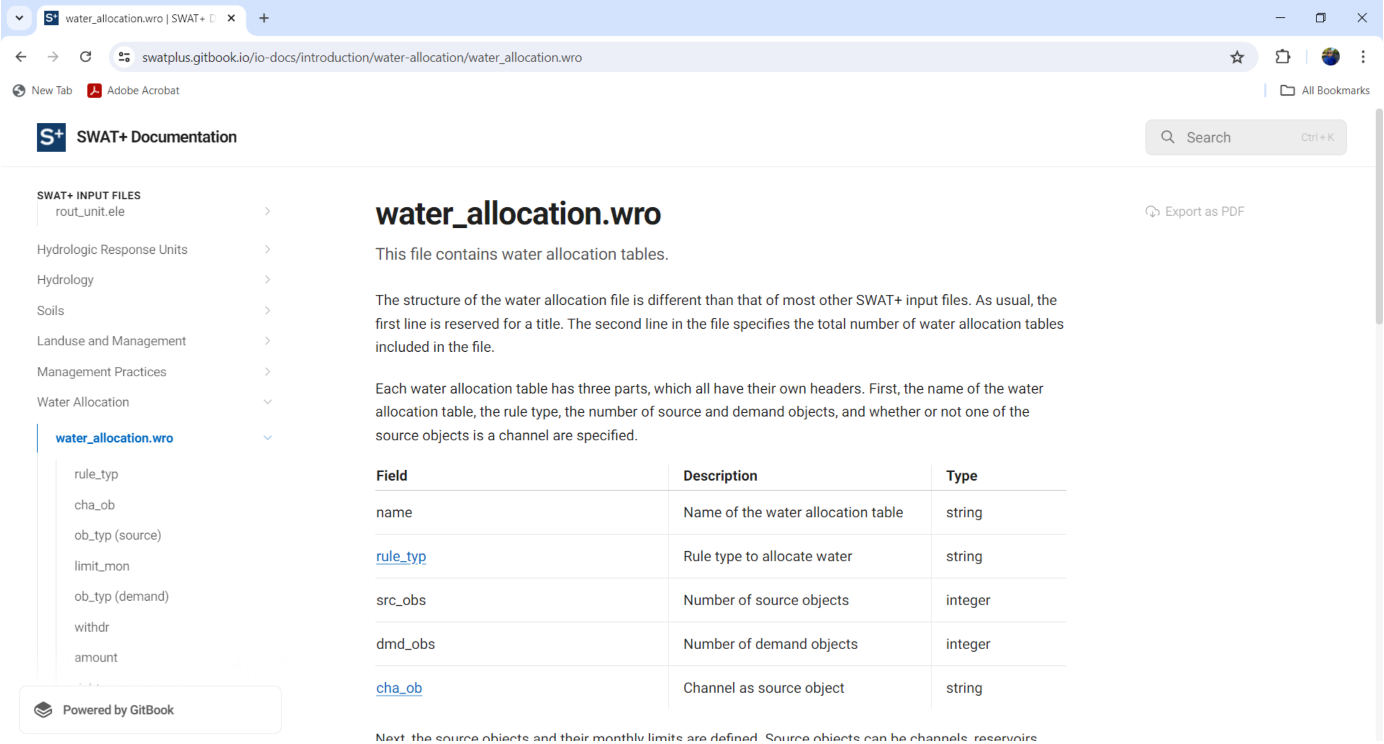
- Natalja Cerkasova – A&M Temple – plant growth and management, routing structure, etc. Pathway for her to become ARS scientist
- Mike White - ARS Temple – phosphorus, in-stream nutrients, structural practices
- Kelly Thorp - ARS Temple – crop growth and water management
- Jaehak Jeong - A&M Temple– rice paddy management, urban bmp's
- Ryan Bailey - Colorado State – groundwater, salt, metals

SWAT+
SOIL & WATER ASSESSMENT TOOL

Documentation

Git Books

- Katrin developed input/output documentation in GitBooks
- Translated the SWAT2012 theoretical documentation into Git Books
- Integrate theory and i/o and ultimately link code documentation
- Easy to update – multiple contributors


water_allocation.wro | SWAT+

swatplus.gitbook.io/io-docs/introduction/water-allocation/water_allocation.wro

SWAT+ Documentation

SWAT+ INPUT FILES
rout_unit.ele
Hydrologic Response Units
Hydrology
Soils
Landuse and Management
Management Practices
Water Allocation
water_allocation.wro
rule_typ
cha_ob
ob_typ (source)
limit_mon
ob_typ (demand)
withdr
amount

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Export as PDF

water_allocation.wro

This file contains water allocation tables.

The structure of the water allocation file is different than that of most other SWAT+ input files. As usual, the first line is reserved for a title. The second line in the file specifies the total number of water allocation tables included in the file.

Each water allocation table has three parts, which all have their own headers. First, the name of the water allocation table, the rule type, the number of source and demand objects, and whether or not one of the source objects is a channel are specified.

Field	Description	Type
name	Name of the water allocation table	string
rule_typ	Rule type to allocate water	string
src_obs	Number of source objects	integer
dmd_obs	Number of demand objects	integer
cha_ob	Channel as source object	string

New SWAT+ Developments

- Groundwater, salt, metals
- Water allocation
- Carbon
- Rice paddies
- Flood Plain Wetlands

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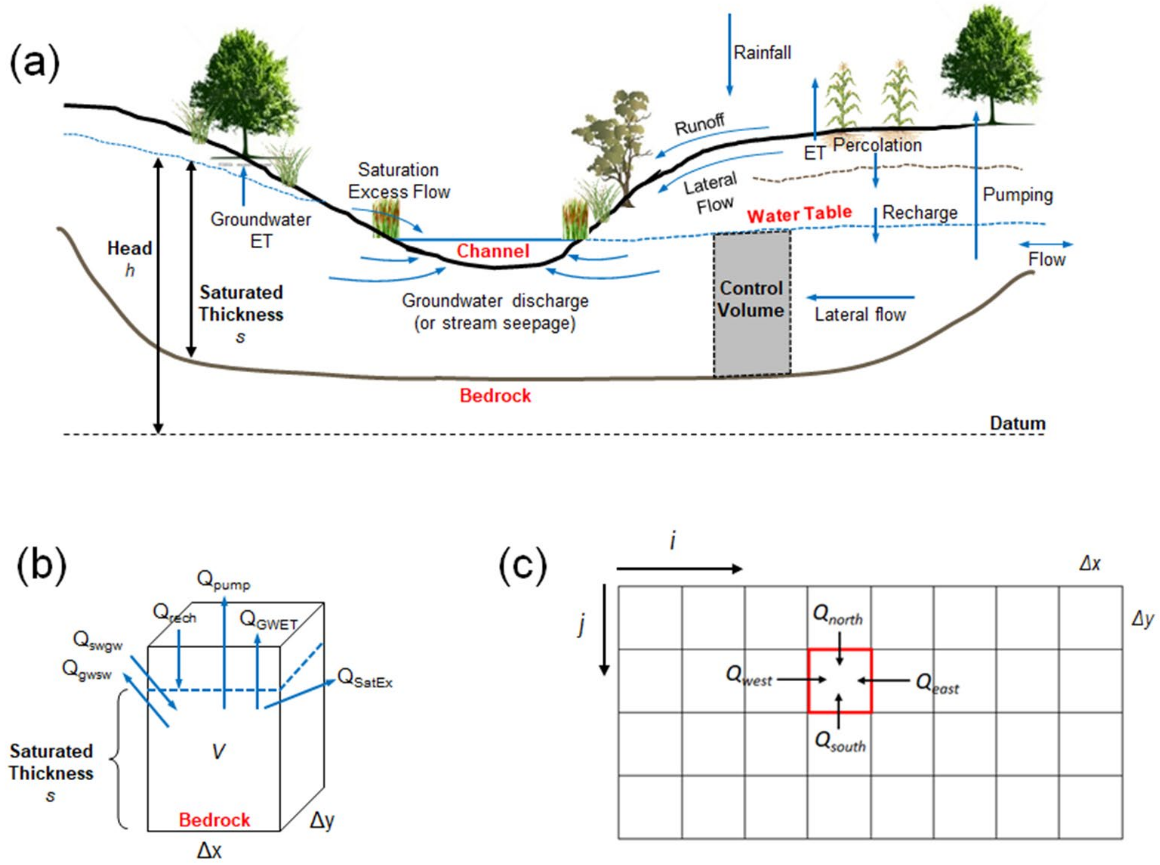
Groundwater Model

GWFLOW – Ryan Bailey

- Physically-based spatially-distributed groundwater flow module called *gwflow*
- Groundwater head and storage are solved using a water balance equation for each grid cell.
- Adds 2-3X to run times
- Interface and global data are available



Ryan T Bailey, Katrin Bieger, Jeffrey G Arnold, David D Bosch
"A new physically-based spatially-distributed groundwater flow module for SWAT+"

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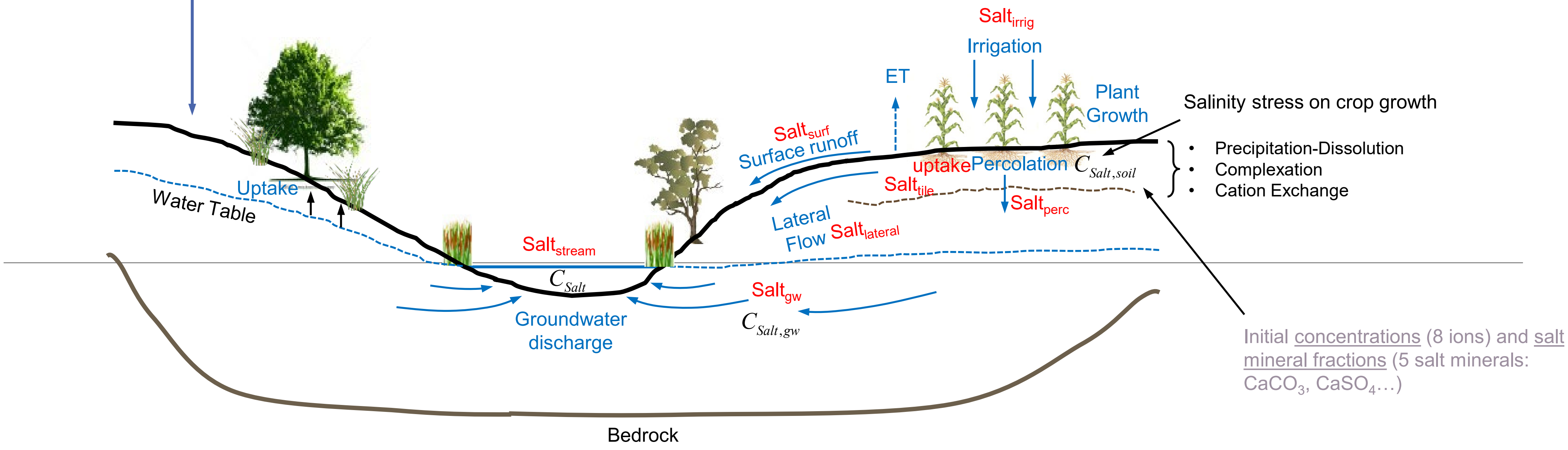
Watershed Salt Transport

External Loadings

1. **Atmospheric Deposition** (rainfall)
2. **Road Salt** (winter weather)
3. **Point Sources** (e.g. WWTP, industry)



Salt = SO_4, Ca, Mg, Na, K, Cl, CO_3, HCO_3

Also: salt mass and concentration in reservoirs/ponds/wetlands

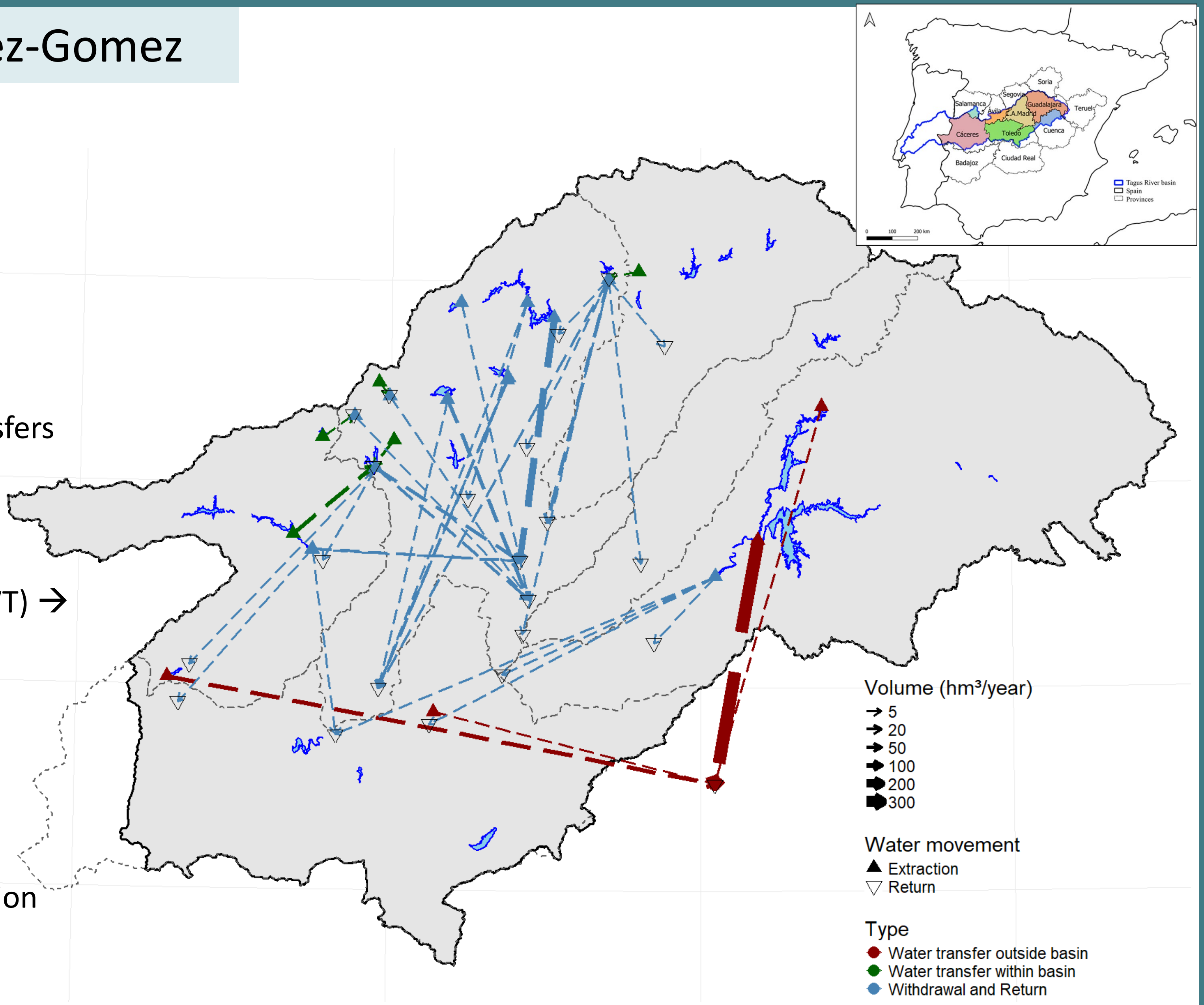
Water Allocation - Alejandro Sanchez-Gomez

Water movements simulation: Water transfers

- Configuring the water allocation file.

A) Define source and demand objects.

- **Source objects** → Reservoirs where water transfers are located.
- **Demand objects** identification:
  - Water diverts outside the basin (e.g., TSWT) → Non SWAT objects (arbitrary).
  - Water transfers (between reservoirs) → Receiver reservoirs.
  - Transfers for human consumption → 17 receiver points (channels) were defined according to the WWTPs/discharges location and volumes.



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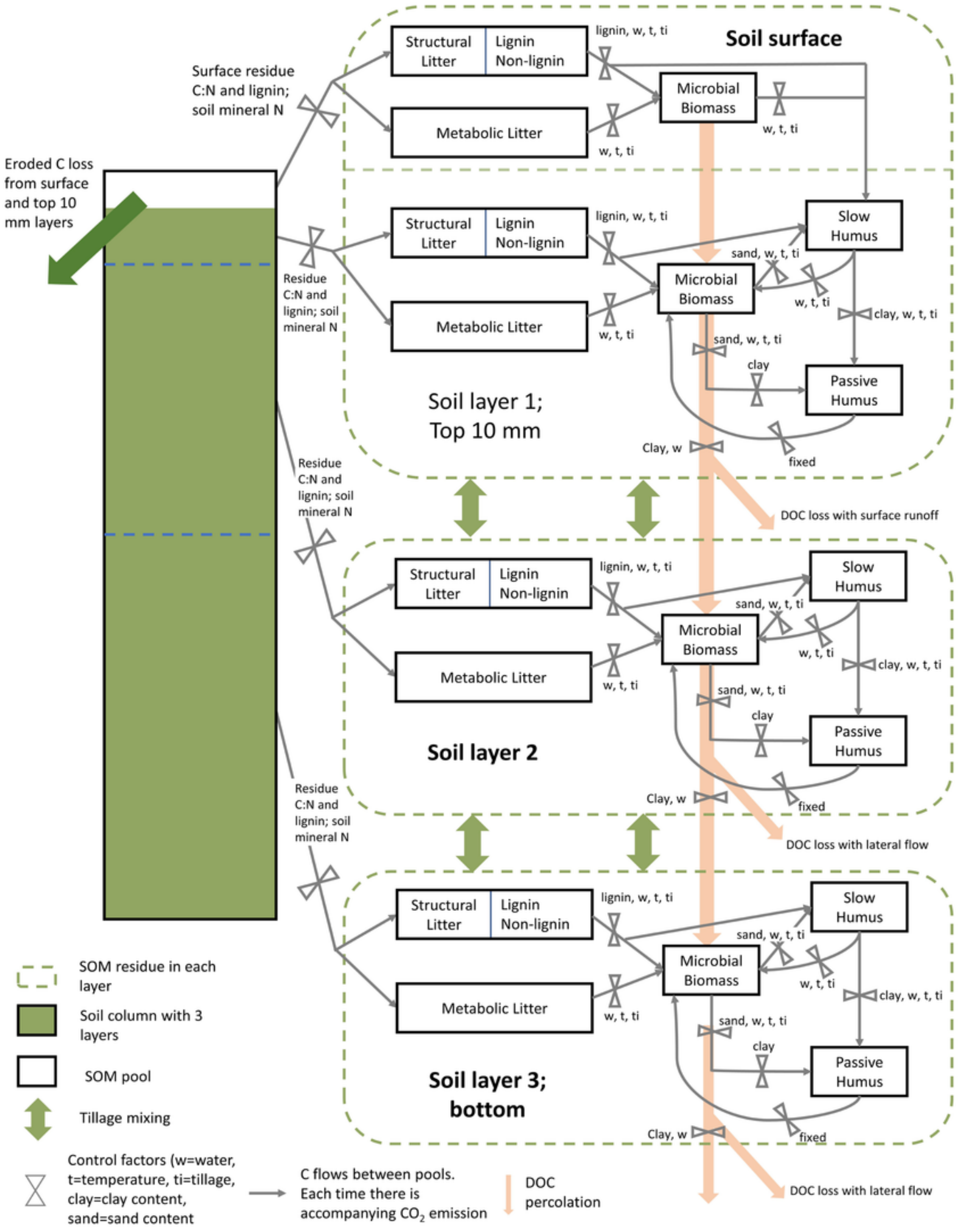
Carbon Model

SWAT-C

- Xuesong Zhang USDA-ARS has developed and is supporting SWAT-C
- Plans to incorporate into SWAT+. Organic object will make cleaner code – require modifications from SWAT
- Soil carbon budget and sequestration.
- Plant growth and management impacts
- Transport in channels and reservoirs



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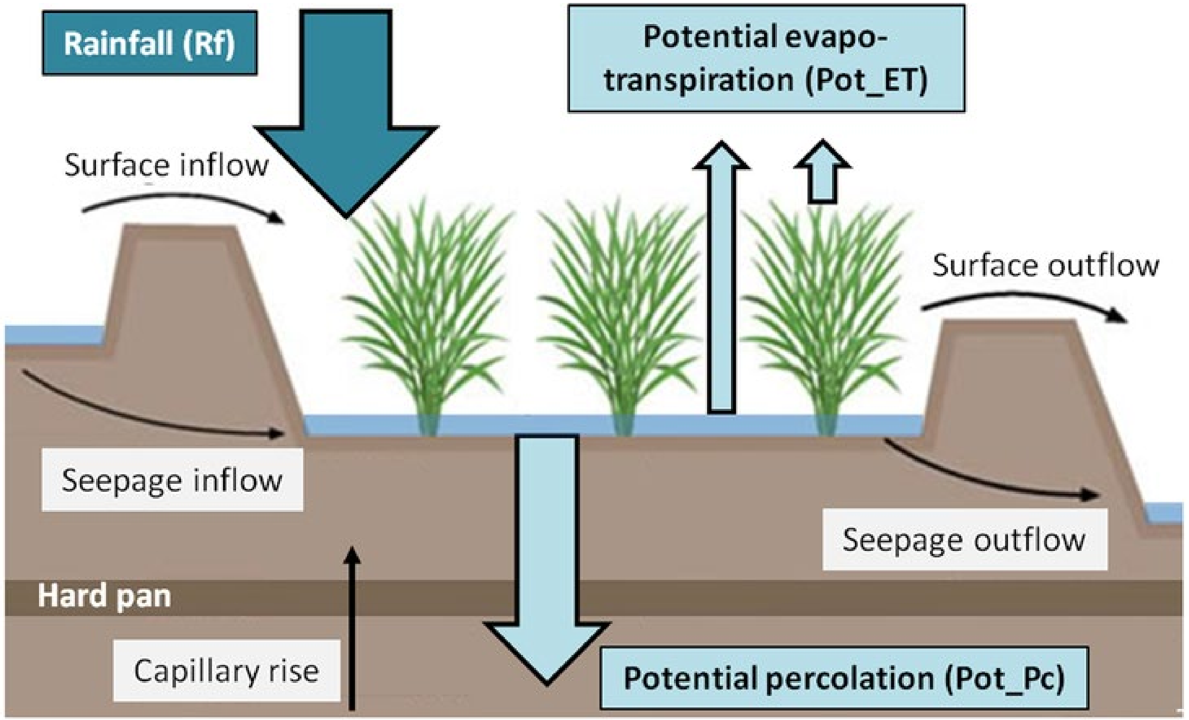
Rice Paddy Management

Rice Paddy

- Jaehak/Phil and international team
- Management – puddling, transplanting, nutrient and pesticide applications
- Dynamic changing of weir height
- Integrating with Water Allocation model



Flood Plain Wetlands

- Interaction between flood plain and uplands, flood plain and channel, and wetland storage and flood routing in the flood plain

Large Wetlands Representation in SWAT+: the case of the Pantanal in the Paraguay River Basin

Osvaldo Luis Barresi Armoa, Jeffrey G. Arnold, Katrin Bieger, Sabine Sauvage, and Jose Miguel Sanchez-Perez

Thanks – appreciate everyone's efforts

SWIFT – Simple Watershed Integrated Forecasting Tool

- Export Coefficients for loading
- Uses SWAT+ routing structure – same connect files – same channel and reservoir inputs
- SWIFT run generated by SWAT+ or use output from other models (APEX, SPARROW) or measured data
- Routines for reservoir and channel routing – routes mean flow and uses flow duration curve
- Model with 10,000 hru runs in 10 seconds
- Scenario analysis – approach used in Mississippi River Basin analysis and in Chesapeake Bay Model

SWIFT – Scenario Watershed Integrated Forecasting Tool

- Uses SWAT+ routing structure – same connect files – same channel and reservoir inputs
- SWIFT run generated by SWAT+ or use output from other models (APEX, SPARROW) or measured data
- Routines for reservoir and channel routing – routes mean flow and uses flow duration curve
- Model with 10,000 hru runs in 10 seconds

HRU Export Coefficients – Average Annual

Runoff mm	Sediment t/ha	Organic N kg/ha	Sediment P kg/ha	Nitrate kg/ha	Soluble P kg/ha	
257.9	0.81	0.41	0.13	11.10	0.8889	Total runoff
71.87	0.00	0.00	0.00	5.64	0.00	Percolate
25.26	0.81	0.41	0.13	1.15	0.8889	Surface runoff
47.47	0.00	0.00	0.00	3.80	0.00	Lateral flow
185.2	0.00	0.00	0.00	6.14	0.00	Tile flow

–

Output – ave annual sediment and nutrients

- Landscape loadings – by subbasin and land use
- Channel – bank and bed erosion, flood plain deposition
- Reservoir – inflow/outflow, trapping efficiency

Scenarios

- Climate – annual precipitation and PET
- Land use – complete change (ag -> forest) or BMP efficiency
- Channels – dimensions, bed/bank material, vegetation
- Reservoir – size, trapping efficiency

Documentation

- Katrin – Model Inputs and Outputs in GitBooks
- SWAT2012 Theoretical Documentation in GitBooks
- GitHub for code documentation

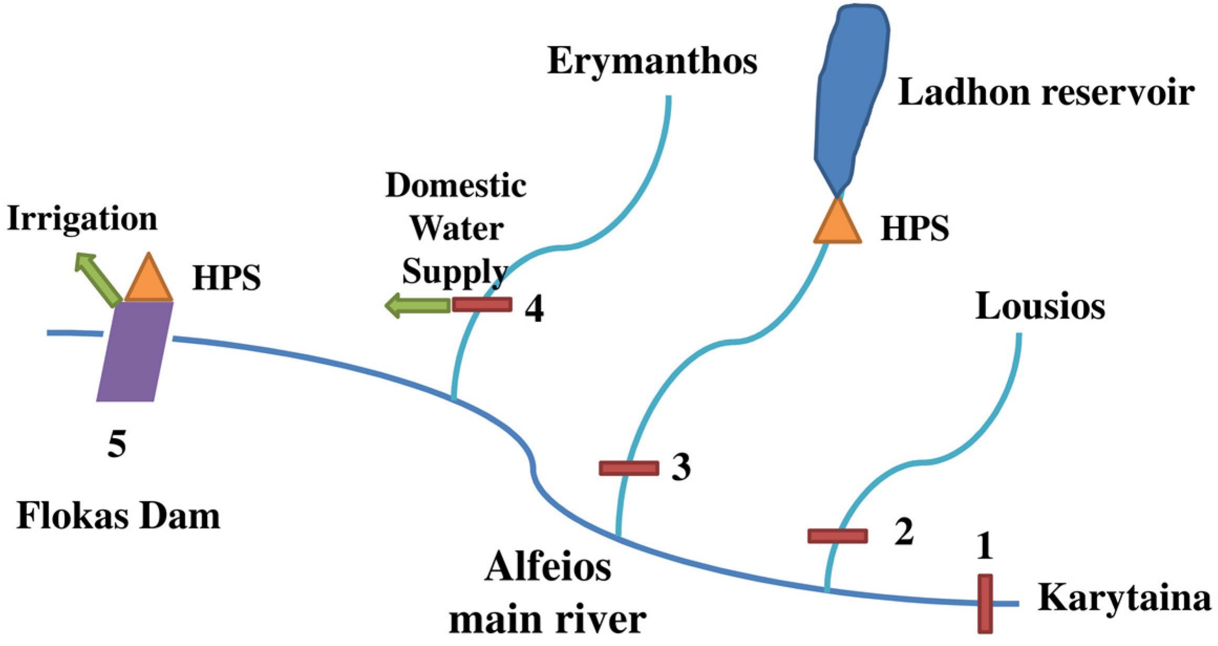
Water Allocation

Source Objects

- Reservoir
- Aquifer
- Channel
- Unlimited source
- No limit on number of objects

Monthly Minimum For Withdrawals

- Reservoir – fraction of principal spillway volume
- Aquifer – water table depth
- Channel – minimum flow
- Unlimited source – no limits



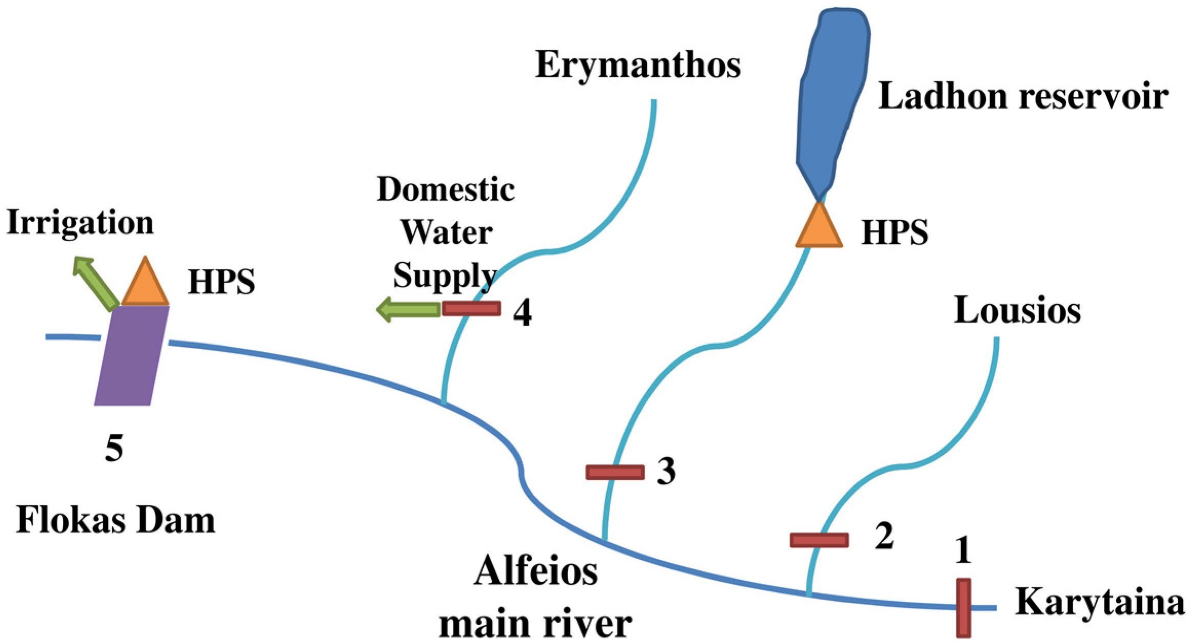
Water Allocation

Demand Objects

- Municipal and Industrial – input constant daily amount or decision table to specify daily withdrawals
- HRUs for irrigation – based on irrigation demand. Triggered by water stress or soil moisture deficit in decision table.

Link to Sources

- Take water from multiple source objects
- Input fraction from each source – 75% gw, 25% res
- Can source compensate if other sources are limiting
- Output withdrawal from each source and when demand was not met



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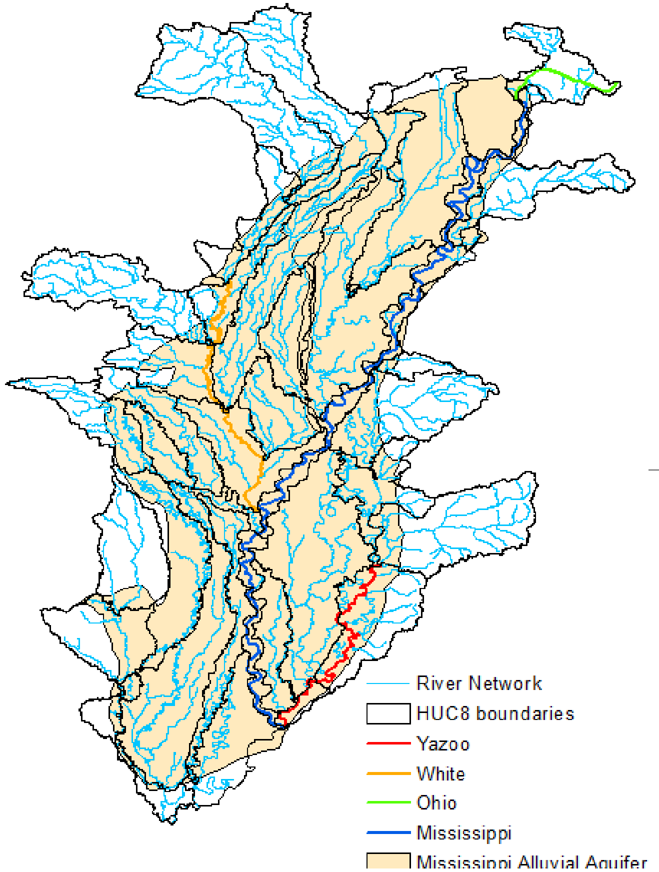
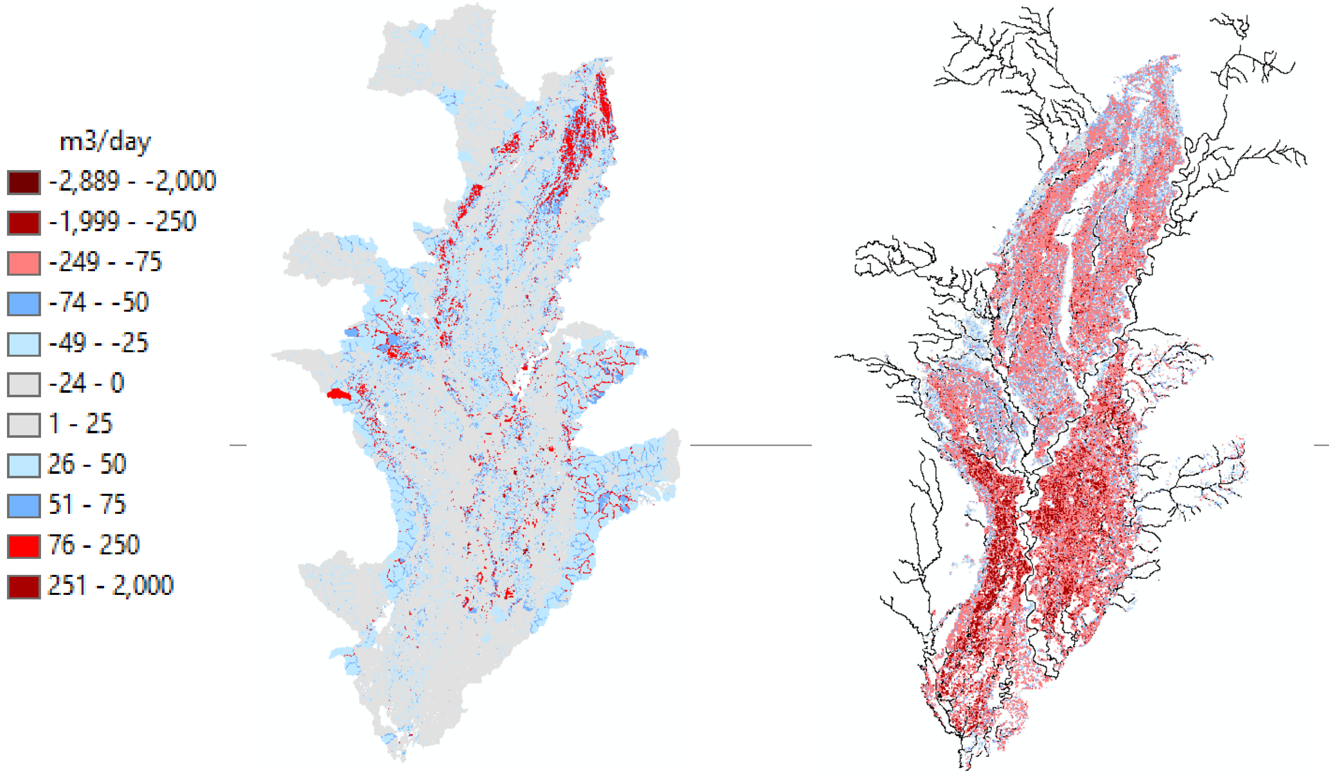
Example with National Agroecosystem Model

Mississippi Alluvial Plain
(intense groundwater irrigation)

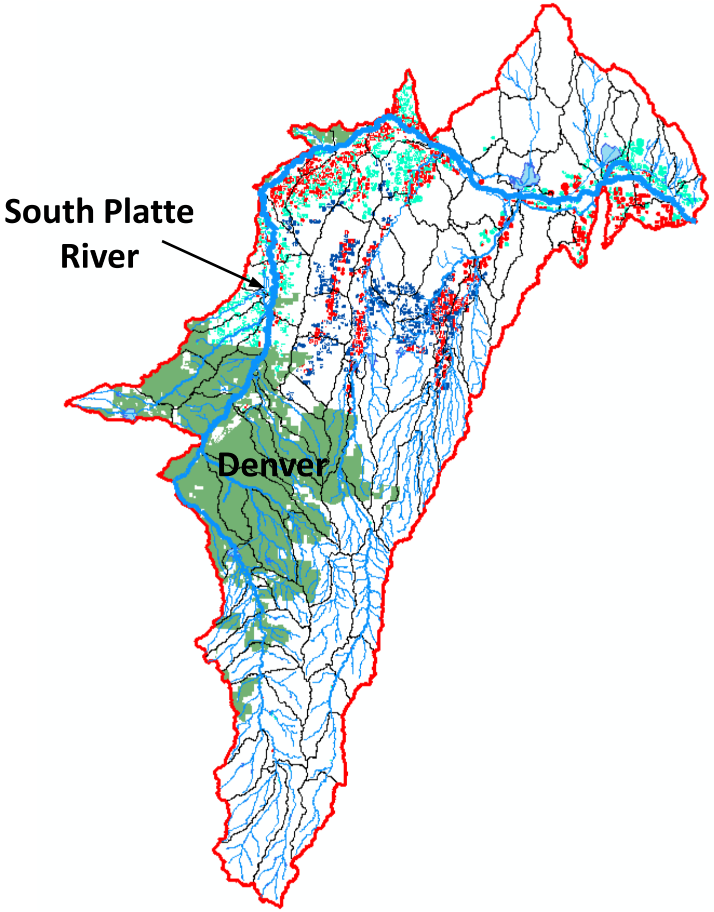


Recharge **Pumping**



Example with National Agroecosystem Model

Middle South Platte – Cherry Creek
(HUC8 10190003)



Salinity Module

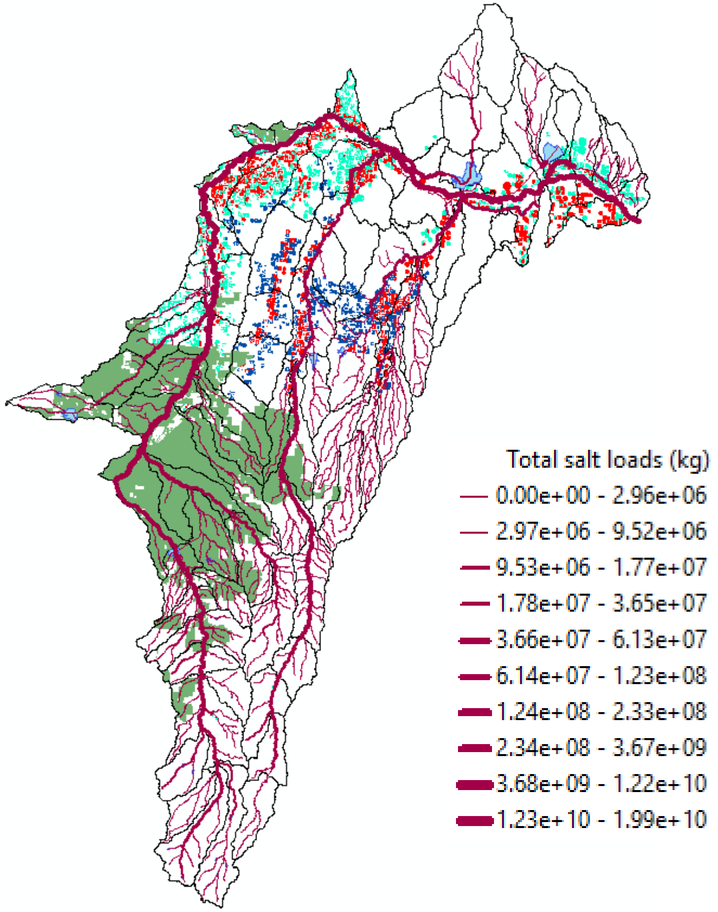
Account for:

- Salt minerals in soil profile
- Salt in aquifer
- Salt in rainwater
- Salt in applied road salt (winter)
- Salt in WWTP effluent (Denver)
- Salt in tributary inflows

Track salt mass and concentration in each spatial object:

- HRU soil profile
- Aquifer
- Reservoir / wetland
- Channel
- Routing Units

Check results for salt mass balance
Test model for in-river salt loads



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Pesticide Model

- Hendrik - complete fate and transport, updated database, daughter compounds, more complete output files
- Hendrik is currently adding plant uptake
- Rice paddy application

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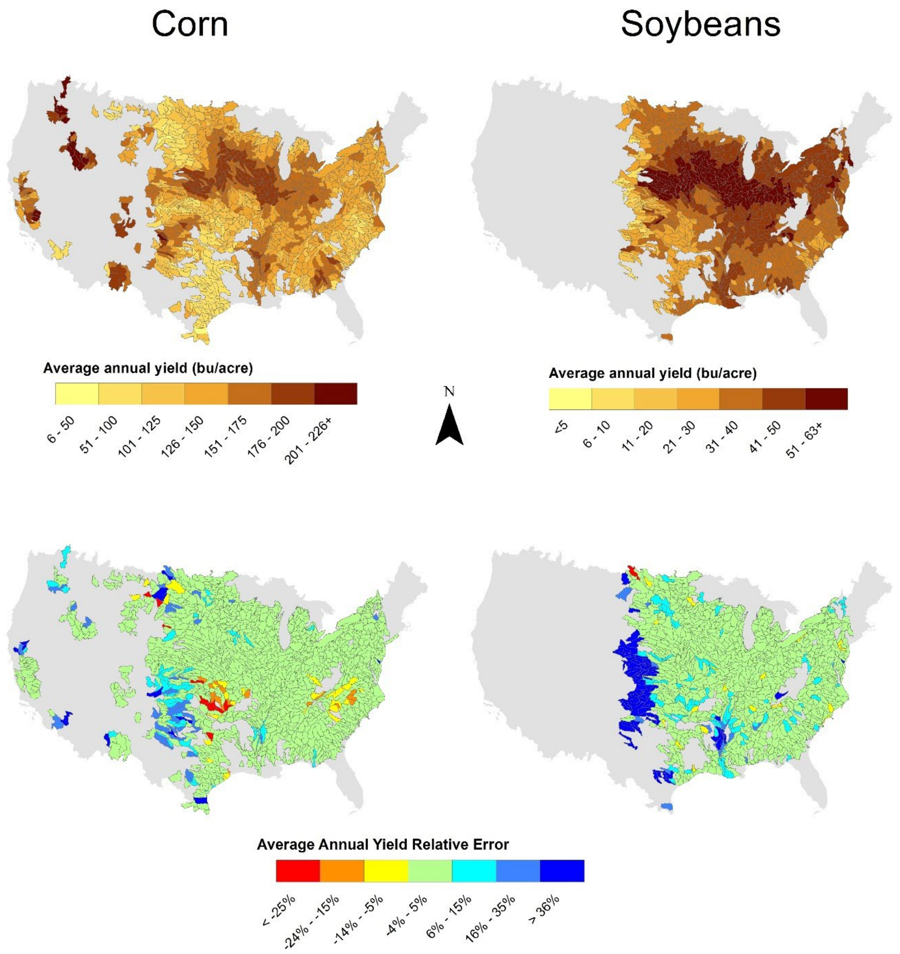
Plant Growth and Management

- Natalja and Temple Team - Crop yield soft calibration – National scale corn and soybeans
- Tassia/Phil - Plant parameters for fruits and vegetables
- Tadesee - Tropical plant growth



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Urban Water Allocation

Mazdak Arabi and Sybil Sharvelle at Colorado State

Local Water Sources

- ➢Urban Water Demand
- ➢Urban Water Reuse
- ➢Wastewater, Greywater
- ➢Stormwater, Runoff

Monthly Minimum For Withdrawals

- ➢Urban water demand/consumption model
- ➢Integrated land use and water supply planning model. Gray and green stormwater infrastructure model
- ➢Synthetic water distribution network model

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Manure Allocation

Status - Conceptual
- Cibin Raj – Penn State
- Started with Water Allocation module

Source Objects
- Feedlots, Confined Animal Feeding Operations
- Composting centers

Manure Applications
- Use decision tables to condition applications
- Condition on soil phosphorus concentrations
- Condition on distance from source

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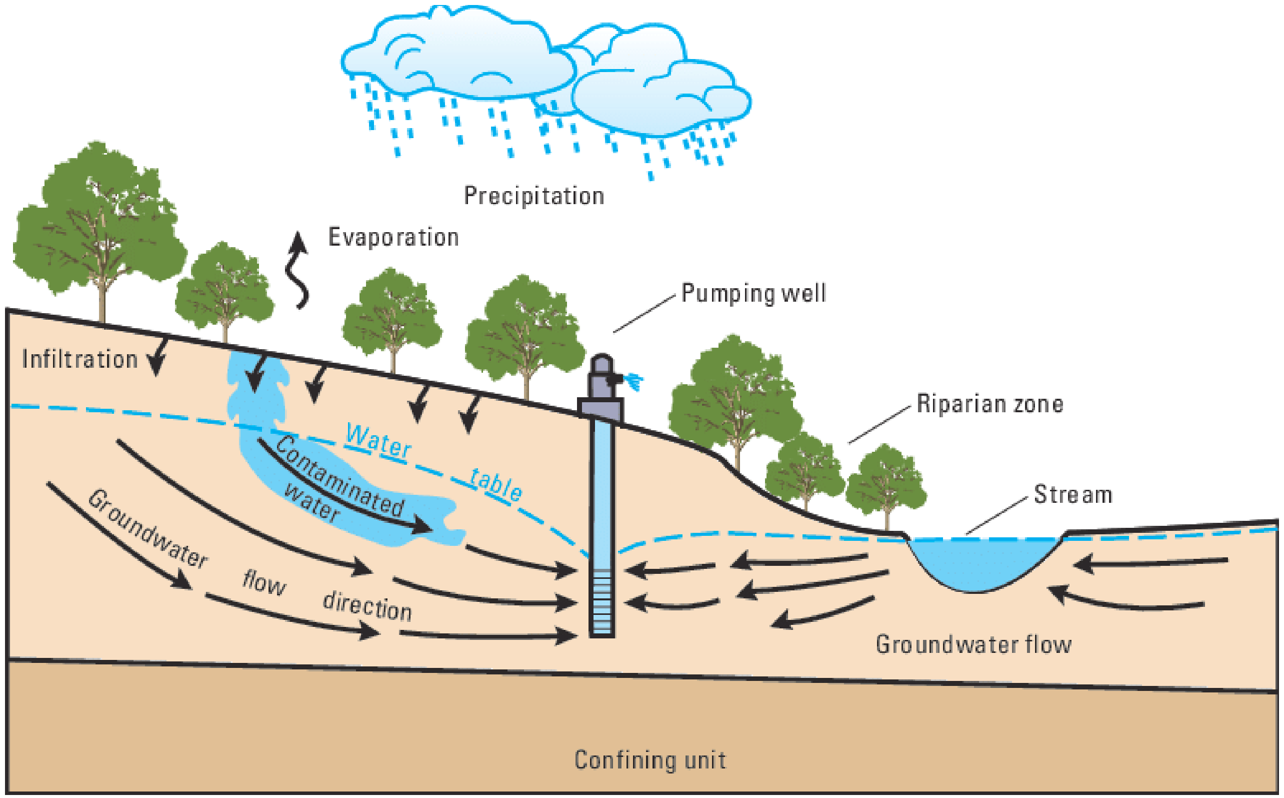
Groundwater Model

Existing Lag Model

- Input depth of aquifer and initial depth to groundwater
- Input depth of revap (related to root depth) and depth to sustain flow (related to channel depth). Specific yield becomes sensitive parameter
- Provides physical meaning to the input parameters



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Plant Growth and Management

- Organic Objects to partition plants – and soil and residue
- Partitioning is transparent and allows realistic harvest operations – grain, biomass, root, biomass+root, residue

```
type organic_mass
    real :: m = 0.        !kg/ha     |total object mass
    real :: c = 0.        !kg/ha     |carbon mass
    real :: n = 0.        !kg/ha     |organic nitrogen mass
    real :: p = 0.        !kg/ha     |organic phosphorus mass
end type organic_mass
```

```
type plant_community_mass
    character(len=4) :: name
    type (organic_mass), dimension(:), allocatable :: tot      !kg/ha    |total biomass for individual plant in community
    type (organic_mass), dimension(:), allocatable :: ab_gr    !kg/ha    |above ground biomass for individual plant in community
    type (organic_mass), dimension(:), allocatable :: leaf     !kg/ha    |leaf mass for individual plant in community
    type (organic_mass), dimension(:), allocatable :: stem     !kg/ha    |wood/stalk mass for individual plant in community
    type (organic_mass), dimension(:), allocatable :: root     !kg/ha    |root mass for individual plant in community (by soil layer)
    type (organic_mass), dimension(:), allocatable :: seed     !kg/ha    |seed (grain) mass for individual plant in community
end type plant_community_mass
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SWAT+
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Decision Tables

Precise, compact way to model complex rule sets and their corresponding actions

CONDITIONS	**ALTERNATIVES**
ACTIONS	**ACTION ENTRIES**

Actions

irrigate
reservoir release
fertilize
plant
harvest
tillage
drainage
lu_change
structural practices

Alternatives

< > =

Action Entries

yes no

Conditional Variables

soil_water	soil_p
w_stress	n_applied
month	biomass
jday	cover
hu_plant	lai
hu_base0	vol
year_rot	flow
year_cal	lat
year_seq	long
prob	elev
land_use	day_len
ch_use	plant
n_stress	plant_type
soil_n	

Decision tables

Precise, compact way to model complex rule sets and their corresponding actions

Current Uses in SWAT+

- Land management
- Reservoir release
- Land use updates
- Scenario Analysis

- Land Use updates – land use change, structural practice changes
- Decision tables can be easily maintained and supported

Auto Irrigation Example

Name	Conditions	Alternatives	Actions			
auto_irr	1	1	1			
VAR	OBJ	OB_NUM	LIM_VAR	LIM_OP	LIM_CONST	ALT1
w_stress	hru	0	null	-	0.8	<
ACT_TYP	NAME	OBJ	OB_NUM	TYPE	CONST	OUTCOME
irrigate	stress_0.8	hru	0	sprinkler	25.	y

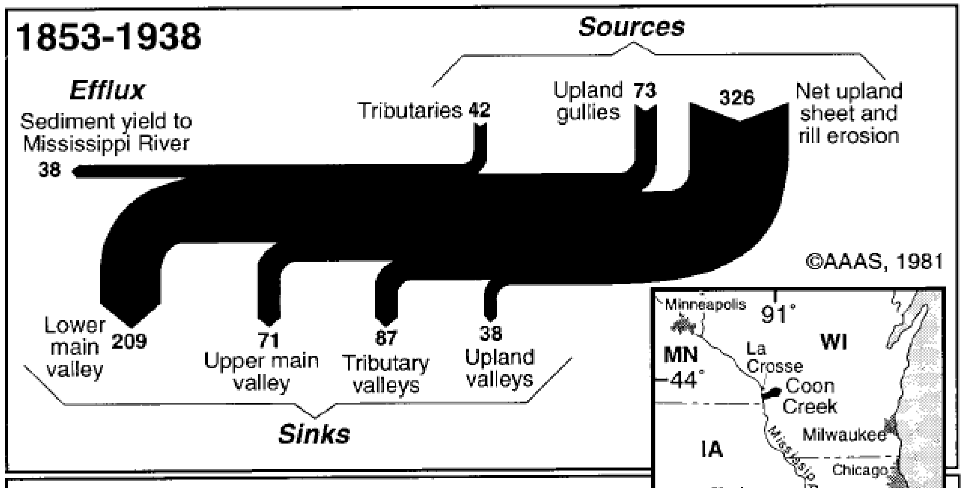
Soft Calibration – Coded in SWAT+

Soft calibration of water balance

- Surface Runoff, Baseflow, Tile Flow, and ET as % of Precip.
- Simple heuristic procedure has been included in SWAT+ with one/two variables for each process. Initial guess at parameter variables and linear interpolation in following runs. Calibrates within 15 simulations.

Soft calibration of crop yields

- Input average annual crop yields by region
- Simple heuristic procedure using hi, bio_e, esco, epco, and lai_potential
- Natalja completed paper on corn and soybean calibration across the US



Elevation Bands

Replaced Elevation Bands

- Input elevation of each object, weather gage, and weather generator station
- Input temperature lapse rate and precipitation lapse rate
- More physically realistic – elevation bands are lumping on top of hru lumping within a subbasin
- Input lapse rates by hru

Simulating Carbon and
Pesticides, Salts, Pathogens, and Metals

- Pesticides – Hendrik - complete fate and transport, updated database, daughter compounds, more complete output files
- Salt – Ryan has developed complete fate and transport routines. He is transferring into SWAT+
- Pathogens – SWAT code transferred over to SWAT+, no updating or testing
- Metals – framework in place but no progress on process algorithms
- Carbon – Xuesong Zhang has complete carbon budget in SWAT, haven't begun transfer into SWAT+

Subdaily Routing

- Green and Ampt with subdaily precipitation or daily precip and unit hydrograph
- Muskingum and Variable Storage Coefficient methods
- Using rating curves – calculated from channel dimensions or input from US HAND database

- Connecting overbank flood with flood plain. Flood plain/channel link file. Structure is there but still a work in progress