Linking edge-of-field results to stream flow and water quality - a comparison between APEX and SWAT

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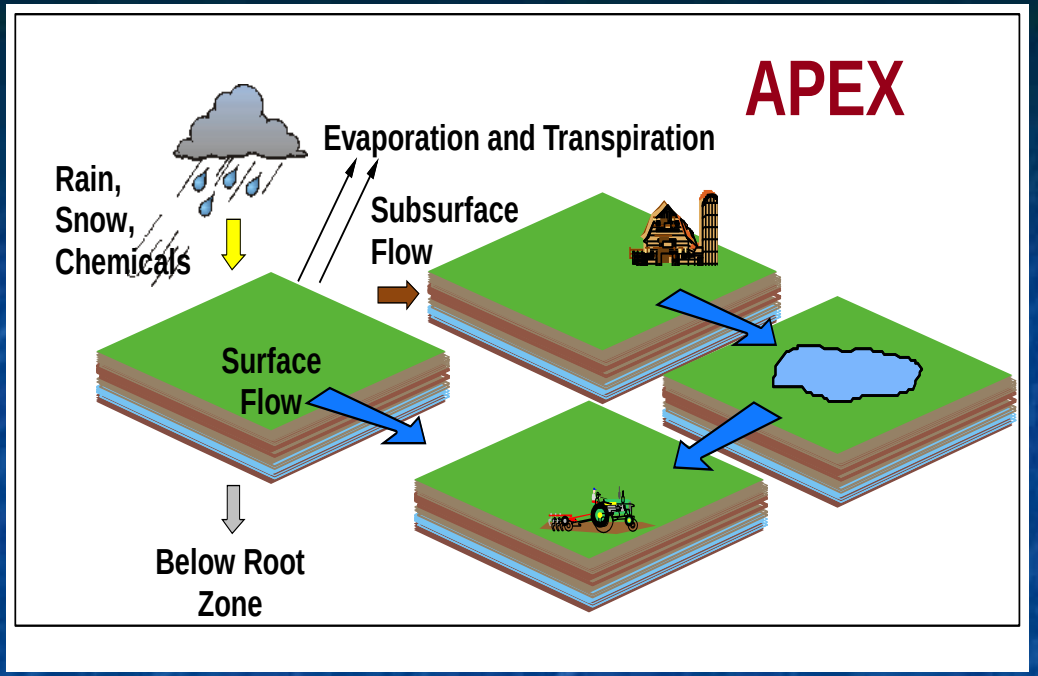
USDA ARS

Agricultural Research Service
the in-house research arm of the U.S. Department of Agriculture

APEX: a farm/watershed scale model



- Weather (simulated or actual)
- Heat transfer to the soil
- Runoff
- Percolation
- Evapotranspiration
- Snowmelt
- Erosion (wind & water)
- Crop growth
- Crop rotations & inter-cropping
- Weed competition
- Fertilization/nutrient movement
- Tillage
- Irrigation and furrow diking
- Pesticide application & movement
- Drainage
- Grazing
- Manure application & movement
- Ponds and reservoirs
- Buffer strips & waterways
- Surface & subsurface flows between subbasins

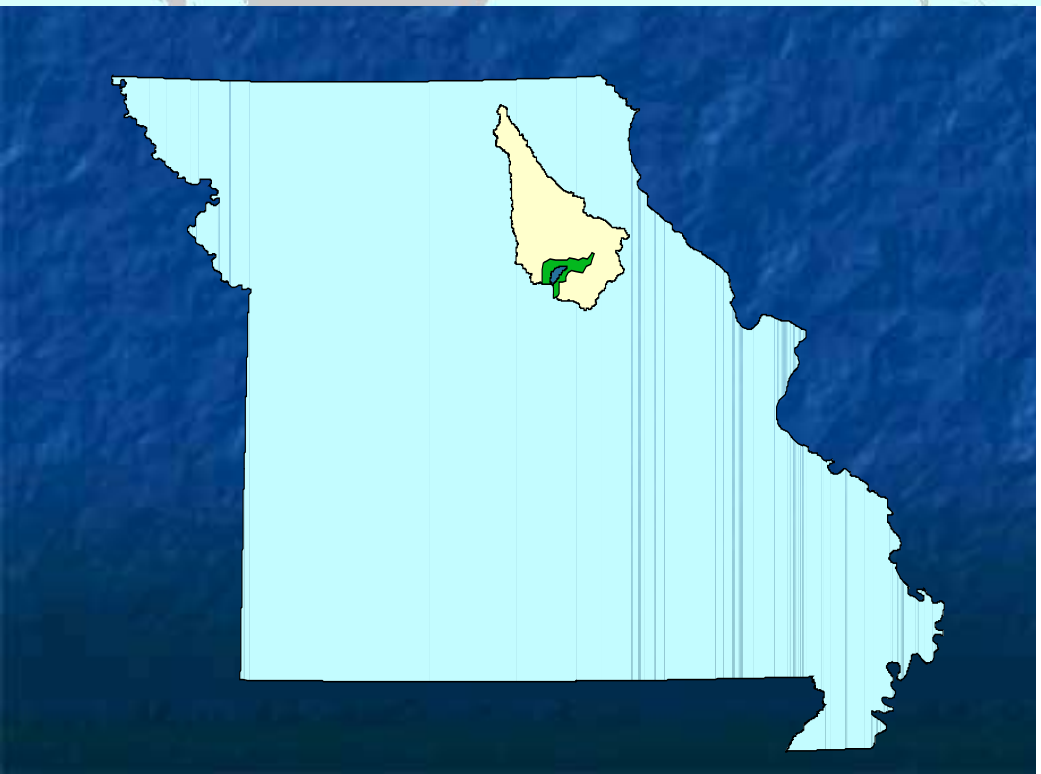
Estimating Practice Effectiveness with APEX-SWAT combination

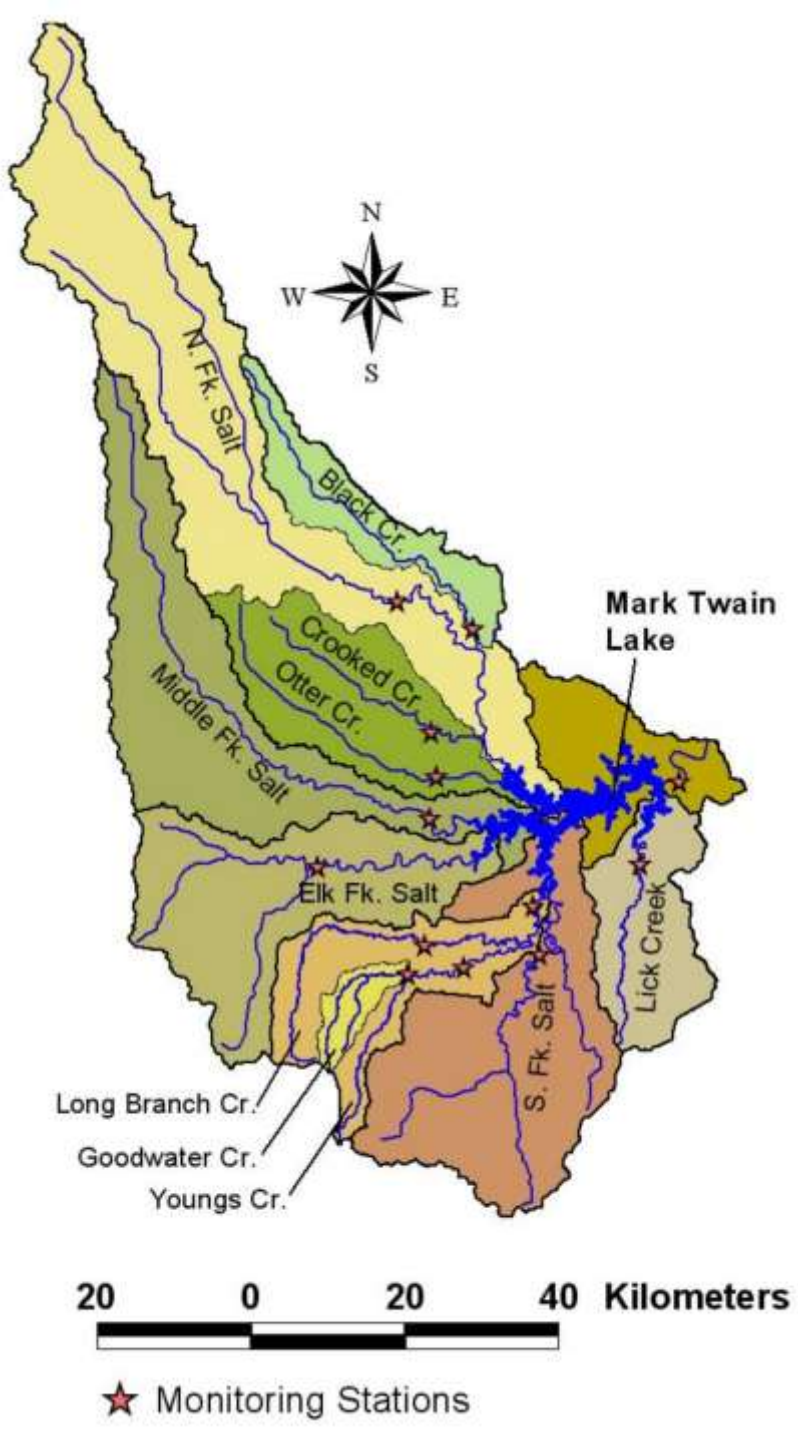
- Calibrate SWAT for the watershed using one (or more) flow gauge where water quality is also collected.
- Select fields (HRUs) or subbasins that will be represented with APEX:
  - need for within field variability
  - need to represent the landscape continuum
- Feed the output of APEX to SWAT.

Extending Effects of practice

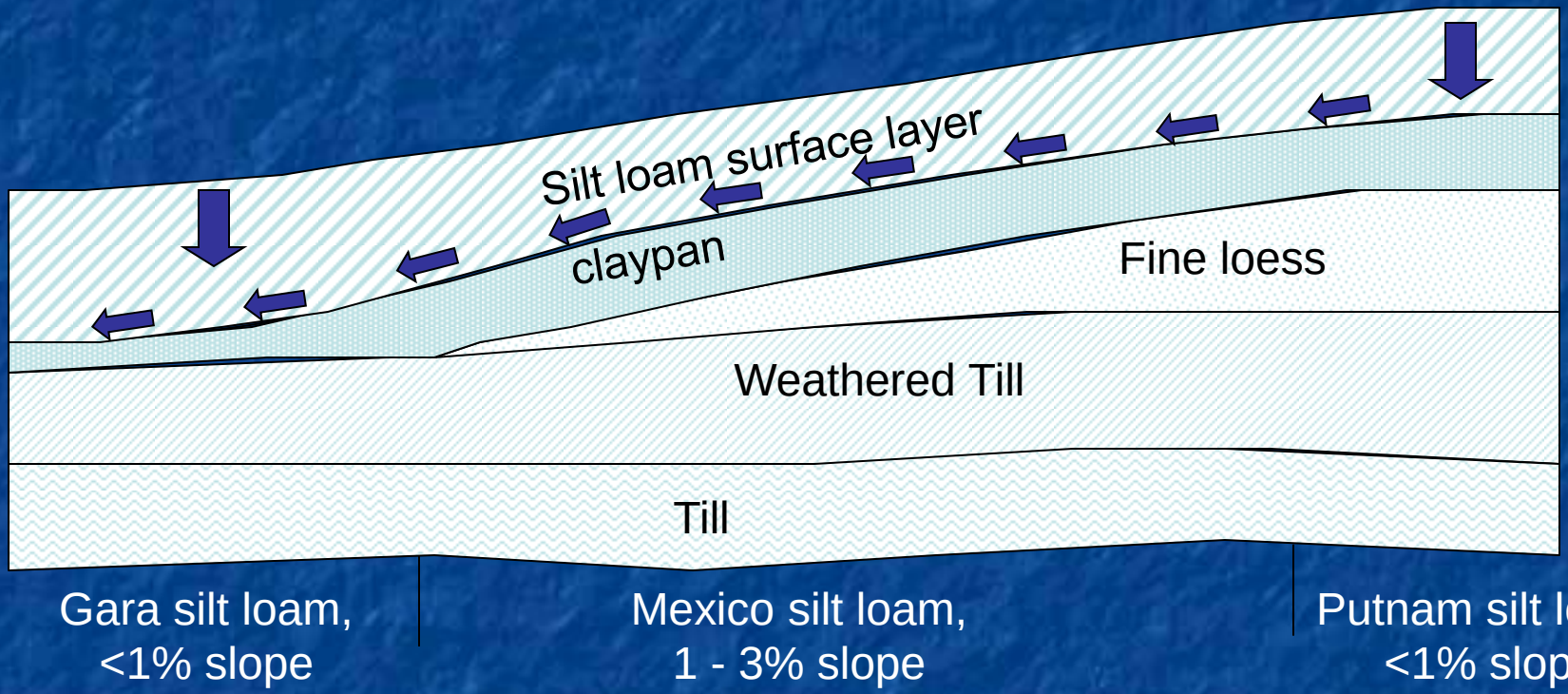
- Calibrate APEX to a field →
  - Detailed representation of within field variability
  - Representation of the landscape continuum
- Increase the study area →
  - Lump spatial variations
  - Use SWAT instead of APEX: simplify process algorithms.
- How do the models compare? How can we lump parameters? What is the effect of aggregation?


Canada
WASHINGTON
OREGON
CALIFORNIA
IDAHO
NEVADA
MONTANA
WYOMING
UTAH
ARIZONA
COLORADO
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
WEST VIRGINIA
PENNSYLVANIA
NEW YORK
MARYLAND
DELAWARE
NEW JERSEY
CONNECTICUT
MASSACHUSETTS
VERMONT
NEW HAMPSHIRE
MAINE
Atlantic Ocean
Pacific Ocean
Mexico
Gulf of Mexico



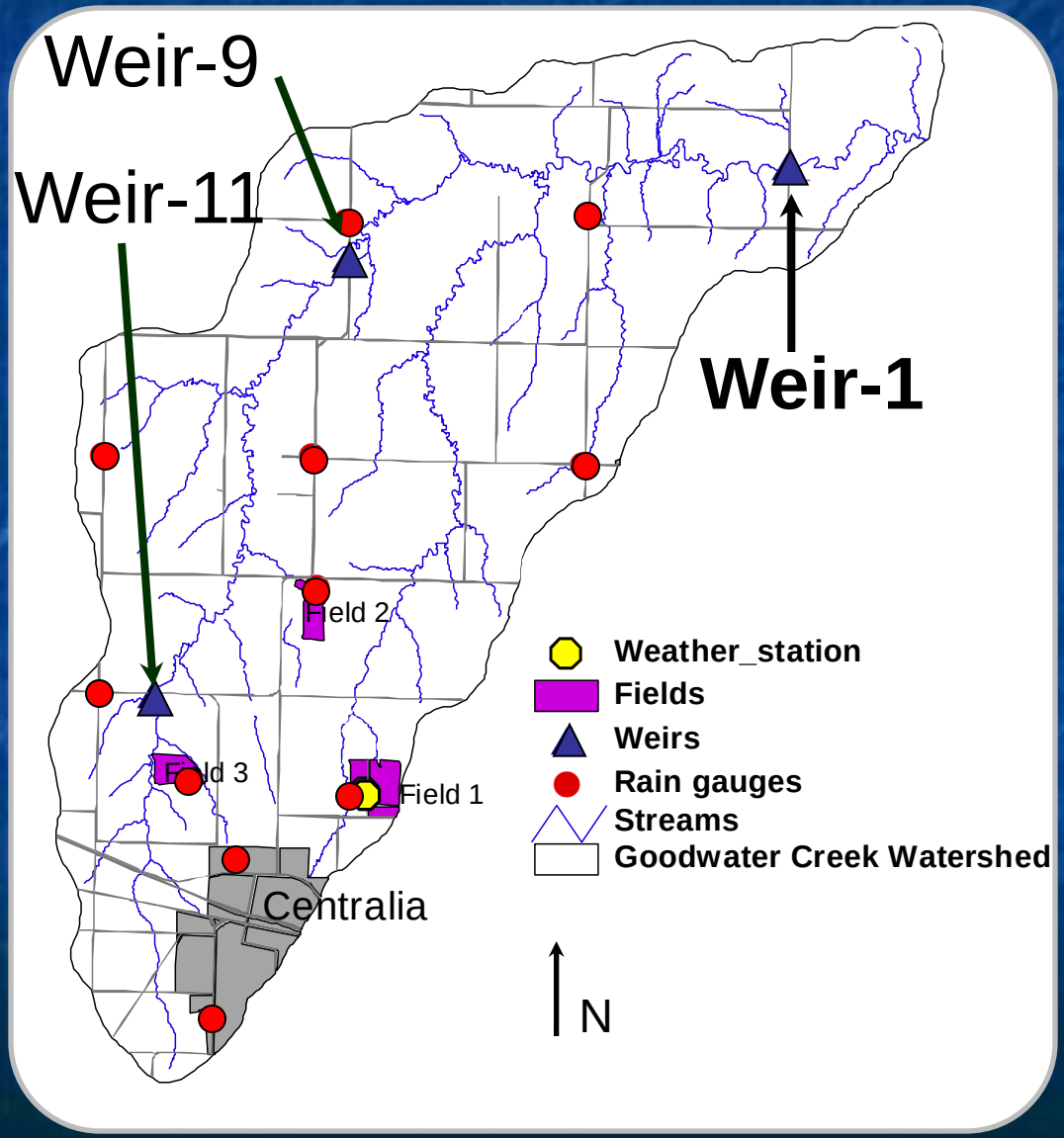

N
W
E
S
N. Fk. Salt
Black Cr.
Crooked Cr.
Otter Cr.
Middle Fk. Salt
Elk Fk. Salt
S. Fk. Salt
Lick Creek
Mark Twain Lake
Long Branch Cr.
Goodwater Cr.
Youngs Cr.
20 0 20 40 Kilometers
Monitoring Stations

A typical claypan landscape

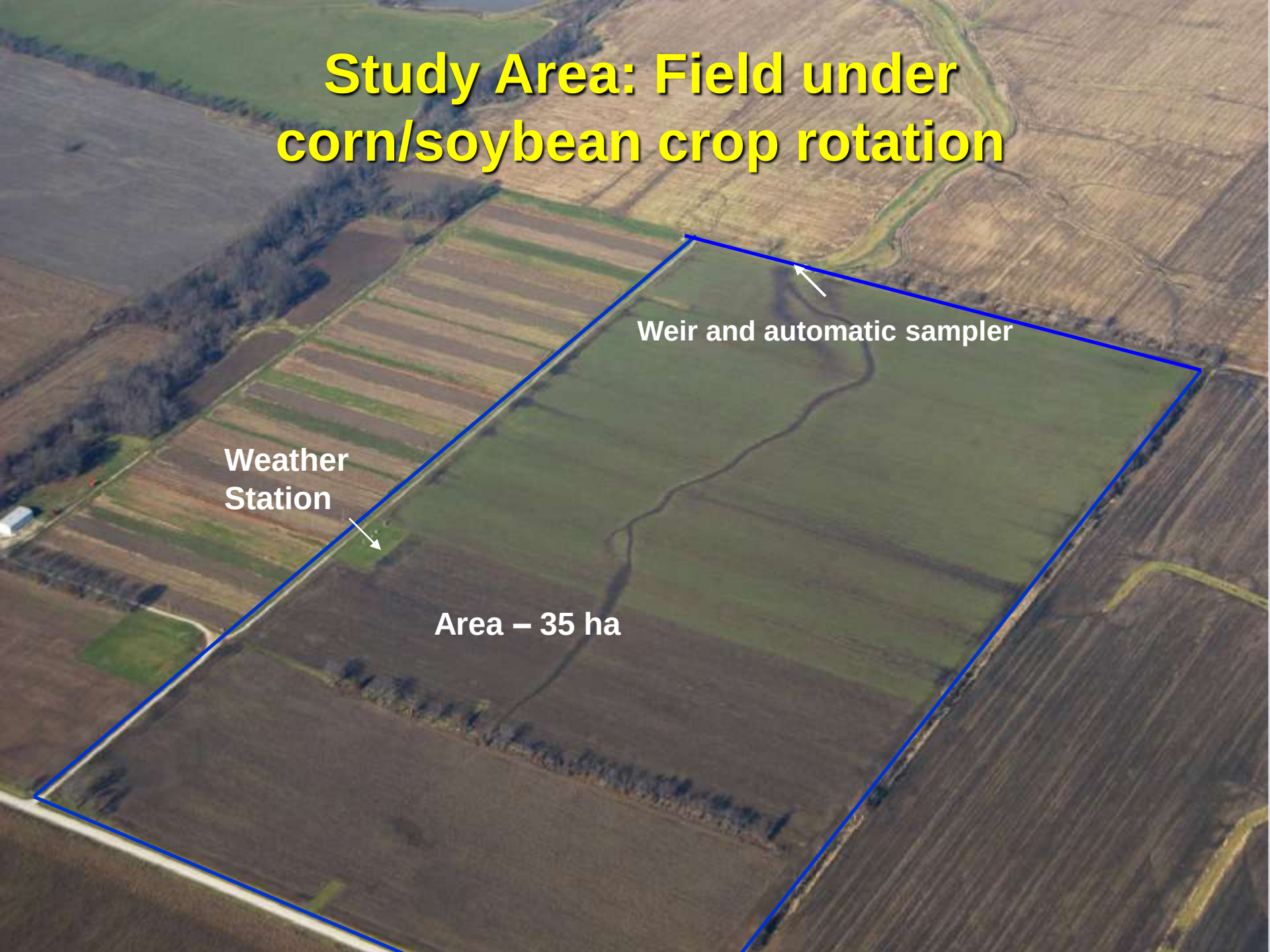


Schematic of a claypan landscape, after Jamison and Peters, 1967

Goodwater Creek Watershed



- 72 km^2
- Land use
  - 74% Row Crops
  - 18% Grassland
  - 6% Woodland
  - 2% Urban
- 0-3% slopes
- Claypan 15 to 45 cm below surface


Study Area: Field under corn/soybean crop rotation
Weir and automatic sampler
Weather Station
Area – 35 ha

Represent this field as one field and 35 areas

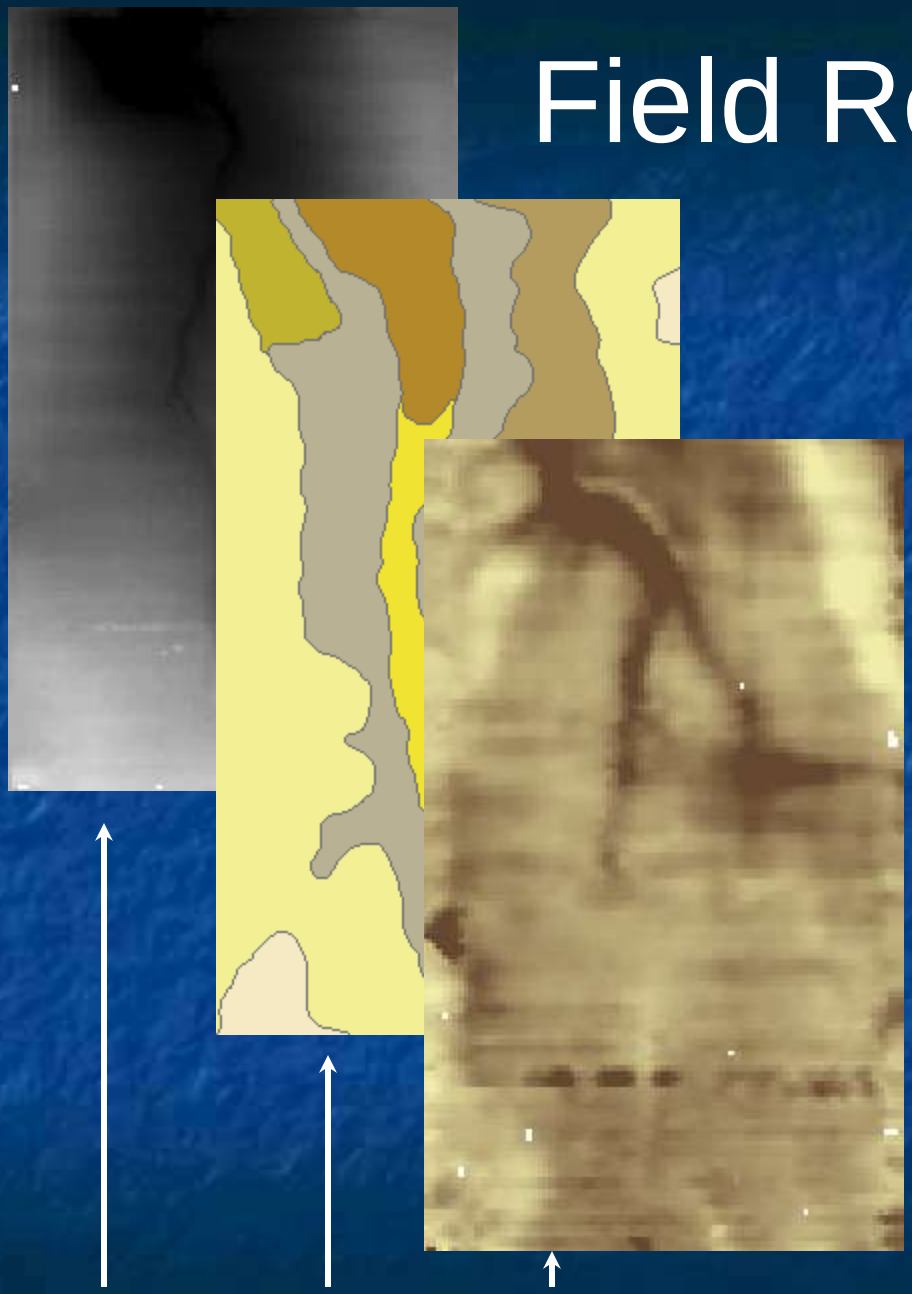
Represent this field as one field and 1 area

Represent this field as one HRU of a SWAT model

APEX 0604

SWAT2009

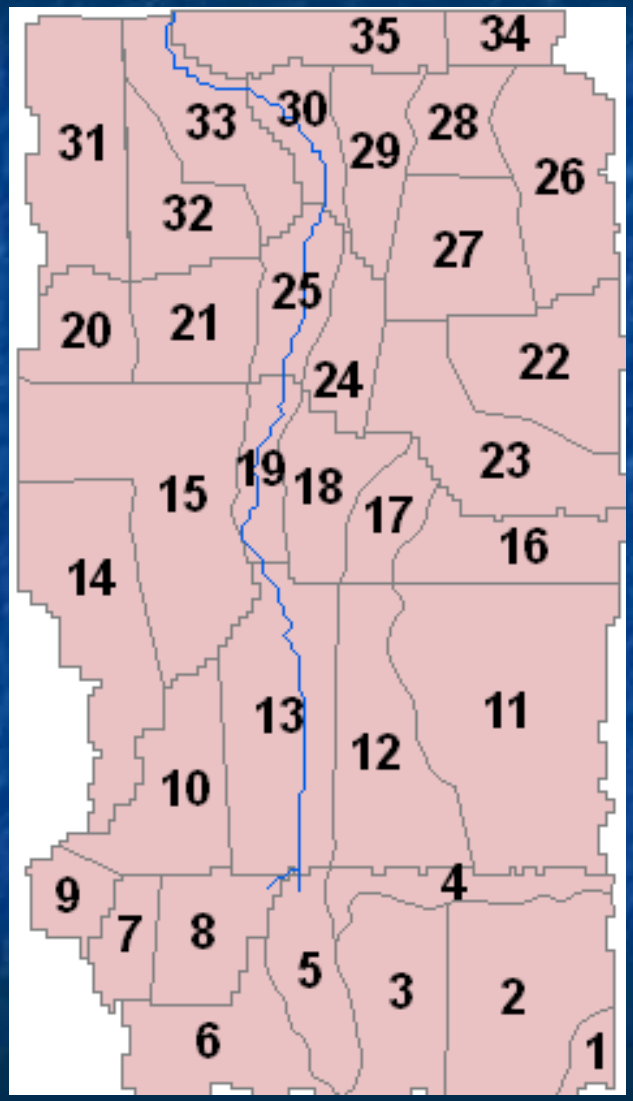
Field Representation



Topo

Soils

Depth to clay



Calibration and Validation

- **Calibration on a runoff event basis**
- **Goodness of fit evaluated by**
  - **Regression (R^2) method**
  - **Nash-Sutcliffe efficiency**
  - **Percent bias**
- **Event runoff and atrazine loads, and crop yields from 1993 to 2002.**

Aggregation to 1 subarea

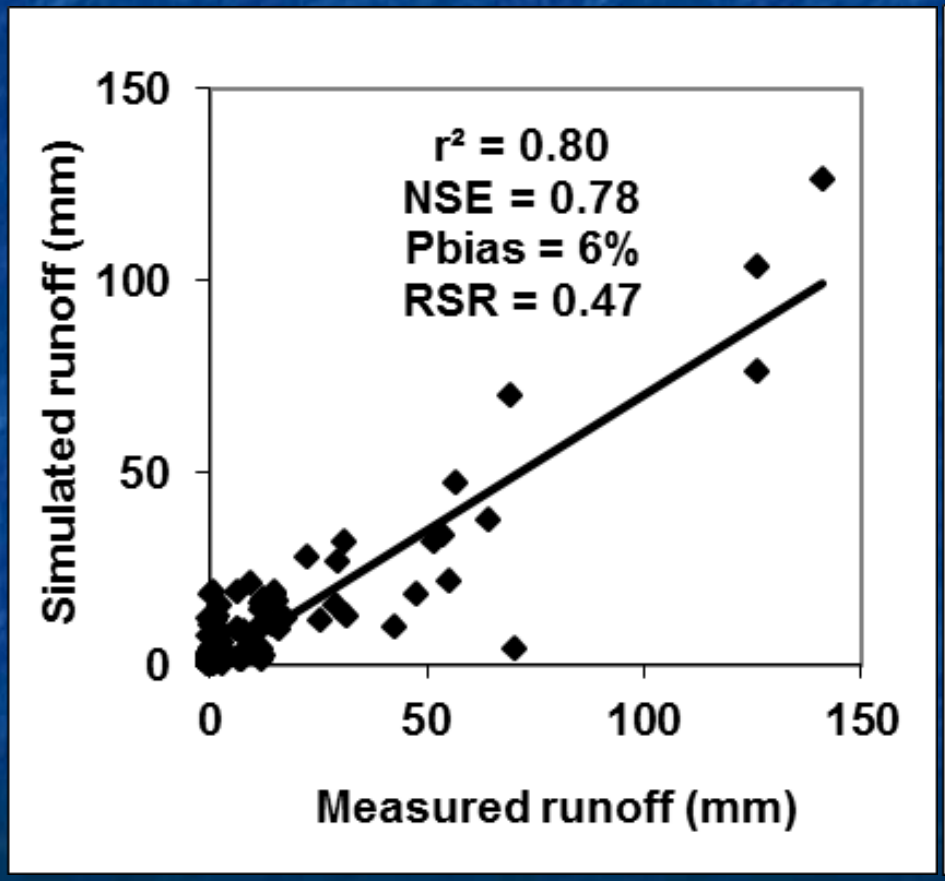
- Area weighted average of soil properties between all the subareas
  - Ksat surface : 5.55-136 mm/hr → 40.1mm/hr
  - Depth to clay: 15 to 100 cm → 33 cm
  - Overland slope: 0.005 – 0.015 → 0.008 m/m
- Channel length weighted average of channel dimensions and properties

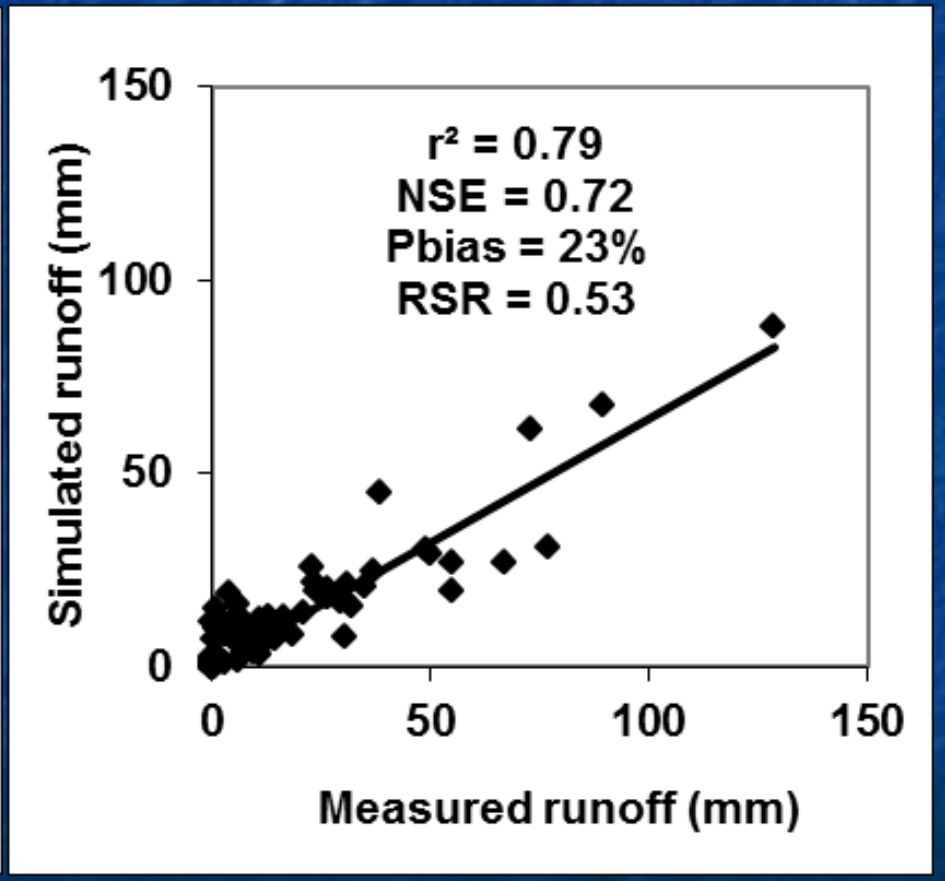
Simulation as 1 SWAT HRU

- Use the same properties as previous case
- Some processes are represented in similar ways → match process parameters
- Some processes are simulated differently in APEX and SWAT.

Runoff – APEX – 35 subareas

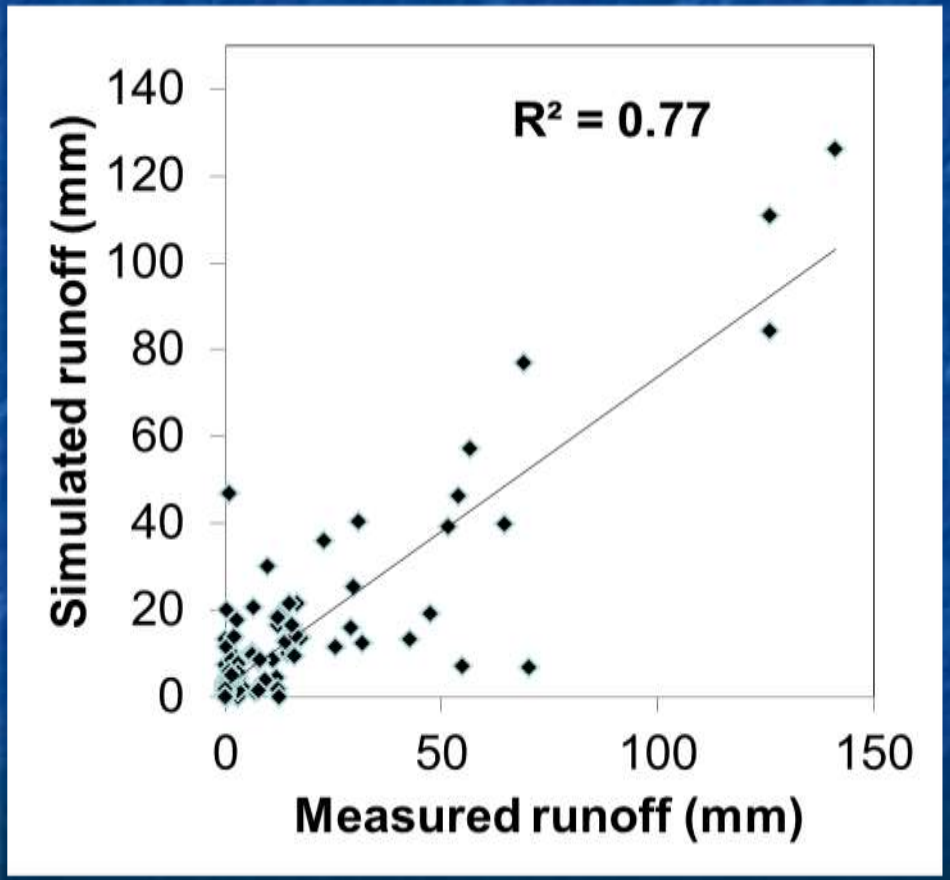
Calibration: 1993-1997 Validation: 1998-2002

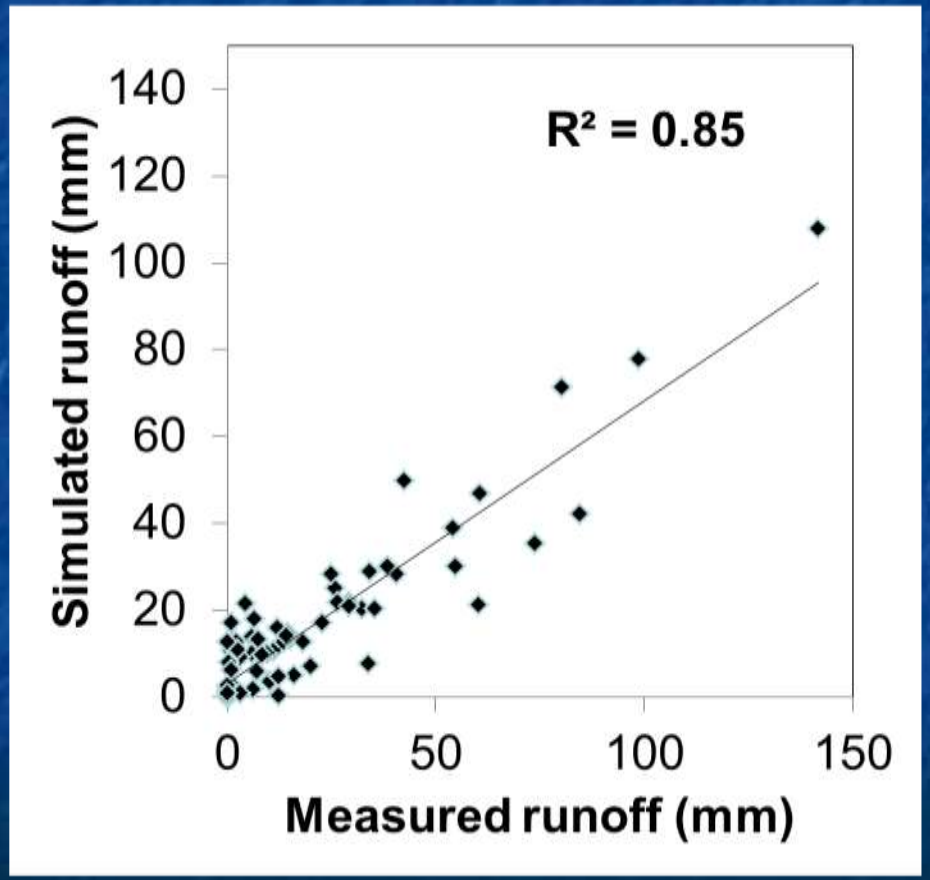




Runoff – APEX – 1 subarea

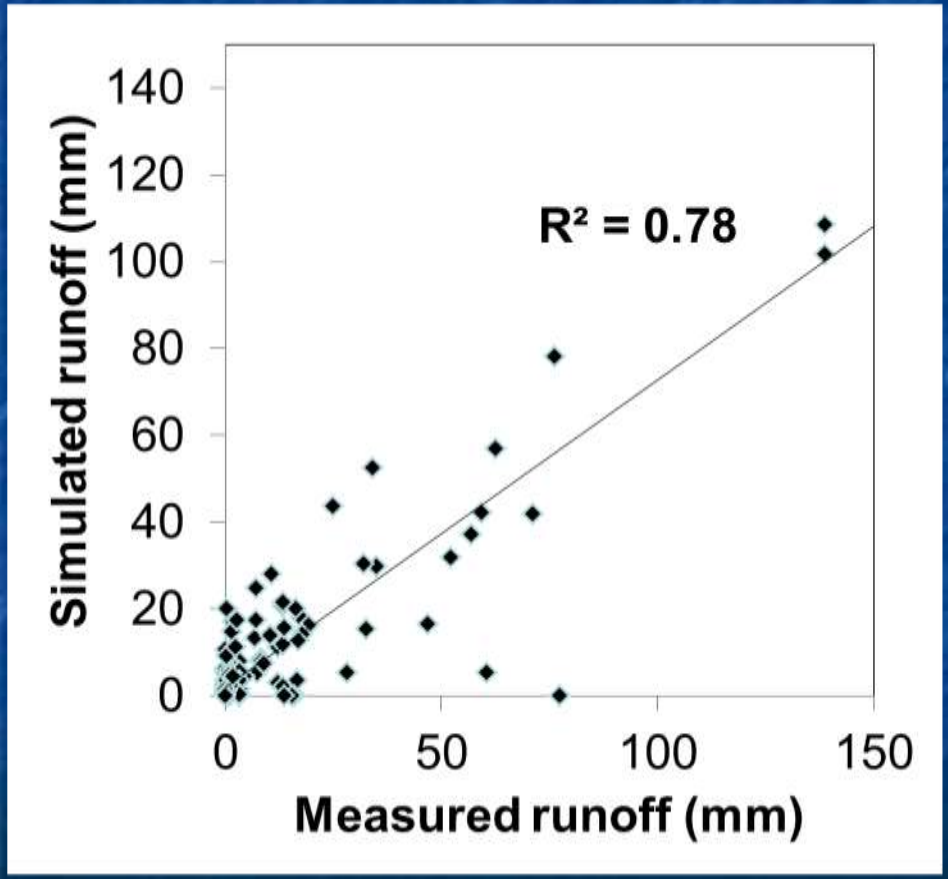
Calibration: 1993-1997 Validation: 1998-2002

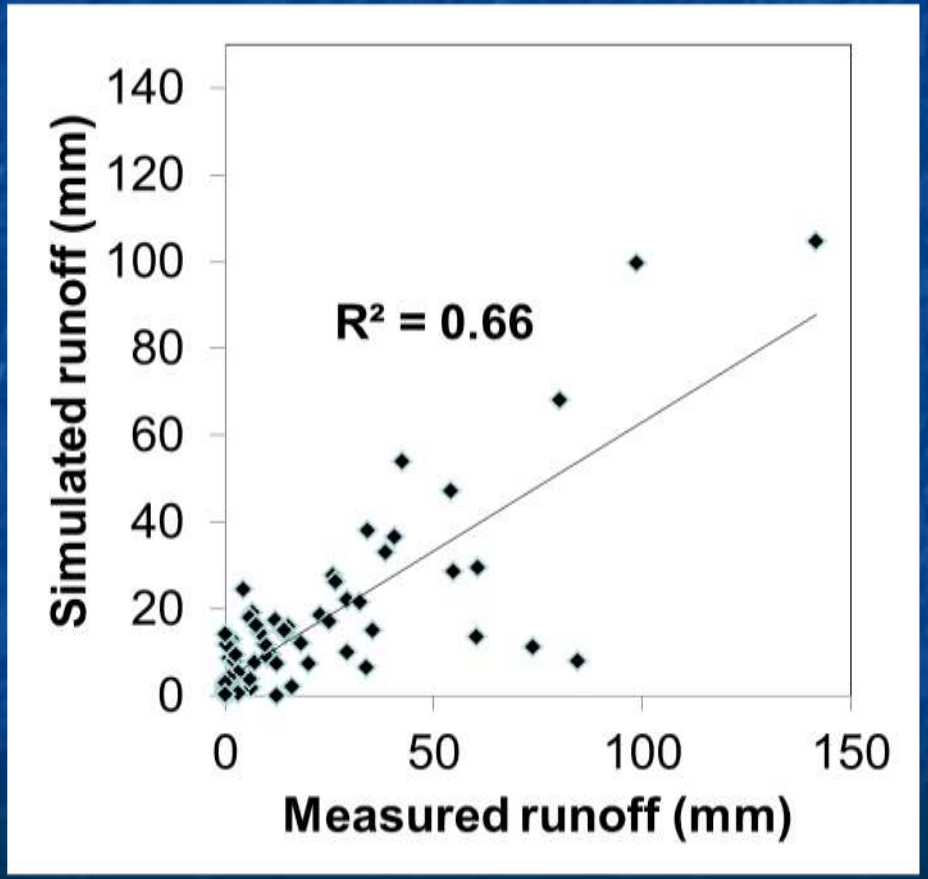




Runoff – SWAT – 1 Subbasin

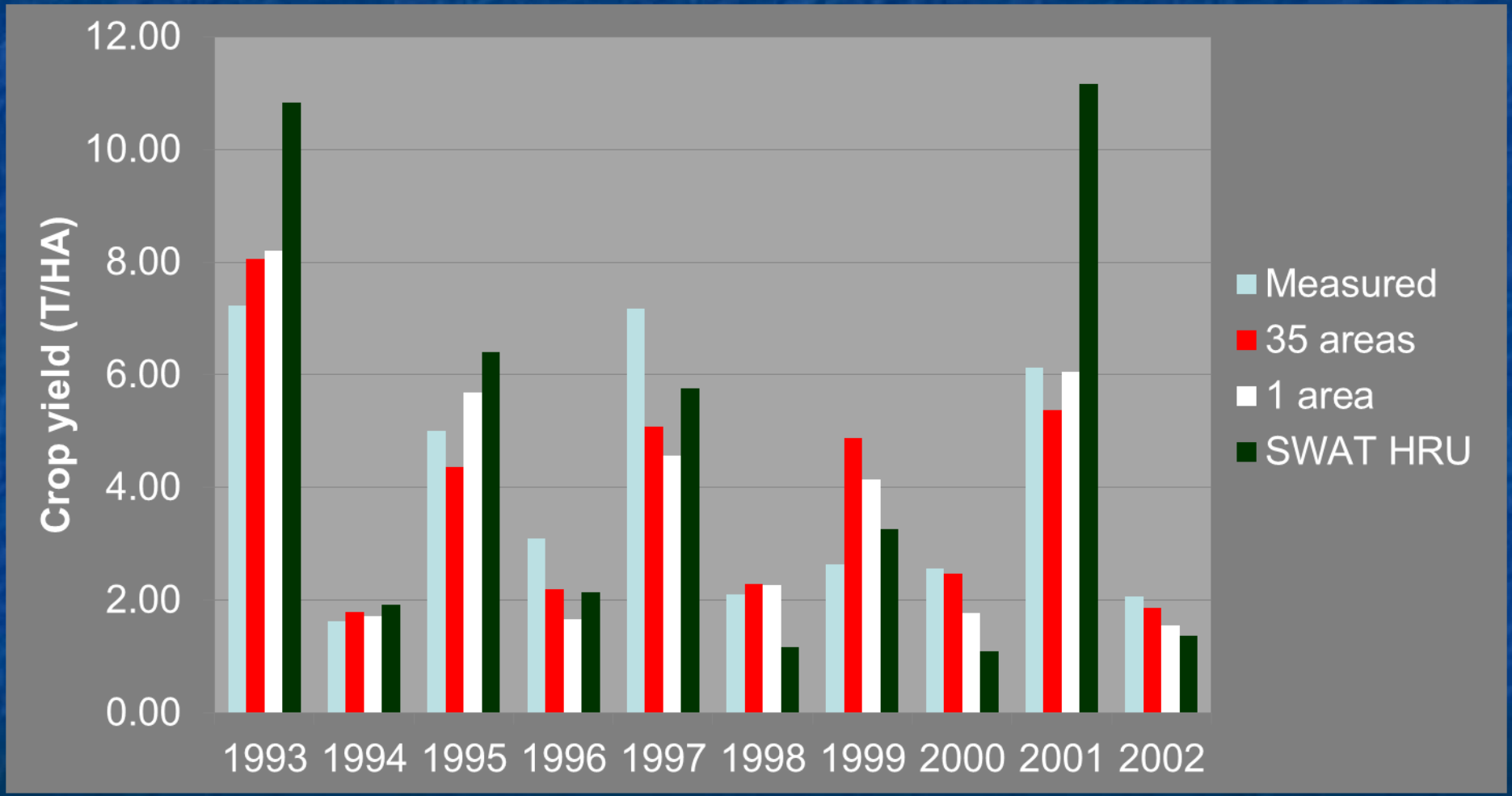
Calibration: 1993-1997 Validation: 1998-2002





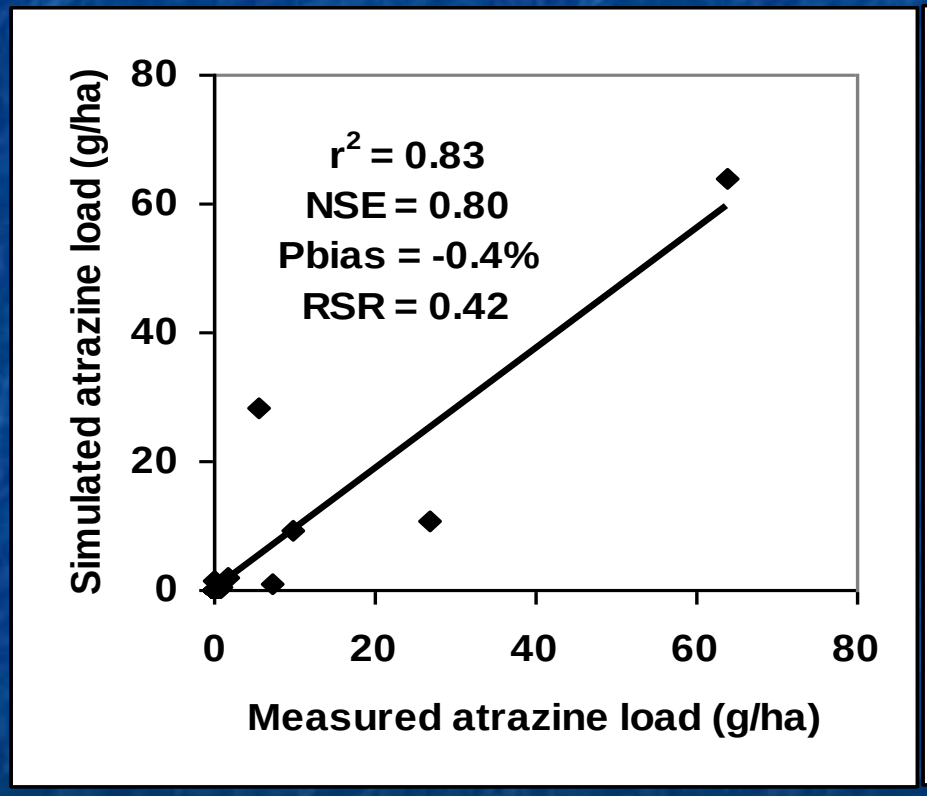
Taken at the outlet of the subbasin (no primary channel routing)

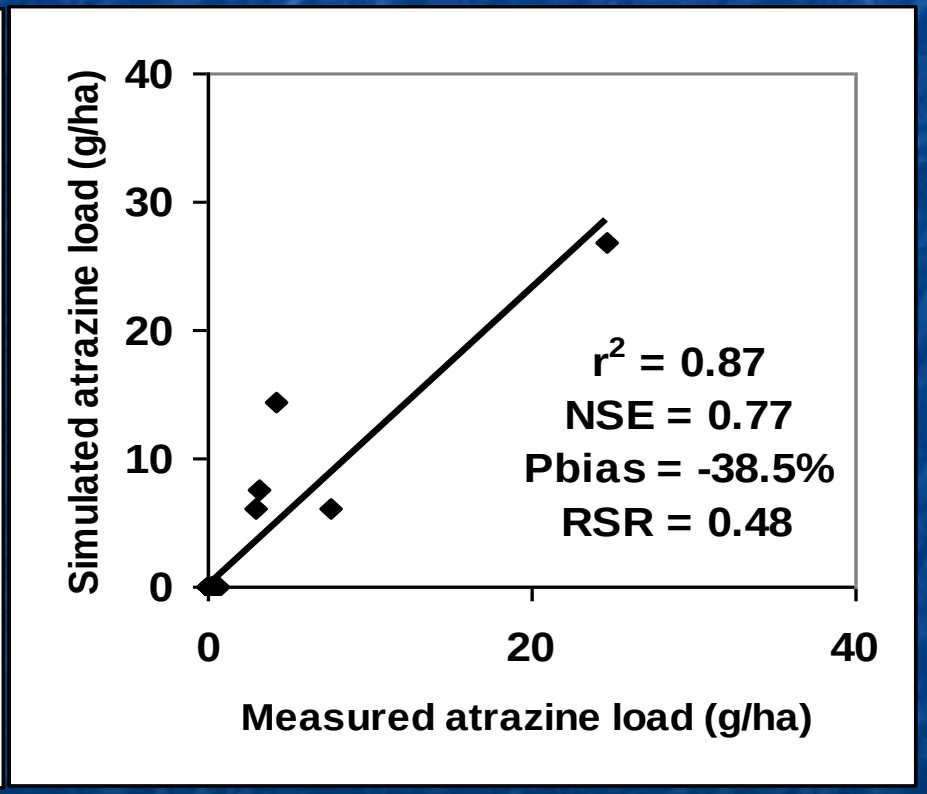
Crop yields


12.00
10.00
8.00
6.00
4.00
2.00
0.00
Crop yield (T/HA)
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Measured
35 areas
1 area
SWAT HRU

Atrazine – APEX – 35 subareas

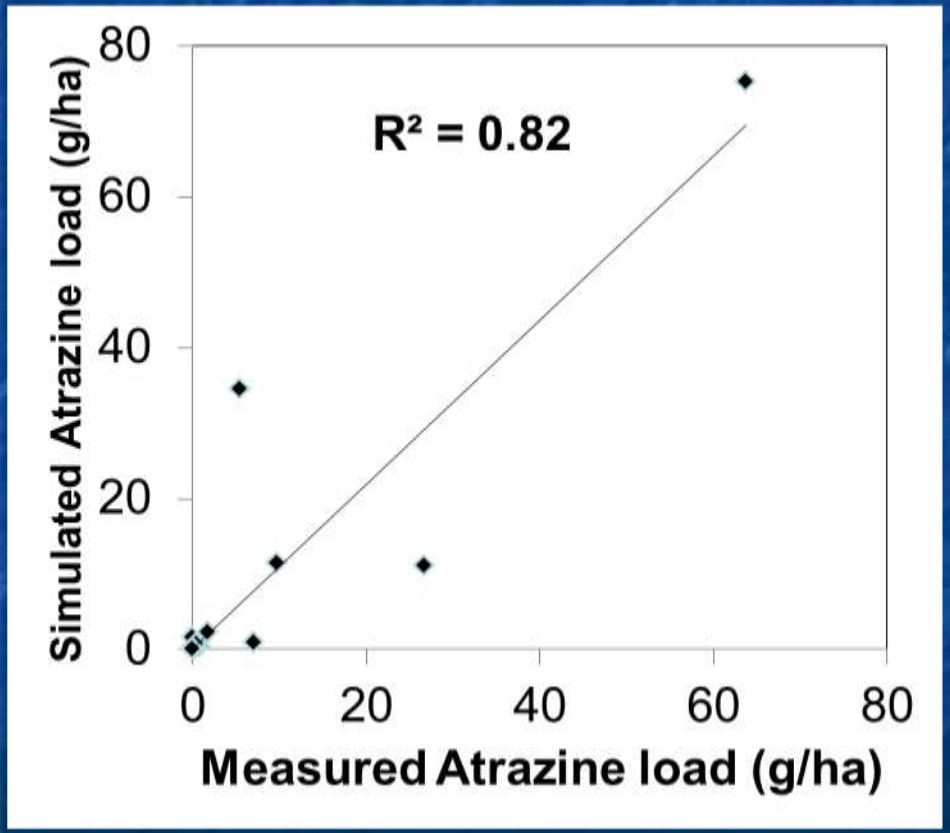
Calibration: 1993-1997 Validation: 1998-2002

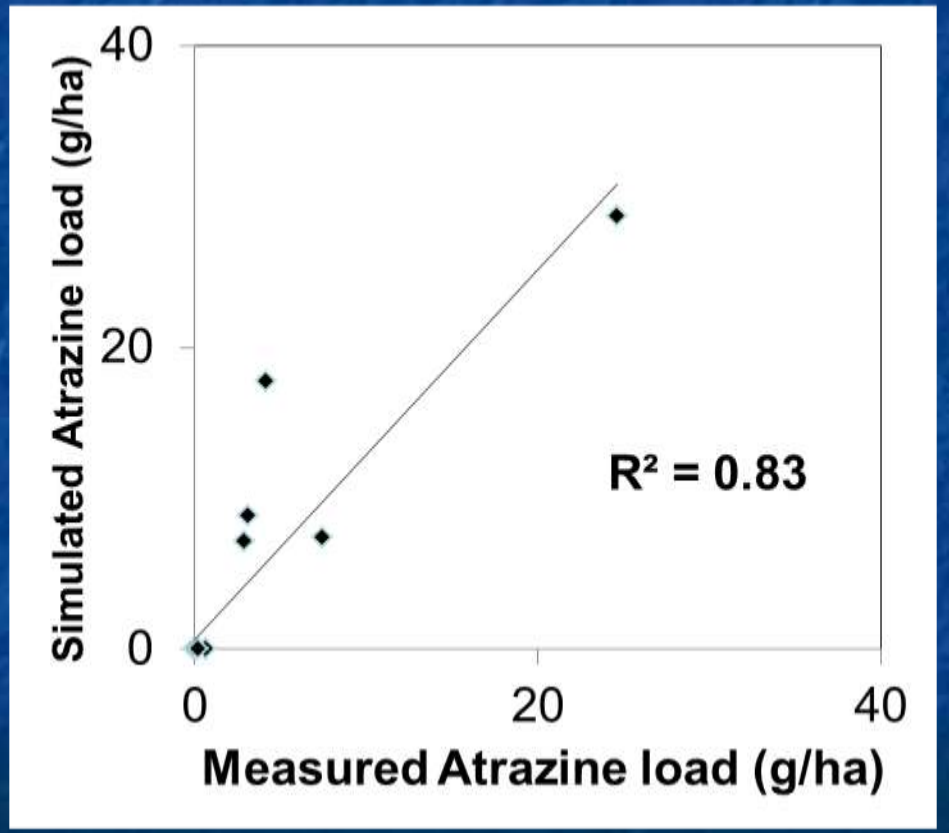




Atrazine – APEX – 1 subarea

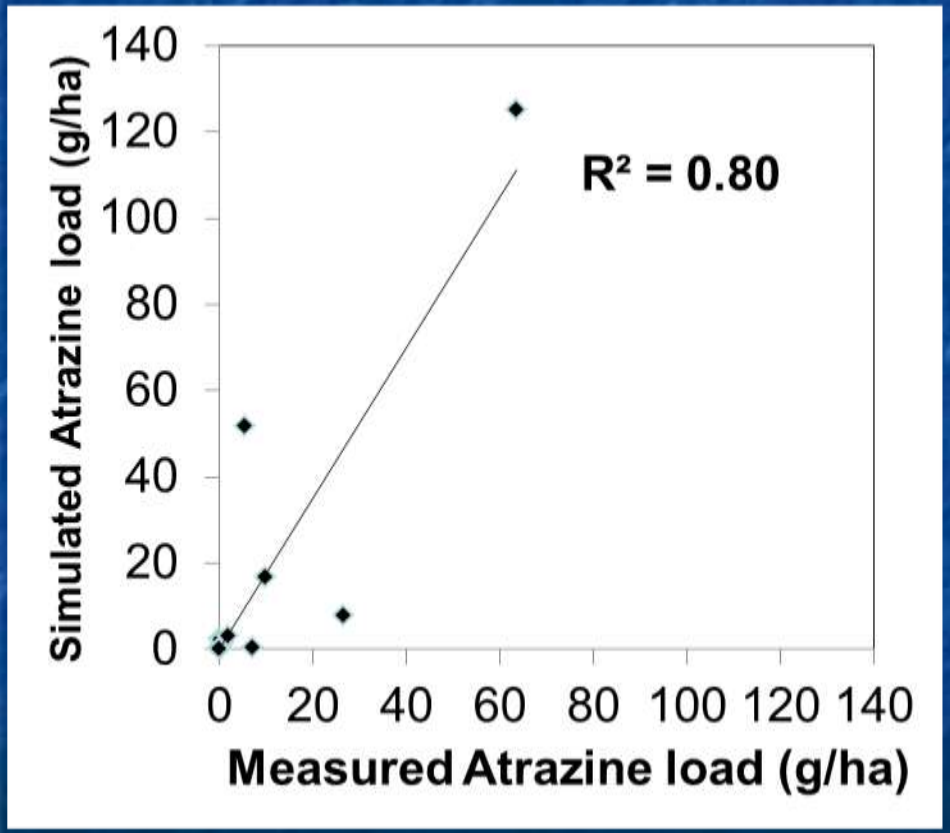
Calibration: 1993-1997 Validation: 1998-2002

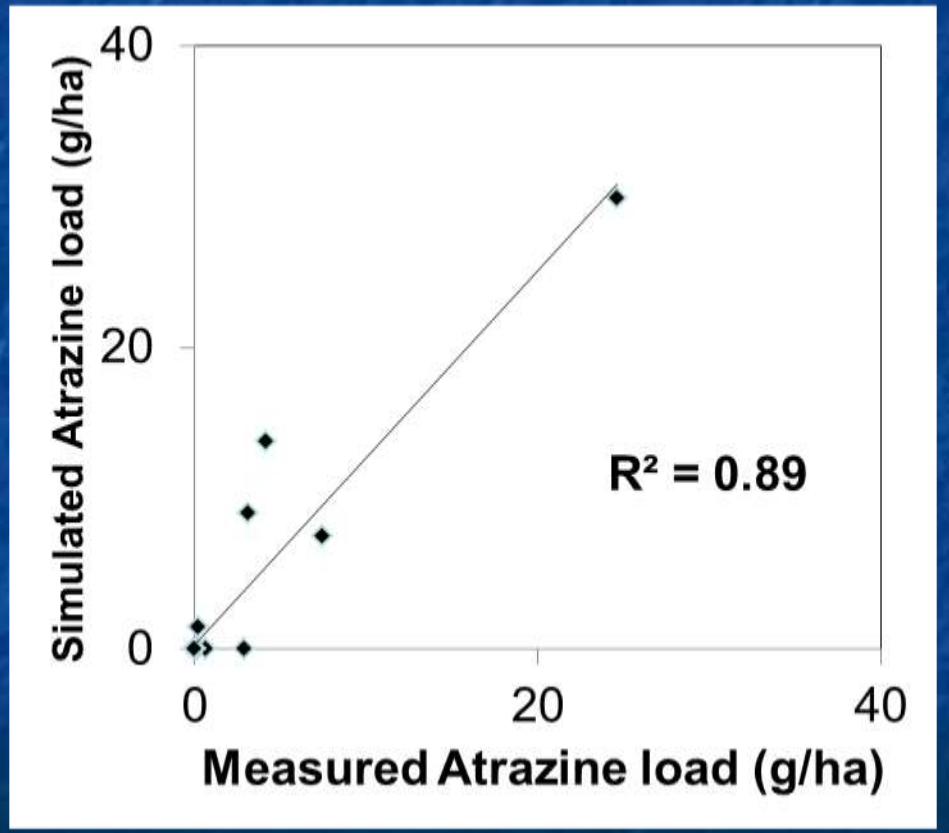




Atrazine – SWAT – 1 HRU

Calibration: 1993-1997 Validation: 1998-2002





Conclusions

- Using an area weighed average of soil properties and a length weighed average of channel properties produced good results to aggregate 35 areas into 1.
- SWAT results were different for crop yields and atrazine loadings.

Challenges for infering edge of field results from watershed studies

- Different results with SWAT and APEX make it difficult to do economic & environmental analyses at the field level using a combined model calibrated at a larger scale.
- Future work: define the relationship between SWAT and APEX process parameters.
- Results may be specific to the claypan type of hydrology: probably applicable to any soil with a shallow restrictive layer.