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SWAT+
Use of SWAT for Food, Energy and Water Solutions
Presentation Overview

- SWAT Background and History
- Water Solutions
  - Blue-Green Water Assessment
  - Virtual Water Trade
  - US National Conservation Assessment
- Water, Food and Energy Solutions
  - Midwest US – corn for ethanol
  - Hawaii – sugar cane for Navy bioenergy
- Future
  - CEAP downscaling
  - Export Coefficients – Delivery Ratios
  - Global Model
  - Sustainability Indicators
Non-Cultivated Lands - SWAT
Channel/Flood Plain Processes - SWAT
APEX Cultivated Fields
Point Sources

SWAT Watershed System
SWAT Model Capabilities

**Upland Processes**
- Weather
- Hydrology
- Sedimentation
- Plant growth
- Nutrient cycling
- Pesticide dynamics
- Carbon dynamics
- Pathogen fate

**Management**
- Crop rotations
- Removal of biomass as harvest conversion of biomass to residue
- Tillage/biomixing of soil
- Fertilizer applications
- Grazing
- Pesticide applications
- Irrigation
- Subsurface (tile) drainage
- Water impoundment (e.g., rice)
- Urban BMP’s – water retention, green roof, water garden
History of Conservation Assessment for USDA Policy Development at Temple

1980's
- Resource Conservation Assessment (RCA)
- Watershed Assessment
- HUMUS
- Field Based
- EPIC

1990's
- RCA
- Watershed Assessment
- HUMUS
- CEAP
- Detailed field scale linked with watershed assessment
- APEX and SWAT

2000's
- CEAP
- Spatially detailed, regional models

2010's
- CEAP II
- Spatially detailed, regional models

Future
- Web based decision support
- Continue to develop, support, and maintain the technology

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SWAT Publications and Support

- 3,000+ journal articles related to SWAT development and application
- 87 journal articles on bioenergy production and economic and environmental impact
Water Solutions

- SWAT applied to solve water problems related to sustainability (blue/green water), regional irrigation planning, reservoir management, ground water recharge, climate change and storm water detention.
Blue and green water

Blue Water Flow

Green Water Flow

Evaporation and Transpiration

Precipitation

Green Water Storage

Groundwater Recharge

Root Zone

Unsaturated Zone

Shallow (unconfined) Aquifer

Confining Layer

Deep (confined) Aquifer

Lateral Flow

Surface Runoff

Return Flow

Recharge to Deep Aquifer
Food and Water - Iran

Yield (t/ha)

Water Use (m³/ha)

Crop Water Productivity (kg/m³)

Regional virtual water balances
(only agricultural trade)

Arrows show trade flows >10 Gm³/yr

[Hoekstra & Chapagain, 2008]
Water, Food and Energy

Upper Mississippi – Ethanol Production

• Corn based ethanol production is projected to increase to meet growing demand for alternative fuels

• Rivers are subject to increased sediment, nutrient and pesticide loadings

• SWAT used to estimate effects of increased corn production in the Upper Mississippi River Basin
## Ethanol Production

<table>
<thead>
<tr>
<th></th>
<th>Scenario Average Yield</th>
<th>Corn Area</th>
<th>Ethanol Produced</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(bu/ac)</td>
<td>(t/ha)</td>
<td>(Million Ha)</td>
</tr>
<tr>
<td>Baseline</td>
<td>140.7</td>
<td>8.2</td>
<td>9.6</td>
</tr>
<tr>
<td>2010</td>
<td>149.6</td>
<td>8.7</td>
<td>13.5</td>
</tr>
<tr>
<td>2015</td>
<td>159.0</td>
<td>9.3</td>
<td>14.4</td>
</tr>
<tr>
<td>2020</td>
<td>169.0</td>
<td>9.9</td>
<td>14.0</td>
</tr>
<tr>
<td>2022</td>
<td>173.2</td>
<td>10.1</td>
<td>13.9</td>
</tr>
</tbody>
</table>

## Nitrogen Loads in Mississippi

<table>
<thead>
<tr>
<th></th>
<th>Unit Load (kg/ha)</th>
<th>Total Load (Million Kg)</th>
<th>Outflow in River (Million Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>17.5</td>
<td>860.46</td>
<td>650.22</td>
</tr>
<tr>
<td>2010</td>
<td>18.4</td>
<td>904.33</td>
<td>686.19</td>
</tr>
<tr>
<td>2015</td>
<td>18.2</td>
<td>896.43</td>
<td>680.52</td>
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<tr>
<td>2020</td>
<td>17.9</td>
<td>879.29</td>
<td>666.55</td>
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<tr>
<td>2022</td>
<td>17.8</td>
<td>873.80</td>
<td>662.06</td>
</tr>
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</table>
Production and Environmental Sustainability of Bioenergy for a Hawaiian Sugarcane Plantation

J. Jeong, J. G. Arnold, C. A. Jones, R. Srinivasan, M. Nakahata
Bioenergy Feedstock Trials

Energy Sorghum

Banagrass

Jatropha Curcus

Energy Cane

Vetiver Grass
Maui Sugarcane Plantation
Bioenergy Production for US Navy

Area: 141 km²
Production: 200,000 tons/yr
Water Use: 1 Mil m³/day (70% rainforest water and 30% groundwater)
Water storage capacity: 1 day
**Real-Time Decision Support Tool**

**SQL Database**
- Rainfall/Irrigation
- Temp/Humidity
- Wind/Solar
- Fertilizer/Pest
- MGT Operations
- Crop Age

**Web Interface**

**SWAT**
- ET/PET
- Soil Water
- GW Recharge
- Crop Growth
- MGT Operations
- Erosion/Transport
CEAP
Conservation Effects Assessment Program

- OMB requests for outcome-based reporting
- 2002 Farm Bill
- 40-fold increase in authorization for conservation programs call for better accountability
- Assessment to guide design and implementation of conservation programs
- Tier I – full biogeochemistry, detailed agricultural management, routing
- USGS 8-digit subbasins – 3,000 km²
Nitrogen - Local and Delivered
Surface Water Sustainability

Surface Water Budget

Local Water Yield - Local Use
Groundwater Depletion

Ground Water Budget

Groundwater Recharge - Local Use
Crop water content sourced from groundwater depletion in m³/ton.
CEAP II National Cropland Assessment

Downscaling from 8-digit subwatersheds (3,000 km$^2$) to 12-digits (75 km$^2$)

Example: 8-digit vs. 12-digit Subwatershed Configurations for the Raccoon River Watershed in West Central Iowa
Subbasin (12-digit) Configuration

- Gully/First order channels.
- Delineation of main channel flood plain and tributary riparian zones.
- HRU overlay within upland and valley bottom.
- Wetlands within the valley bottom.
- Updated point sources, reservoirs, atmospheric deposition, etc.
**Hydrologic and Water Quality System (HAWQS)**

**HAWQS** is an advanced, state-of-the-art total water quantity and quality modeling system with databases, interfaces and models that is being developed for the U.S. Environmental Protection Agency’s Office of Water to evaluate the impacts of management alternatives, pollution control scenarios, and climate change scenarios on the quantity and quality of water at a national scale.

- Is a server/client modeling system that uses a web-based interface to access datasets for modeling at the three spatial scales for any watershed over the contiguous lower 48 states.
- Uses latest nationally available federal government databases at three spatial resolutions (NHD+, 10-digit and 8-digit watershed levels)
- Uses the latest SWAT model
- Uses National Hydrography Dataset (NHD+) stream network
Export Coefficients – Tier I

- Export Coefficient – average annual loading from uplands
- Delivery Ratio – delivery through channels and reservoirs
- SWAT+ has exco/dr as objects. Use the same connect files as subbasins, channel, and reservoirs
- Advantage – simple, fast and easily linked to economic models
- Disadvantages – need to pre-run all scenarios, doesn’t simulate seasonal variability
- Full library of SWAT simulations for US – 40,000,000 simulations
- Potential for linking with economic models and developing simple interfaces. Link with other Risk Indicators and Loss Index.
Export Coefficients Compared with CEAP
Global Model—Tier II

- 10 km x 10 km cells – 4-6 soil land use overlays
- hru-lte – water balance and plant growth, erosion
- 20 years of generated weather
- No channel or reservoir routing
- Each continent is a SWAT simulation - North America takes 5 minutes per year (748,833 hru-lte)

- Link with Risk Indicators and Loss Index

**Global Model Subbasins (10km vs 1km)**

<table>
<thead>
<tr>
<th>Continent</th>
<th>Number of grid cells (10 km resolution) [*1,000]</th>
<th>Number of grid cells (1 km resolution) [*1,000,000]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>367</td>
<td>37</td>
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<td>Asia</td>
<td>463</td>
<td>46</td>
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<td>Australia</td>
<td>103</td>
<td>10</td>
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<tr>
<td>Central America</td>
<td>33</td>
<td>3</td>
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<tr>
<td>Europe</td>
<td>233</td>
<td>23</td>
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<tr>
<td>North America</td>
<td>238</td>
<td>24</td>
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<tr>
<td>South America</td>
<td>223</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>1,661</td>
<td>166</td>
</tr>
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</table>
Ratio of ET/Precipitation
Water Yield (Blue Water)

Legend

WYLD [mm]
- 0 - 50
- 50 - 100
- 100 - 200
- 200 - 500
- 500 - 1,000
- > 1,000
Indicators SWAT Could Provide

• **Environmental Pillar**
  - GHG Emissions – EPIC simulates emissions from landscape
  - Erosion productivity impact calculator
  - Loss of nutrients – total N and P balance
  - Link SWAT to harmful algal blooms in Gulf of Mexico and W. Lake Erie
  - Link SWAT to fish habitat and populations in Western Lake Erie

• **Social Pillar**
  - Supply of national food basket
  - Changes in production due to weather conditions

• **Economic Pillar**
  - Productivity – amount of bioenergy by mass, volume of energy
Thank You