2009 International SWAT Conference
Book of Abstracts

August 5-7, 2009

University of Colorado at Boulder
Boulder, Colorado

Soil & Water Assessment Tool | SWAT

Texas AgriLife Research, Texas A&M University
USDA-Agricultural Research Service



Wednesday, August 5, 2009

7:30 - 8:30 a.m. **Participant check-in and Registration**
University Memorial Center - Room 235

8:30 - 10 a.m. **Opening Ceremony**
University Memorial Center - Room 235
Moderator: Jeff Arnold
USDA-ARS

Welcome Address: *Dr. Bryan Kaphammer*
USDA-ARS

Keynote Speakers: *Dr. Steve Shafer*
USDA-ARS

Dr. Bill Dugas
Texas AgriLife Research, Texas A&M University System

Model Development History: Dr. *Jimmy Williams*
Blackland Research & Extension Center, Texas AgriLife Research

Closing: *Dr. Raghavan Srinivasan*
Texas A&M University & Blackland Research & Extension Center

9:45 - 10:15 a.m. Coffee Break and Group Photo

10:15 a.m. - 12 p.m. **SESSION A1 - Large Scale Applications**
University Memorial Center - Room 386
Moderator: Karim Abbaspour
Eawag

10:15 - 10:35 a.m.	*Anthony Lehmann*	*EnviroGRIDS – Integrating SWAT in the Black Sea Catchment Observation and Assessment System*
10:35 - 10:55 a.m.	*Samira Akhavan*	*Application of SWAT Model to Investigate Nitrate Leaching in Hamadan-Bahar Watershed, Iran*
10:55 - 11:15 a.m.	*Huan Meng* *Aisha Sexton*	*Modeling Chesapeake Bay Watershed Using SWAT*
11:15 - 11:35 a.m.	*Kendra Riebschleager*	*Application of SWAT for Water Quality Modeling of the Caddo Lake Watershed*
11:35 - 11:55 a.m.	*Monireh Faramarzi*	*Integrated Water Resources Management: Implications for Water and Food Security in Iran*
11:55 - 12:00 p.m.	*Discussion & Wrap Up*	

10:15 a.m. - 12 p.m. **SESSION A2 - Sensitivity, Calibration and Uncertainty**
University Memorial Center - Room 384
Moderator: Ann van Griensven
UNESCO-IHE

10:15 - 10:35 a.m.	*Tamie L. Veith*	*How To: Applying and Interpreting the SWAT Autocalibration Tools*
10:35 - 10:55 a.m.	*Haw Yen* *Mazdak Arabi*	*Uncertainty Analysis of the SWAT Model Using Bayesian Techniques*
10:55 - 11:15 a.m.	*Adam Freihoefer*	*Event Based Hydrologic Calibration of Field-Scale Watersheds in Southwestern Wisconsin Using the SWAT Model*

11:15 - 11:35 a.m.	*John Joseph*	*Preliminaries to Assessing the Quality of SWAT Parameter Confidence Intervals*
11:35 - 11:55 a.m.	*Xuesong Zhang* *Jeff Arnold* *Raghavan Srinivasan*	*Simultaneous Calibration of Surface Flow and Baseflow Simulations of SWAT*
11:55 - 12:00 p.m.	*Discussion & Wrap Up*	

10:15 a.m. - 12 p.m. **SESSION A3 - Urban Processes and Management** **Moderator:** Allan Jones, Texas A&M AgriLife

University Memorial Center - Room 382

10:15 - 10:35 a.m.	*Roger H. Glick*	*Issues in Modeling Physical Systems with the SWAT Model in Urban Areas*
10:35 - 10:55 a.m.	*Jaehak Jeong*	*Development of urban modeling tools in SWAT*
10:55 - 11:15 a.m.	*Tony Spencer* *Brian Walker* *Mazdak Arabi*	*Hydrologic response of watershed systems to land use/land cover change*
11:15 - 11:35 a.m.	*Yihun Dile Taddele*	*Hydrological Response of Gilgel Abay River Flow to Climate Change, Lake Tuna Basin, Ethiopia*
11:35 - 11:55 a.m.	*Roger H. Glick*	*Predicting Aquatic Life Potential under Various Development Scenarios in Urban Streams using SWAT*
11:55 - 12:00 p.m.	*Discussion & Wrap Up*	

12 p.m. - 1 p.m. **Lunch**

Restaurants located on the first floor of the University Memorial Center include: Alferd Packer Grill, Al's Fresco, El Canibal, Slumgullion, Soup/Chili & Salad Bar, The Tabor, Subway, Wok & Roll and more.

1:00 p.m. - 2:45 p.m. **SESSION B1 - Comprehensive Modeling for Watershed Protection Plan Development - A Water Supply Perspective: Tarrant Regional Water District Case Study, North-Central Texas** **Moderator:** Darrel Andrews, Tarrant Regional Water District

University Memorial Center - Room 386

1:00 - 1:20 p.m.	*Darrel Andrews*	*Watershed sediment contribution to SWAT Modeling: A Case Study of the Challenges Faced in a Watershed Application*
1:20 - 1:40 p.m.	*Balaji Narasimhan*	*Hydrologic Modeling of Cedar Creek Watershed using SWAT*
1:40 - 2:00 p.m.	*Mark Ernst*	*Steady State Nutrient Modeling in Streams*
2:00 - 2:20 p.m.	*Darrel Andrews* *Jennifer Owens*	*Sediment: Translating Between Physical Measurements and SWAT Parameters*
2:20 - 2:40 p.m.	*Balaji Narasimhan*	*Channel Erosion and Water Quality Modeling using SWAT*
2:40 - 2:45 p.m.	*Discussion & Wrap Up*	

1:00 p.m. - 2:45 p.m. **SESSION B2 - Upper Mississippi River Basin** **Moderator:** Philip Gassmann, Iowa State University

University Memorial Center - Room 384

1:00 - 1:20 p.m.	*Gerald Whittaker*	*Comparison of water quality effects of biofuel production in the Upper Mississippi River Basin using a Malmquist index*
1:20 - 1:40 p.m.	*Paul Hummel*	*Water Quality Modeling Efforts to Assess the Impacts of Ethanol Corn Production in the Upper Mississippi River Basin*
1:40 - 2:00 p.m.	*C. Santhi*	*An integrated modeling approach used for assessment of conservation practices on water quality conditions in the Upper Mississippi River Basin*
2:00 - 2:20 p.m.	*Philip Gassmann*	*Effect of potential future climate change on the cost-effective nonpoint source pollution reduction strategies in the Upper Mississippi River Basin*
2:20 - 2:40 p.m.	*Rich Alexander*	*Advances in Tracking Nutrient Sources in the Mississippi and Atachafalaya River Basin Using the SPARROW Model*
2:40 - 2:45 p.m.	*Discussion & Wrap Up*	

1:00 p.m. - 2:45 p.m. **SESSION B3 - Landscape Processes and Landscape/River Continuum**
University Memorial Center - Room 382

Moderator: Martin Volk, Helmholtz Centre for Environmental Research - UFZ, Germany

1:00 - 1:20 p.m.	*Ann van Griensven*	*Modelling wetland functions and services using SWAT*
1:20 - 1:40 p.m.	*Emily Boyd* *Mazdak Arabi*	*Role of spatial aggregation on sediment processes in SWAT*
1:40 - 2:00 p.m.	*Kyle Flynn*	*Validation of the SWAT Model for Sediment Prediction in a Mountainous, Snowmelt-dominated Catchment*
2:00 - 2:20 p.m.	*LJ Thibodeaux*	*An Earth-Surface Landscape Evolution Model with a Biological Life Signature (poster or platform)*
2:20 - 2:40 p.m.	*Prasad Daggupati* *Aleksey Sheshukov* *Kyle Douglas-Mankin*	*Field-Scale Targeting of Cropland Sediment Yields Using ArcSWAT*
2:40 - 2:45 p.m.	*Discussion & Wrap Up*	

2:45 p.m. - 3:15 p.m. **Break** (beverages & snacks in UMC 235)

3:15 a.m. - 5:00 p.m. **SESSION C1 - Comprehensive Modeling for Watershed Protection Plan Development - A Water Supply Perspective: TRWD Case Study, North-Central Texas**
University Memorial Center - Room 386

Moderator: Darrel Andrews
Tarrant Regional Water District

3:15 - 3:35 p.m.	*Mark Ernst*	*Development and Application of a WASP Model on a large Texas Reservoir to Assess Eutrophication Control Strategies*
3:35 - 3:55 p.m.	*Allen Sturdivant*	*Integrating SWAT Modeling and Economic Considerations to Develop an Economic-Based Watershed Management Plan*
3:55 - 4:15 p.m.	*Taesoo Lee*	*Assessment of Cost-Effective BMPs to Reduce Total Phosphorous Level Using SWAT in Cedar Creek Reservoir, TX*
4:15 - 4:35 p.m.	*Clint Wolfe*	*Utilizing SWAT to Enhance Stakeholder-based Watershed Protection Planning*
4:35 - 4:55 p.m.	*Clint Wolfe*	*Integrating SWAT Modeling and Economic Considerations to Develop an Economic-Based Watershed Protection Plan*
4:55 - 5:00 p.m.	*Discussion & Wrap Up*	

3:15 p.m. - 5 p.m. **SESSION C2 - Database and GIS Application and Development**
University Memorial Center - Room 384

Moderator: Mauro DiLuzio
Texas AgriLife Research

3:15 - 3:35 p.m.	*Jeyakanthan Veluppilai*	*Migrating a complex environmental modeling system from a proprietary to an open source GIS platform*
3:35 - 3:55 p.m.	*Jingshan Yu*	*SWAT Application Tool Development for Water Resources Management at County Level in Beijing, China*
3:55 - 4:15 p.m.	*Aleksey Sheshukov* *Prasad Daggupati* *Kyle Douglas-Mankin*	*ArcMap Tool for Pre-processing SSURGO Soil Database for ArcSWAT*
4:15 - 4:35 p.m.	*Lan Zhao*	*A web based interface for SWAT modeling on the TeraGrid*
4:35 - 4:55 p.m.	*Pierluigi Cau*	*A multi model and multiscale, GIS oriented Web framework based on the SWAT model to face issues of water and soil resource vulnerability*
4:55 - 5:00 p.m.	*Discussion & Wrap Up*	

3:15 p.m. - 5 p.m. **SESSION C3 - Climate Change Applications**
University Memorial Center - Room 382

Moderator: Xuesong Zhang
Joint Global Change Research Inst.
Pacific Northwest Laboratory

3:15 - 3:35 p.m.	*Tirupati Bolisetti*	*Effect of climate change on low flow conditions in Ruscom River watershed, Ontario*
3:35 - 3:55 p.m.	*Pranay Sanadhya* *Mehdi Ahmadi* *Mazdak Arabi*	*Consequences of climate change on water yield in mountainous snow-dominated Colorado watersheds*
3:55 - 4:15 p.m.	*Fred F. Hattermann* *Shaochung Huang* *Valentina Krysanova*	*Changes in plant phenology and physiology under climate change and related impacts on regional water resources*
4:15 - 4:35 p.m.	*Jae Ryu*	*Application of SWAT to climate-driven low flow (drought) frequency analysis*
4:35 - 4:55 p.m.	*Michael Strauch*	*Simulating the effects of climate change and energy crop production on water balance and water quality of the Parthe catchment (Germany) using SWAT*
4:55 - 5:00 p.m.	*Discussion & Wrap Up*	

6:00 p.m. - 8:00 p.m. **Welcome Reception - Millennium Harvest House**
(Reception will be located in the Hotel Gardens area - map included in registration packet - 1.0 miles)

Thursday, August 6, 2009

8:00 a.m. - 9:45 a.m. **SESSION D1 - Environmental Applications**
University Memorial Center - Room 386

Moderator: Hiroaki Somura
Shimane University, Japan

8:00 - 8:20 a.m.	*Benedikt Notter*	*Setting up SWAT to quantify water-related ecosystem service availability in a large data-scarce watershed in East Africa*
8:20 - 8:40 a.m.	*Nicola Fohrer*	*Adapting SWAT to a lowland catchment and using model results for ecohydrological assessments*
8:40 - 9:00 a.m.	*Karolina Smarzynska* *Maria Smietanka*	*Application for SWAT model to small agricultural catchment in Poland*
9:00 - 9:20 a.m.	*Dharmendra Saraswat*	*Development and Evaluation of An Algorithm for Generating Field Based Output From SWAT*
9:20 - 9:40 a.m.	*Milo Anderson*	*Combining a conceptual hydrologic model (SWAT) and a hydrodynamic model (Telemac 3D) to simulate reservoir dynamics in Eagle Creek Reservoir, Indiana*
9:40 - 9:45 a.m.	*Discussion & Wrap Up*	

8:00 a.m. - 9:45 a.m. **SESSION D2 - Sensitivity, Calibration and Uncertainty**
University Memorial Center - Room 384

Moderator: Mazdak Arabi
Colorado State University

8:00 - 8:20 a.m.	*Martin Volk*	*Influence of uncertainties in nitrate-N monitoring data on SWAT model calibration and evaluation*
8:20 - 8:40 a.m.	*Ann van Griensven*	*Multi-Objective calibration to improve pesticide simulations*
8:40 - 9:00 a.m.	*Barmak Azizimoghaddam* *Mazdak Arabi*	*A framework for sensitivity analysis of distributed watershed models*
9:00 - 9:20 a.m.	*Tamie L. Veith*	*How To: Understanding SWAT Model Uncertainty Relative to Measured Results*
9:20 - 9:40 a.m.	*Mahdi Ahmadi* *Mazdak Arabi*	*Multisite-Multivariate Calibration of Watershed Models*
9:40 - 9:45 a.m.	*Discussion & Wrap Up*	

8:00 a.m. - 9:45 a.m. **SESSION D3 - Bacteria, & Pathogens**
University Memorial Center - Room 382

Moderator: Claire Baffaut; Ali Sadeghi
USDA-ARS

8:00 - 8:20 a.m.	*Claire Baffaut* *Ali Sadeghi*	*Bacteria modeling with SWAT for assessment and remediation studies - A review*

8:20 - 8:40 a.m.	*Michelle Soupir*	*Predicting in-field decay and edge-of-field transport of fecal indicators*
8:40 - 9:00 a.m.	*Mehran Niazi*	*Watershed-Scale Fate and Transport of Bacteria Using the Arc-SWAT Model*
9:00 - 9:20 a.m.	*Jung-Woo Kim*	*Including sediment-associated bacteria resuspension and settling in SWAT predictions of microbial water quality*
9:20 - 9:45 a.m.	*Discussion & Wrap Up*	

9:45 a.m. - 10:15 a.m. **Break** (beverages & snacks in UMC 235)

10:15 a.m. - 12 p.m. **SESSION E1 - Model Structures to Simulate Spatially Distributed Landscape Processes with SWAT**
University Memorial Center - Room 386

Moderator: Fred Hattermann
Potsdam Institute for Climate Impact Research

10:15 - 10:35 a.m.	*Jeff Arnold* *Peter Allen* *Martin Volk* *Cole Rossi* *Jimmy Williams* *David Bosch*	*Simulation of Landscape Processes in SWAT*
10:35 - 10:55 a.m.	*David D. Bosch*	*Simulation of a Heavily Buffered Watershed using the SWAT Landscape Model*
10:55 - 11:15 a.m.	*Stefan Liersch* *Fred F. Hattermann*	*Integration of tropical and sub-tropical wetlands in regional catchment modelling*
11:15 - 11:35 a.m.	*Jorge Escurra*	*SWAT Application for Adaptation Strategies in Cocibolca Basin*
11:35 - 12:00 p.m.	*Discussion & Wrap Up*	

10:15 a.m. - 12 p.m. **SESSION E2 - BMPs**
University Memorial Center - Room 384

Moderator: Mike White
USDA-ARS

10:15 - 10:35 a.m.	*Heather B. Hill* *Mehdi Ahmadi* *Mazdak Arabi*	*A Targeting Strategy for Cost-Effective Implementation of Watershed Plans*
10:35 - 10:55 a.m.	*Indrajeet Chaubey* *Chetan Maringanti*	*Development of a tool to estimate Best Management Practices (BMP) efficiency using SWAT*
10:55 - 11:15 a.m.	*Lizhong Wang*	*Water Quality Impacts of Agricultural BMPs in a Suburban Watershed in New Jersey*
11:15 - 11:35 a.m.	*Gerardina Santese*	*Evaluation of BMPs effectiveness on water quality in an intermittent Italian River*
11:35 - 11:55 a.m.	*Aleksey Sheshukov* *Kyle Douglas-Mankin* *Prasad Daggupati*	*Evaluating Effectiveness of Unconfined Livestock BMPs using SWAT*
11:55 - 12:00 p.m.	*Discussion & Wrap Up*	

10:15 a.m. - 12 p.m. **SESSION E3 - Biofuel Plant Simulation**
University Memorial Center - Room 382

Moderator: Jim Kiniry
USDA-ARS

10:15 - 10:35 a.m.	*Jim Kiniry*	*Experiences with simulating switchgrass in diverse latitudes in the U.S.*
10:35 - 10:55 a.m.	*Peter Schweizer*	*Use of the SWAT Model to Evaluate the Sustainability of Bioenergy Production at a National Scale*
10:55 - 11:15 a.m.	*Rob Mitchell*	*Agronomic considerations for simulating switchgrass for biomass energy*
11:15 - 11:35 a.m.	*Ken Vogel*	*Switchgrass genetics: status, future directions and implications for simulations*
11:35 - 12:00 p.m.	*Discussion & Wrap Up*	

12 p.m. - 1 p.m. **Lunch**

Restaurants located on the first floor of the University Memorial Center include: Alferd Packer Grill, Al's Fresco, El Canibal, Slumgullion, Soup/Chili & Salad Bar, The Tabor, Subway, Wok & Roll and more.

1:00 p.m. - 2:45 p.m. **SESSION F1 - Pharmaceuticals**
University Memorial Center - Room 386

Moderator: Virginia Jin
USDA-ARS

1:00 - 1:20 p.m.	*LJ Thibodeaux*	*Conceptual Chemical Fate and Transport Models for Emerging Contaminants and SWAT Submodel Development*
1:20 - 1:40 p.m.	*Kenneth Carlson* *Mazdak Arabi*	*Irrigation Ditch Facilitated Transport of Veterinary Pharmaceutical Compounds in a Semi-Arid Watershed*
1:40 - 2:00 p.m.	*Dr. Thomas Heberer*	*Behavior and redox sensitivity of pharmaceutical residues during bank filtration - Final lessons from the NASRI project*
2:00 - 2:20 p.m.	*Larry Barber*	*Watershed Scale Chemical Signaling Networks, Endocrine Disruption, and Ecosystem Responses*
2:20 - 2:45 p.m.	*Discussion & Wrap Up*	

1:00 p.m. - 2:45 p.m. **SESSION F2 - Sediments, Nutrients, Carbons**
University Memorial Center - Room 384

Moderator: Armen Kemanian
Texas AgriLife Research

1:00 - 1:20 p.m.	*Solomon Folle*	*Modeling Upland and Channel Sources of Sediment in the Le Sueur River Watershed, Minnesota*
1:20 - 1:40 p.m.	*Ann van Griensven*	*In-Stream water quality processes in SWAT with different routing methods and adapted water quality modules for daily or sub-daily time steps*
1:40 - 2:00 p.m.	*Armen Kemanian*	*Integrating Nitrogen and Phosphorus Carbon Cycling in SWAT*
2:00 - 2:20 p.m.	*Nicola Fohrer*	*Assessing the impact of point and diffuse sources pollution on nitrate load in a rural lowland catchment using the SWAT model*
2:20 - 2:40 p.m.	*Hiroaki Somura*	*Numerical analyses on seasonal variations of nutrient salts and load discharges in Abashiri River Basin*
2:40 - 2:45 p.m.	*Discussion & Wrap Up*	

1:00 p.m. - 2:45 p.m. **SESSION F3 - Conservation Effects Assessment Project (CEAP)**
University Memorial Center - Room 382

Moderator: Jay Atwood
USDA-NRCS

1:00 - 1:20 p.m.	*Jay D. Atwood*	*The CEAP National Cropland Assessment: Conversion of Crop Management Survey Data into APEX Simulation Input*
1:20 - 1:40 p.m.	*Michael Shannon*	*ARS CEAP Watershed Assessment Study Overview*
1:40 - 2:00 p.m.	*Indrajeet Chaubey*	*Effectiveness of BMPs in controlling nonpoint source pollutant losses from a CEAP watershed*
2:00 - 2:20 p.m.	*David Bosch*	*Little River Watershed Conservation Practice Assessment with SWAT*
2:20 - 2:40 p.m.	*Susan Wang*	*APEX simulation of CEAP sample points*
2:40 - 2:45 p.m.	*Discussion & Wrap Up*	

2:45 p.m. - 3:00 p.m. **Break and depart for Conference Outing**

3:30 p.m. to 6:30 p.m. - **Bus 1** - tour Celestial Seasonings Tea Factory and the Shops on Pearl Street (*http://www.celestialseasonings.com*) (*http://www.boulderdowntown.com/*)

3:30 p.m. to 7:00 p.m. - **Bus 2** - depart to Chautaqua Historic District (hiking trails; picnic/park area) Naturalist, Dave Gustafson, (at Ranger Cottage) will give an overview covering the history and ecology of Boulder's Open Space and Mountain Parks. (*http://www.chautauqua.com/*)

7 p.m. to 9 p.m. - Dinner at Chautaqua Dining Hall
9 p.m. - buses will drop off at various locations

Friday, August 7, 2009

8:00 a.m. - 9:45 a.m. **SESSION G1 - Hydrology**
University Memorial Center - Room 386

Moderator: Nam Won Kim
Korea Institute of Construction Technology

8:00 - 8:20 a.m.	*Aisha M. Sexton*	*Comparison of Flow Calibration Using NEXRAD and Surface Rain Gauge Data in ArcSWAT*
8:20 - 8:40 a.m.	*Rajesh Shrestha*	*Application of SWAT in Hydrologic and Nutrient Transport Modelling of the Lake Winnipeg Watershed*
8:40 - 9:00 a.m.	*Nam Won Kim* *Il Moon Chung* *Jeongwoo Lee*	*An analysis on the spatio-temporal variation of groundwater-surface water interactions in small watershed*
9:00 - 9:20 a.m.	*Ilyas Masih*	*Assessing the benefit of improved precipitation input in SWAT model simulations*
9:20 - 9:40 a.m.	*Matjaz Glavan*	*Application of SWAT Model in small flysch catchments in Slovenia*
9:40 - 9:45 a.m.	*Discussion & Wrap Up*	

8:00 a.m. - 9:45 a.m. **SESSION G2 - BMPs**
University Memorial Center - Room 384

Moderator: Indrajeet Chaubey
Purdue University

8:00 - 8:20 a.m.	*David Waidler*	*Conservation Practice Modeling Manual for SWAT and APEX*
8:20 - 8:40 a.m.	*Michael White*	*Development of a Simple Conservation Practice Evaluation Tool using SWAT*
8:40 - 9:00 a.m.	*Carl Amonett*	*Modeling Nutrient Loads From Poultry Operations in the Toledo Bend Reservoir and Sam Rayburn Reservoir watersheds of East Texas*
9:00 - 9:20 a.m.	*Pushpa Tuppad*	*Modeling Environmental Benefits of Conservation Practices in Richland-Chambers Watershed, Texas*
9:20 - 9:45 a.m.	*Discussion & Wrap Up*	

8:00 a.m. - 9:45 a.m. **SESSION G3 - Metals & Pesticides**
University Memorial Center - Room 382

Moderator: Cole Rossi
USDA-ARS

8:00 - 8:10 a.m.	*Cole Rossi*	*Metal Transport in SWAT*
8:10 - 8:50 a.m.	*Madgi Selim*	*Transport and Retention of Heavy Metals in Soils: An Overview*
8:50 - 9:10 a.m.	*Michael Winchell*	*Evaluation of a SWAT parameterization strategy for pesticide concentration predictions without site-specific calibration*
9:10 - 9:30 a.m.	*Heather B. Hill* *Maya Motorova* *Tony Spencer* *Mehdi Ahmadi* *Mazdak Arabi*	*Modeling the Fate and Transport of Pesticides in Agricultural Watersheds Using SWAT*
9:30 - 9:45 a.m.	*Discussion & Wrap Up*	

9:45 a.m. - 10:15 a.m. **Break** (beverages & snacks in UMC 235)

10:15 a.m. - 12 p.m. **SESSION H1 - Model Development**
University Memorial Center - Room 386

Moderator: Jeff Arnold
USDA-ARS

10:15 - 10:35 a.m.	*Getnet Betrie* *Ann van Griensven*	*Migration of SWAT 2005 in to Open Modeling Interface (OpenMI) and its Application on the Simulation of Sediment Transport in the Blue Nile*
10:35 - 10:55 a.m.	*Josiane Belanger*	*Freeze/Thaw Dynamics in Soils on the Boreal Plain: Comparison of SWAT Predictions to Measured Data*
10:55 - 11:15 a.m.	*Balaji Narasimhan* *Peter Allen*	*Improved Physically Based Approaches for Channel Erosion Modelling SWAT*
11:15 - 11:35 a.m.	*Daniel R. Fuka*	*Integration of a simple process-based snowmelt model into SWAT*

11:35 - 11:55 a.m.	*Gabriel Vazquez-Amabile*	*AGRIRISK -SWAT: an add-on application for AVSWAT2000 to compute hydrologic and NPS pollution risk analysis in rural watersheds*
11:55 - 12:00 p.m.	*Discussion & Wrap Up*	

10:15 a.m. - 12 p.m. **SESSION H2 - Hydrology**
University Memorial Center - Room 384

Moderator: Claire Baffaut
USDA-ARS

10:15 - 10:35 a.m.	*Alejandra Stehr*	*Evaluation of different spatial discretizations schemes in the hydrological response of an Andean watershed*
10:35 - 10:55 a.m.	*Jiayu Wu*	*Estimating Hydrologic Budgets for Gravity Irrigation District under Semiarid Climate Condition in the Yellow River basin*
10:55 - 11:15 a.m.	*Imuwahen Priscilla Igbinosun*	*Integration of satellite data in the SWAT watershed water quality model: A case study of Roxo reservoir watershed, Portugal.*
11:15 - 11:35 a.m.	*Johnathan R. Bumgarner*	*Challenges in Calibrating a Large Watershed Model with Varying Hydrogeologic Conditions*
11:35 - 11:55 a.m.	*Zachary M. Easton*	*SWAT-Water Balance: Development and application of a physically based landscape water balance in the SWAT model*
11:55 - 12:00 p.m.	*Discussion & Wrap Up*	

10:15 a.m. - 12 p.m. **SESSION H3 - SWAT Applications**
University Memorial Center - Room 382

Moderator: Antonio Lo Porto
Water Research Institute (IRSA), Italy

10:15 - 10:35 a.m.	*Dr. Vinay K. Pandey*	*Development of Effective Management Plan for a Small Watershed Using AVSWAT*
10:35 - 10:55 a.m.	*Shaochun Huang* *Valentina Krysanova* *Fred F. Hattermann*	*Assessment of Spatial-Temporal Dynamics of Water Fluxes in Germany under Climate Change*
10:55 - 11:15 a.m.	*Emmanuel Obuobie*	*Climate Change Inpacts on Hydrology and Water Resources in the White Volta River Basin, West Africa*
11:15 - 11:35 a.m.	*Hua Xie*	*The Use of Global Databases in Developing SWAT Applications to Sub-Saharan Africa and South Asia for Large-scale Hydrological and Crop Simulation: Preliminary Results of Data Preprocessing and Harmonization*
11:35 - 11:55 a.m.	*Pedro Chambel Leitao*	*Satellite Data and New Methodolgoies for SWAT Validation in Euthrophication Studies*
11:55 - 12:00 p.m.	*Discussion & Wrap Up*	

12 p.m. - 1 p.m. **Lunch**
Restaurants located on the first floor of the University Memorial Center include: Alferd Packer Grill, Al's Fresco, El Canibal, Slumgullion, Soup/Chili & Salad Bar, The Tabor, Subway, Wok & Roll and more.

1:00 p.m. - 2:45 p.m. **SESSION I1 - SWAT Applications**
University Memorial Center - Room 386

Moderator: Pushpa Tuppad
Texas AgriLife Research

1:00 - 1:20 p.m.	*Maya Motorova* *Mahdi Ahmadi* *Barmak Azizimoghaddam* *Mazdak Arabi*	*Spatiotemporal Variability of Nutrient Processes under Changing Climate*
1:20 - 1:40 p.m.	*Michael W. Van Liew*	*A post processing tool to assess sediment and nutrient source allocations from SWAT stimulations*
1:40 - 2:00 p.m.	*Pedro Chambel Leitao*	*Land Use Resolution Impact on Modelling Water Quantity and Quality - Tagus Watershed*
2:00 - 2:20 p.m.	*Dave Bubenheim*	*Modeling River Flows and Sediment Dynamics for the Laguna de Santa Rosa Watershed in Northern California*
2:20 - 2:45 p.m.	*Discussion & Wrap Up*	

1:00 p.m. - 2:45 p.m. **SESSION I2 - InStream Sediment & Pollutant Transport**
University Memorial Center - Room 384

Moderator: Pedro Chambel Leitao
IST-MARETEC, Portugal

1:00 - 1:20 p.m.	*Kim Loi Nguyen*	*Application of SWAT Model for Sediment and Water Quality Assessment in La NGA Watershed - Vietnam*
1:20 - 1:40 p.m.	*Xuesong Zhang*	*GIS-based Spatial Precipitation for SWAT*
1:40 - 2:00 p.m.	*Claire Baffaut* *E. John Sadler* *Robert Lerch* *Newell Kitchen* *Kenneth Sudduth*	*SWAT development for simulating flow and pesticide movement in a large clay-pan watershed*
2:00 - 2:20 p.m.	*Michael W. Van Liew*	*Streamflow, Sediment, and Nutrient Simulation of the Bitterroot Watershed Using SWAT*
2:20 - 2:45 p.m.	*Discussion & Wrap Up*	

1:00 p.m. - 2:45 p.m. **SESSION I3 - Environmental Applications**
University Memorial Center - Room 382

Moderator: Nicola Fohrer
Christian-Albrechts-University, Kiel, Germany

1:00 - 1:20 p.m.	*Lula T. Ghebremichael* *T. L. Veith* *M. C. Watzin*	*SWAT modeling of Critical Source Area for Runoff and Phosphorus loss: Lake Champlain Basin*
1:20 - 1:40 p.m.	*Aditya Sood*	*Using SWAT as a Tool for Sustainable Landuse Policy Development*
1:40 - 2:00 p.m.	*Gerald Whittaker*	*Calculation of optimal trade-offs between farm profit, water quality and fish diversity*
2:00 - 2:20 p.m.	*Stefan Julich*	*Management scenarios for reduced nitrate loads in a small catchment in Brittany (France) - the problem of data scarcity and the resulting predictive uncertainty*
2:20 - 2:45 p.m.	*Discussion & Wrap Up*	

2:45 p.m. - 5:00 p.m. **Open Forum for Future SWAT Discussion**
University Memorial Center - Room 235

Moderator: Raghavan Srinivasan; Jeff Arnold
Texas AgriLife Research; USDA-ARS

EnviroGRIDS – Integrating SWAT in the Black Sea Catchment Observation and Assessment System

Anthony Lehmann

The European EnviroGRIDS project aims at building capacities in the Black Sea region on new international standard to gather, store, distribute, analyze, visualize and disseminate crucial information on past, present and future states of this region in order to assess its sustainability and vulnerability. In order to achieve its objectives, EnviroGRIDS will build an ultra-modern GRID enabled Spatial Data Infrastructure (SDI) that will be able to become one of the integral systems in the Global Earth Observation System of Systems (GEOSS), and will be compatible with the new EU directive on Infrastructure for Spatial Information in the European Union (INSPIRE). It will gridify the SWAT code in order to allow its use on large clusters of computers.

The scientific aim of the EnviroGRIDS project is to start building an Observation System that will address several Societal Benefit Areas as defined by GEOSS within a changing climate framework. This system will incorporate a shared information system that operates on the boundary of scientific/technical partners, stakeholders and the public. It will contain an early warning system that will inform in advance decision makers and the public about risks to human health, biodiversity and ecosystems integrity, agriculture production or energy supply provoked by climatic, demographic and land cover changes on a 50 year time horizon.

The main objectives of the EnviroGRIDS project are to: create spatially explicit scenarios of key changes in land cover, climate and demography; distribute the calculations of SWAT on large computer clusters (GRID); streamline the production of indicators on sustainability and vulnerability of societal benefits; provide policy-makers and citizens with early warning and decision support tools at regional, national and local levels; build capacities in the implementation of many new standards and frameworks (INSPIRE, GEOSS).

Application of SWAT Model to Investigate Nitrate Leaching in Hamadan-Bahar Watershed, Iran

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Application of large amounts of mineral and organic fertilizers in intensive agricultural regions of Hamadan-Bahar watershed in western Iran contributes to excessive nutrient loads in soils and groundwater bodies. Nitrogen leaching from agriculture land is a common global problem in groundwaters. We employed SWAT to examine the effects of agricultural management on nitrate leaching in Hamadan-Bahar watershed. Groundwater supplies approximately 80% of the water consumed in Hamadan, with the remainder coming from surface water reservoirs. Objectives of this study is to investigate temporal and spatial variability of the nitrate leaching in Hamadan-Bahar plain and suggest best management practices (BMP) to reduce nitrate leaching in the future. The SWAT model is calibrated and validated with uncertainty analysis with SUFI-2 (Sequential Uncertainty Fitting, ver. 2) procedure using measured daily discharge data from 7 discharge stations, and 1 measured daily nitrate station at the outlet of the watershed. We further calibrated the model for crop yield to improve the confidence on soil moisture, evapotranspiration, water percolation from the root zone, and plant uptake of nitrogen. The calibration and validation results are quite satisfactory. This validated model will be used along with an optimization routine for BMP analyses.

Modeling Chesapeake Bay Watershed Using SWAT

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Chesapeake Bay (CB) is the largest estuary in North America, and has been listed as impaired under the Clean Water Act since 2000. Deteriorating water conditions are largely due to contaminants carried into the Bay by the many tributaries in the CB watershed. The Earth System Science Interdisciplinary Center of the University of Maryland at College Park is developing a Chesapeake Bay Forecast System (CBFS) to perform regional Earth System predictions for the Chesapeake Bay watershed. SWAT is the watershed component of CBFS land module to simulate the hydrology and water quality of the prominent tributaries in the CB watershed. This paper reports the model configuration and results for Rappahannock, one of the major CB river basins. The data used in this work comes from many sources including project survey, literature, and various government databases and reports. The complete configuration of the model involves the following steps: watershed delineation and the establishment of HRUs, sensitivity analysis, balancing water budget, adjusting crop yields, balancing flow partition, manual and auto-calibration, and validation. The simulated quantities include daily average stream flow and daily loads of sediment, nitrate and phosphate. Calibration results show satisfactory model simulations of the first three variables and good prediction of phosphate load. Validation of nitrate load also satisfies a set of stringent evaluation criteria. Other variables underperform during validation especially phosphate due to several reasons.

The Rappahannock SWAT model currently produces a routine 14-day forecast in an automated system. The system retrieves 14-day ensemble climate forecast from the CBFS regional atmospheric model, runs SWAT, and delivers the output to the CBFS ocean model. Eventually, an independent SWAT model will be adopted for each of the major river basins and some of the second-order river basins in the CB watershed.

Application of SWAT for Water Quality Modeling of the Caddo Lake Watershed

Kendra Riebschleager

A watershed protection plan (WPP) for Caddo Lake, Texas, and the Cypress Basin is currently in development in cooperation with local stakeholders and the Northeast Texas Municipal Water District. As a part of the WPP, modeling of both the watershed and the lake are underway to characterize and quantify the spatial distribution of pollutants and their sources. The Caddo Lake Watershed is comprised of three major subbasins – the Little Cypress Creek, Big Cypress Creek, and the remaining contributing drainage areas to Caddo Lake. The Soil and Water Assessment Tool (SWAT) is used in this watershed to model the hydrologic processes of the watershed and predict pollutant loading from nutrients (nitrogen and phosphorus), dissolved oxygen, and sediment transport. Model scenarios representing Best Management Practice alternatives are evaluated to determine impacts to loading and water quality conditions. The ultimate goal of the WPP project is to provide recommendations for water management alternatives for the protection of Caddo Lake addressing concerns such as nuisance vegetation and observed elevated chlorophyll-a concentrations.

Integrated Water Resources Management for Water and Food Security in Iran

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Population growth and industrialization on the one hand and extended droughts, environmental degradation, and possible adverse impacts of climate change on the other hand are major factors limiting water resources availability in most of Iran. As the agriculture is the largest water user in Iran, there are various attempts to increase agricultural water use efficiency in the country. A major problem is that the traditional techniques to increase water use efficiency are no longer appropriate. Overlapping responsibilities among different agencies often worsen the situation. Hence, there is an emerging need for the design of an integrated approach to water resources management (IWRM) in order to provide services to the growing population and to simultaneously provide adequate and sustainable environmental protection. To design an IWRM for a region, a sound knowledge of water resources, water and crop relationships, climate change impacts, socio-economic conditions, and stakeholder interests is necessary.

In this study, we used SWAT to first, quantify the water resources availability, second, to model the cereal yield, consumptive water use (ET) and crop water productivity (CWP), and third, to assess the impact of climate change on water resources availability and agricultural productivity in Iran. The results were then used to examine stakeholder and governmental oriented objectives in terms of water and food security through changes in agricultural landuse planning, and finally, the possible impact of these changes on socio-economic and environmental factors by employing the concept of sustainability solution space (SSP). This study provides a strong basis for a multi-criteria decision analysis to test the strategies on the enhancement of water and food security taking into account water resources, agricultural productivity, and climate change impacts.

How To: Applying and Interpreting the SWAT Autocalibration Tools

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Watershed-level modelers have expressed a need, through ongoing discussions within the USDA-ARS Conservation Effects Assessment Program and the broader international research community, for a better understanding of uncertainty related to hard-to-measure input parameters and to the remaining internal processes of a model. One water quality model of interest in this regard is the Soil and Water Assessment Tool (SWAT), which is being used internationally to aid in assessing the effects of various conservation practices. This paper defines and explains the main outputs provided by the three components of the SWAT Autocalibration Tool: parameter sensitivity analysis, parameter uncertainty, and model uncertainty. The goal of the paper is to aid future users by demonstrating a straightforward process for applying and interpreting the results of the Autocalibration Tool relative to a specific watershed or region. The paper is intended to serve as a reference guide to the Autocalibration Tool user community.

Uncertainty Analysis of the SWAT Model Using Bayesian Techniques

Haw Yen and Mazdak Arabi*

In recent years, a number of prior data management techniques have been developed to deal with parameter estimation of nonlinear simulation models. At the watershed scale, flow dynamics and the fate and transport of contaminants tend to be highly nonlinear. Thus, identification of model parameters that represent these processes presents a challenge and may bear significant uncertainty. In this study, three Bayesian approaches including the Uniform Covering by Probabilistic Rejection (UCPR), Metropolis-Hastings Algorithm (MHA) and Gibbs Sampling Algorithm (GSA) are linked with the SWAT model in order to reduce parameter uncertainties. The results of the analysis in the Eagle Creek watershed, Indiana, revealed the inefficiency of these methodologies individually. However, their combinations show promise for improving efficiency, convergence and reliability of the uncertainty estimates. The shortcomings of these methodologies especially when dealing with high dimensional parameter space are discussed.

Event Based Hydrologic Calibration of Field-Scale Watersheds In Southwestern Wisconsin Using the SWAT Model

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Simulation models are increasingly being used to test how alternative management scenarios can reduce phosphorus export from agricultural watersheds. Calibrating these models using short term monitoring records at watershed outlets can lead to questions about the appropriate combination of parameter changes especially when parameters are strongly correlated. This can be particularly important for the hydrologic calibration. This research determined and compared the sensitivity of common hydrologic calibration parameters in the Soil and Water Assessment Tool (SWAT) model for individual runoff events at the field-scale. Runoff volume and composition was measured for six years from alfalfa and corn fields at the University of Wisconsin – Platteville Pioneer Farm in southwestern Wisconsin. SWAT2005 was used with a daily time-step and model results were summarized on an event, not daily, basis to be consistent with field collection efforts. SWAT was used with PEST, a nonlinear parameter estimation tool, to evaluate parameter sensitivity and uncertainty different calibration techniques. The results show improvement in model fit using a temporally varied NRCS curve number (CN) rather than a single value representative of the entire simulation. The field-scale watersheds were able to be acceptably calibrated to the individual storm events (S2 R^2 = 0.70; S3 R^2 = 0.51). Analysis of parameter sensitivity and parameter correlation indicated that the temporal variation of the CN improved calibration, yet the soil parameters AWC and ESCO were highly sensitive in hydrologic event-based calibration. The correlation of parameters suggests that achieving a unique solution is difficult with the SWAT model.

Preliminaries to Assessing the Quality of SWAT Parameter Confidence Intervals

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While the Soil and Water Assessment Tool (SWAT) is typically calibrated and validated based on streamflow, the prediction of quantities related to contaminant transport or other phenomena are often of greater interest than the prediction of streamflow itself. The reliable prediction of these quantities hinges upon the quality of the SWAT parameter confidence intervals. Various methods have been proposed for providing unbiased parameters with relatively narrow confidence intervals. These methods may be tested by comparison with field data if the field data is abundant in its spatial and temporal coverage. The soil moisture data set of the Little River Experimental Watershed (LREW) is such a data set. For facilitating the comparison of the results of various methods against the field data, minor modifications of the SWAT code are proposed such that the number of SWAT hydrologic response units (HRU's) may be kept minimal and simulation times kept conveniently short, without introducing aggregation errors that would degrade parameter confidence intervals. It is found that aggregation to 102 HRU's provides simulated streamflow values very close to that of a very large reference number of HRU's (10,372) for subwatershed I of LREW. The Nash-Sutcliffe Efficiency of the former relative to the latter scenario is 0.9954 when the parameters are uninhibited by a calibration process. Also, providing ten relatively thin soil layers as opposed to the typical three to five soil layers found in the soil data base used allows for a noticeable difference in simulated streamflow while increasing simulation time by approximately 10%.

Simultaneous Calibration of Surface Flow and Baseflow Simulations of SWAT

Xuesong Zhang, Raghavan Srinivasan, Jeff Arnold*

It is important to calibrate Soil and Water Assessment Tool (SWAT) predictions to match different flow components (e.g. surface flow and baseflow), because the roles of different flow components differ in terms of plant water use, sediment and nutrient transport. In this study, we proposed a framework for simultaneous calibration of surface flow and baseflow simulations of SWAT using evolutionary multi-objective optimization method. The baseflow filter developed by Arnold et al. (1995) was used to separate the total flow at monitoring station B of the Little River Experimental Watershed in Georgia into surface flow and baseflow. Two objective functions (Nash-Sutcliffe efficiency of surface flow and baseflow) were simultaneously calibrated using a multi-objective optimization algorithm. The calibration results show that there is evident tradeoff between the objective functions of surface flow and baseflow. The parameters that favor surface flow simulation are very different from those with good performance for baseflow. Bayesian model averaging (BMA) was used to combine these Pareto optimal simulations for uncertainty analysis. The 90% uncertainty interval estimated by BMA includes about 90% of the observations.

Issues in Modeling Physical Systems with the SWAT Model in Urban Areas

L. Gosselink, R. Glick, J.Moran-Lopez*

Modeling creek systems in the Austin, Texas area is being performed using the Soil and Water Assessment Tool (ArcSWAT) to assess impacts of urban development scenarios and benefits of Best Management Practices (BMPs). Extensive data available in the Austin area was provided as model input for this urban area. During the process of calibration, physical systems and characteristics of urban areas were identified that could not be directly represented by current SWAT input parameters. These urban issues include 1) large stormwater systems that route water contrary to topographic delineations, 2) bypasses where large volumes of water over a certain level are diverted creating two watershed outlets, 3) leaking infrastructure providing an underground distributed water source, 4) physical channel characteristics such as shape and restrictions from pipes or culverts allowing no local overflow from the creek channel, and 5) rapid runoff and response that may not be readily characterized by a daily time step.

Some problems have been addressed by preparing model input with equivalent characteristics, such as burning in channels where storm sewers exist and modifying channel dimensions to provide the same flow capacity. Finding a function, like reverse shallow water pumping, may be sufficient to simulate an urban input such as leaking infrastructure. To address some concerns, the city is working with Texas AgriLife Research and Texas A&M, who are developing model capabilities to include further BMP modeling capabilities and a smaller time step. Some issues, such as large diversion channels, however, have not yet been successfully addressed.

Development of urban modeling tools in SWAT

Jaehak Jeong

In collaboration with City of Austin, Texas, USA, Texas AgriLife Research Scientists are developing algorithms within SWAT for simulation of stormwater best management practices (BMPs) such as detention basin, wet pond, sedimentation filtration pond, and retention irrigation. Modeling urban watersheds often requires time steps as small as minutes to realistically capture the instantaneous flow and pollutant transport coming from urban impervious areas. However, the recent version of SWAT model (SWAT2005) has a limited capability of sub-daily simulation: hourly flow routing is only available.

The objective of this project is to develop sub-hourly simulation capabilities in SWAT for flow, sediment routing and stormwater BMPs. The SWAT model has been modified to run at any time step (as small as one minute). The Green and Ampt method is retained for computation of infiltration and surface runoff at any time step. Flow routing is done at any time step. However, ET and soil water routing are carried out at daily time step only. Splash erosion is calculated based on the kinetic energy delivered by rain drops adapted from EUROSEM model, and rill/interrill erosion is estimated using a physically based equation adapted from ANSWERS model. Three models are available for sediment routing (Brownlie, Yang, and Bagnolds model). The modified SWAT model with newly added routines is expected to yield better results not only for individual storm events but also for long-term simulation periods. Test results to date from the urban version of the model will be presented.

Hydrologic response of watershed systems to land use/land cover change

Tony Spencer, Brian Walker, Mazdak Arabi

Land use change and urbanization can have significant impacts on hydrologic processes within watershed systems. Monitoring data, however, are rarely sufficient to fully understand the spatial and temporal factors that contribute to the change in streamflows. This study presents a modeling approach to evaluate changes in flow regimes at various spatial scales as a result of rapid urbanization in the 273 km2 Eagle Creek watershed in the Midwestern United States. The components of land use change and preexisting conditions, which include previous land use and soil type, were evaluated to determine which components have greater impacts on changes in the streamflows. The Soil and Water Assessment Tool (SWAT) model was used to simulate 50 years of flows for the watershed under the land use conditions of the years 2000 and 2004, as defined by the National Agricultural Statistics Service (NASS) and National Land Cover Data (NLCD) geospatial datasets. Flow duration curves (FDCs) were constructed for 230 subbasins and 230 stream locations within the watershed under the 2000 and 2004 land use conditions. A multivariate regression analysis indicated that change in forest and urban areas, and coverage by soils having moderate to high permeability would bear the greatest impact on the change in streamflow characteristics in the watershed. An analysis of FDCs from several pairs of subbasins that were similar size and land use changes, but were covered by different soil types showed that the paired subbasins did not always experience similar levels of flow regime change. This suggests that the subbasins which are covered by moderate to highly permeable soils are predisposed to larger increases in streamflows under urbanization.

Hydrological Response of Gilgel Abay River Flow to Climate Change, Lake Tana Basin, Ethiopia

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Climate changes have marked impacts on the natural systems. The objective of this paper is to assess the impact of climate change on Gilgel Abay River. Gilgel Abay River is the largest tributary to Lake Tana basin which lies between latitude 10.95^{o} and 12.78^{0}N, and longitude 36.89^{o} and 38.25^{o}E. The HaDCM3 A2a scenario experiment was used for predicting the plausible future climate of the study area. SDSM was used to downscale the GCM data. SWAT was developed, calibrated and validated. SDSM downscaled climate outputs were used as an input to the SWAT model and used to assess the impact of climate change. The decrease in mean monthly precipitation may be up to 30% in 2020s and the increase may reach up to 34% in 2080s. The change in monthly mean maximum temperature ranges between -2.5 ^{0}c in the 2020s and +5 ^{0}c in the 2080s. The change in monthly mean minimum temperature ranges between -1.4 ^{0}c in the 2020s and +4.2 ^{0}c in the 2080s. The impact of climate change may cause a decrease in monthly flow volume up to 46% in the 2020s and increase up to 135% in the 2080s. Seasonal flow volume may show increase up to 136% and 36% for Belg and Kiremit respectively. It is observed that there may be a net annual increase in flow volume in Gilgel Abay River. The increase in flow will help to harness a significant amount of water for the dam projects in the basin. However, it may aggravate flooding problem in the surrounding area.

Predicting Aquatic Life Potential under Various Development Scenarios in Urban Streams using SWAT

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The authors applied SWAT to evaluate the impacts different development conditions on stream-aquatic health in a watershed in the Austin, Texas area. The Walnut Creek watershed was simulated using land used maps developed in 2003 and weather from 2002-2003. The model calibrated well with a Nash-Sutcliffe ratio on 0.872. The model was adequately validated using an estimated land use map based on aerial photographs from 1964 and weather from 1964-1970. A third SWAT model was developed using a projected build-out land use map. The three models were run using weather from 2002-2004 resulting in simulated under different levels of development. The built-out watershed had higher peaks and less baseflow compared to the les developed watersheds. Hydrologic metrics for each development condition were computed at eleven locations in the watershed. The hydrologic metrics correctly refelected changes in development with decreased baseflow, more dry periods, more total dry time and more variable flow in general. These metrics were used to compute an aquatic life potential (AQP) for each condition at location. The AQP indicated decreases in aquatic health that varied with development condition and with location in the watershed. This tool may be used to help planners and regulators evaluate regulations before they are implement rather than waiting for a decline in aquatic health before evaluation.

Watershed Sediment Contribution to SWAT Modeling
A Case Study of the Challenges Faced in a Watershed Application

Darrel Andrews

The impact of sediment runoff from the watershed above a surface water reservoir is critical to the life and quality of the reservoir. The Tarrant Regional Water District (TRWD) supplies raw water for public use to 1.7 million people in the North Central Texas area around Fort Worth, Texas through the construction and operation of its system of water supply reservoirs. In an effort to preserve and protect one of its larger reservoirs, Cedar Creek, TRWD has developed the Cedar Creek Watershed Protection Plan which has utilized various computer models, include SWAT, QUAL2E, and WASP to simulate this dynamic system, beginning in the watershed and continuing through the reservoir itself, to give insight and support in the implementation of BMP's to protect and improve the reservoir. The process of defining the rate and impact of sediment in the modeling efforts has been both enlightening and challenging. This presentation will highlight the efforts, impacts and conclusions which have been integral to this project. Topics will include the development of QUAL2E routines which were integrated into SWAT, the use of various reservoir sedimentation studies and techniques and the implications these have on SWAT, the validation efforts made in the watershed to better predict stream bank erosion and its impact and the role of sediment density in the validation of SWAT's predictions.

Hydrologic Modeling of Cedar Creek Watershed using SWAT

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A SWAT model was developed for Cedar Creek Watershed having a drainage area of about 1008 sq. miles located in the Trinity River basin. EPA BASINS3.0 interface was used for watershed delineation and developing input data for the SWAT model. The watershed was sub divided into106 subbasins which were further subdivided into 1,516 Hydrologic Response Units (HRU's). Data on crop management practices across the watershed such as type of crops, typical growing season, and fertilizer application rates were collected and incorporated into the model. There were about 120 inventory sized dams which includes NRCS flood prevention dams, farm ponds, and other privately owned dams. Four structures were big enough to be simulated as reservoirs and the rest of them were simulated as small ponds. Surface runoff was predicted using the SCS curve number method. SWAT water routing routine using variable Storage method was modified to an iterative approach for determining the flow depth, flow velocity and the flow rate. This modification simulated the flow velocity more realistically than the previous routine which used a "bucket" type approach that overestimated the velocity in smaller reach downstream of two big reaches. The travel time predicted using the modified routines agreed well with the observed data. The travel time is a critical parameter for predicting the natural attenuation of nutrients which is often overlooked in model calibration. The SWAT model was calibrated (1967-1987) for monthly flow using two USGS stream gauge data (Kings Creek R^2: 0.83; Cedar Creek R^2:0.81) and validated using flow balance data to compute inflows to Cedar Creek reservoir (1980-2002) (R^2:80).

Steady State Nutrient Modeling in Streams

Mark R. Ernst

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Recent versions of SWAT have included QUAL2E routines to facilitate instream routing and transformations of water quality parameters from the watershed to a reservoir. In the development of a SWAT model for the Cedar Creek watershed it was decided that an effort to calibrate a stand-alone QUAL2E model on the largest tributary of Cedar Creek Reservoir, Kings Creek, would be a worthwhile exercise. Seven fluorometric time-of-travel dye studies, two 24-hour water quality monitoring studies at numerous stream sites and one year of weekly nutrient sampling at watershed wastewater treatment plants provided the database to begin model parameterization and calibration. A steady state QUAL2E model was calibrated for Sep 2002 at 26 ^{o}C with 4.6 cfs, when flow was heavily influenced by the discharge of three wastewater treatment plants. A second, validation model was built for Feb 2002 at 14 ^{o}C with 11 cfs, when baseflow was more prominent. Model development revealed some inadequacies for our intended purpose, namely denitrification was not available in QUAL2E as a nitrogen sink and dissolved phosphorus could not bind to sediments and settle out of the water column. Even with these inadequacies, the independent development of QUAL2E provided an approximation of the attenuation of phosphorus and nitrogen found in observed data. QUAL2E's sound hydraulics (time of travel) and temperature corrected kinetics makes the model useful for extrapolation to other times of the year and provides a basis for development of the Qual2E portion of the SWAT model.

Sediment: Translating between Physical Measurements and SWAT parameters

Jennifer L. Owens

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Correct calibration of sediment within the SWAT model is an important factor due to the fact that nitrogen and phosphorus are directly tied to the sediment loads. Going into the development of the Cedar Creek Reservoir watershed model, TRWD believed adequate historical data was available for sediment calibration through historic volumetric surveys of Cedar Creek Reservoir and total suspended solids (TSS) concentration data for the major tributaries dating back to 1989. However, throughout the calibration process, several challenges arose in taking the available sediment data resources and applying them to SWAT. The first challenge was determining the rate of sedimentation. The three historic reservoir volumes on record did not lead to a conclusive rate. The two most recent points were volumetric surveys measured by the Texas Water Development Board with a depth sounder. However, the results of the two surveys were conflicting, with the reservoir actually increasing in volume over time. In the end, the sedimentation rate was determined using the most recent volumetric survey done in 2005 and the initial design volume of the reservoir from 1965. Using the difference between these two points, the sedimentation rate of the reservoir was estimated to be 1032 ac-ft/yr. This rate was confirmed somewhat by 5 cores collected from the main thalweg that average 1.23 feet extrapolated over 32,873 acres for an estimated 983 ac-ft/yr. It is possible that a multi-frequency sedimentation survey may be a better indicator of overall post-impoundment sediment accumulation than the comparison of multiple volumetric surveys over time. In addition, the historic data points give a change in volume, but SWAT needs a rate in units of mass. Additional studies were necessary to determine sediment density. From the cores collected from the main pool of Cedar Creek Reservoir, the average density was found to be 21.5 lbs/ft^3. This is the density that was utilized for the calibration of this model, however additional studies on other reservoirs have confirmed that densities can vary greatly between the delta areas and the main pool. Once the global sedimentation rate was determined, a second challenge arose in attempting to calibrate SWAT output on each of the major tributaries to the historic record of TSS data that was available. The sediment concentration parameter for SWAT output is not directly comparable to the grab sample TSS concentrations measured in the tributaries. Physical sediment measurements are useful tools as a basis for the SWAT model, but caution must be taken in their application and interpretation to ensure accurate results.

Channel Erosion and Water Quality Modeling using SWAT

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Channel erosion can be a significant portion of overall erosion dynamics in the watershed. In the current research the erosion dynamics of Cedar Creek watershed located in North-Central Texas has been studied. Cedar Creek Reservoir is a major water supply reservoir with a storage capacity of over 637,200 ac. feet. It is one among the four major drinking water reservoirs owned and operated by Tarrant Regional Water District that supplies raw water to approximately 1.5 million people. Sediment and nutrient loading into the reservoir has been a major source for algae blooms that threatens the drinking water quality. Hence, as a precursor to developing a TMDL, a pollutant source assessment study was undertaken to identify nutrient and sediment hot spots within the watershed area. A rapid geomorphic assessment of watershed sediment budget was done using field survey and reservoir sub-bottom acoustical profiled. These observations were used to calibrate the SWAT model for sediment loading. The field survey and model study showed that channel erosion contributes upto 35% of total annual sediment load into the lake. At present the nutrient loading from the instream channel erosion is not modeled in SWAT. Hence, the instream channel processes in the SWAT model was modified to account for nutrient loading from channel erosion. Nutrient loading from overland region also have to be modeled with prudence. Initial nutrient concentration of soil is very important to get accurate estimates of loads coming from different landuse. Prior to 1980 most of the pasturelands were used for row crop cultivation with intensive fertilizer application. Long term row crop cultivation with fertilizer application would lead to build up of nutrients in the soil especially Phosphorus. Hence, the soil nutrient values were initialized appropriately for estimating current nutrient loads from the pastureland. Nutrient routing in channel was done in SWAT using QUAL2E. The water quality coefficients were calibrated based on data from intensive low flow study and periodical grab samples collected at various sections. After calibration was completed, SWAT output from 1989 to 2002 was converted to a WASP nonpoint source (.nps) input file for modeling the nutrient dynamics within the reservoir.

Comparison of Water Quality Effects of Biofuel Production in the Upper Mississippi River Basin using a Malquist Index.

Gerald Whittaker, Raghavan Srinivasan, Rolf Färe, and Shawna Grosskopf*

One approach to production of biofuel feedstocks is to increase corn production within the Upper Mississippi River Basin (UMRB). In order to assess the water quality effects of alternative levels of increased corn production within the UMRB, we established a SWAT model of a baseline scenario for current conditions, to which the results of alternative production scenarios can be compared. The term "water quality" is based on the construction of a single measure that is representative of the measured components of stream constituents in some sense. Such a measure is typically referred to as an index of water quality. The development of an index for description and monitoring of surface water quality has received significant attention in the water resources literature in recent years, driven by increasing need for assessment of water quality and the complex, multidimensional data collected from water quality monitoring. In this study, we specify a water quality index based on a Malmquist quantity index. The study of index numbers is relatively mature, and properties that are required for construction of a useful index number are well known. The Malmquist index has the properties of homogeneity , time-reversibility, transitivity, and dimensionality. It can also include responses to stream water chemistry, such as suitability for recreation or habitat. It is easy to calculate with a linear program, and lends itself naturally to the characterization of water quality.

In this study, SWAT scenario analyses were performed for the years 2010, 2015, 2020, and 2022 with the national ethanol production goals of 12 billion gallons per year (BG/Y) for 2010, and 15 BG/Y for 2015 - 2022. These national goals were adjusted for the UMRB based on a 42.3% ratio of ethanol production capacity within the UMRB compared to national capacity. This ratio was determined by overlaying a coverage of nationwide ethanol plants with a coverage of the study area. Production from ethanol plants within the study area were totaled and then divided by the nationwide production. Both current production and planned expansion were included in the totals. A Malmquist index approach was used to calculate an index of water quality based on annual outputs of nitrogen, phosphorus and sediment in each of the 131 8-digit Hydrologic Unit Codes (HUC) in the UMRB. The results show a complex pattern of changes in water quality. The simulated changes in water vary geographically, through time, and in scale. Some increased corn production scenarios actually improve water quality in a number of HUCs. This work contributes to the discussion of the environmental effects of biofuel feedstock production, and introduces robust, mathematically rigorous method of constructing a water quality index.

Water Quality Modeling Efforts to Assess the Impacts of Ethanol Corn Production in the Upper Mississippi River Basin

Paul Hummel

The renewable fuel program established by the Energy Independence and Security Act (EISA) mandates the use of 36 billion gallons of renewable fuel by 2022. This volume effectively includes 15 billion gallons of ethanol made from corn kernels by 2015. Of the potential crops for biofuel production, corn has the highest rates of application of fertilizers and pesticides, leading to the concern that higher corn production could result in an increased loading of nutrients, pesticides, and sediment to waterways. The focus of this study was to model and assess the potential impacts on surface waters resulting from the expected increase in corn production in the Upper Mississippi River Basin (UMRB). The UMRB was selected because it represents many potential issues associated with ethanol production, including its connection to major water quality concerns such as the hypoxia problems identified in the Gulf of Mexico. The Soil and Water Assessment Tool (SWAT) model was used to perform the project's modeling due to its established technical capabilities, widespread use, comprehensive representation of watershed processes, and efficient computational execution.

A baseline model scenario was established using the most current databases available for the study area. Using the national ethanol production goals, future model scenarios were run for the years 2010, 2015, 2020, and 2022. A subset of selected land uses were converted to corn to meet the ethanol goals for each future scenario. Additionally, baseline corn yields were adjusted in future scenarios to reflect expected advances in crop science. The 2010 scenario showed increases from baseline conditions of 5.5% and 3% for Nitrogen and Phosphorous loads, respectively. Scenarios beyond 2010 showed lower increases due to a modeled 1.23% annual increase in corn yields and plant uptake. To further assess and support these results, a case study and sensitivity analysis are planned. The case study will model the Raccoon River in central Iowa to provide a more detailed analysis within the UMRB. The sensitivity analysis of the entire UMRB SWAT model will help identify the parameters that have the greatest impact on results.

An Integrated Modeling Approach Used for Assessment of Conservation Practices on Water Quality Conditions in the Upper Mississippi River Basin

C. Santhi

An analytical approach involving modeling strategy and farmer surveys was developed to quantify the environmental benefits of conservation practices on cropland as part of the USDA's Conservation Effects Assessment Project (CEAP) national assessment. The modeling strategy involves using a farm-scale model Agricultural Policy/Environmental Extender (APEX) and a watershed scale model Soil and Water Assessment Tool (SWAT) with GIS databases. APEX is used to simulate conservation practices on cultivated cropland and Conservation Reserve Program land based on a subset of farmer surveys.

Field scale loadings of sediment, nitrogen, phosphorus and atrazine from the APEX simulations for cultivated cropland and CRP were integrated into a regional water quality model—SWAT within a Hydrologic Unit Model of the United States (HUMUS) modeling framework. SWAT simulates non-cultivated land including pasture, range, forest, wetland and urban lands and atmospheric depositions on non-cultivated land. The model routes the pollutants generated from non-cultivated land and point sources along with APEX loadings from cultivated land to 8-digit and 4-digit watershed outlets and finally to the outlet of the river basin.

Water quality effects of the conservation practices are determined by comparing source loads and in-stream loads at various locations in the Upper Mississippi River Basin. This paper presents the integrated modeling approach, the in-stream benefits of current conservation practices, further conservation treatment needed, and other scenarios in the Upper Mississippi River Basin.

Effect of Potential Future Climate Change on the Cost-Effective Nonpoint Source Pollution Reduction Strategies in the Upper Mississippi River Basin

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The Mississippi River Watershed is a vast U.S. national resource that covers an area of 3.2 million km^2 across parts or all of 31 states and two Canadian provinces (Figure 1). The nitrate and phosphorus loads discharged from the mouth of the Mississippi River have been implicated as the primary cause of the seasonal oxygen-depleted hypoxic zone that occurs in the Gulf of Mexico, which covered 20,720 km^2 in 2008, the second largest reported since 1985 (http://www.gulfhypoxia.net/research/shelfwidecruises/2008/PressRelease08.pdf). Recent estimates suggest that 43% of the N and 27% of the P flux to the Gulf originate from the Upper Mississippi River Basin (UMRB), which covers only 15% of the total Mississippi drainage area (Aulenbach et al., 2007). The magnitude of UMRB water quality degradation is also demonstrated by the inclusion of 1,220 stream segments and lakes on the current U.S. Environmental Protection Agency (USEPA) listing of impaired waterways (http://www.epa.gov/owow/tmdl/). Nutrient inputs via fertilizer and/or livestock manure on cropland and pasture areas are the primary sources of nonpoint source nutrient pollution in the UMRB stream system.

While conservation practices can reduce nonpoint source pollution under specific cropping systems and field characteristics, the effectiveness of these conservation practices at the watershed level significantly depends on their placements in the watershed and the physical characteristics of the sites on which they are placed. In addition, multiple conservation practices exist, each of which has different effectiveness at controlling N and/or P. This means that solving for the optimal location of conservation practices within a watershed for water quality improvement requires comparing a very large number of possible land use scenarios. Potential climate change poses another challenge as the watershed hydrology largely depends on the magnitude, intensity, and timing of the precipitation and the air temperature.

The goal of this study is to assess the cost-effectiveness of conservation practices on a full watershed scale with a direct recognition of the role of potential future climate change. The specific objectives are to identify the least cost combinations and placement of conservation practices to achieve nonpoint source water pollution reduction, and to quantify the effects of potential future climate change on these pollution reduction strategies in the UMRB.

A UMRB modeling system has been developed using a watershed based bio-physical model called the Soil and Water Assessment Tool (SWAT) (Arnold et al., 1998), several software and interfaces including GIS and other executables, input databases including topography, land cover, land management practices, weather, point sources, reservoirs, wetlands, and others, and cost data of establishing different land management practices. The SWAT model operates on a

daily time step and is designed to assess the impact of different management practices on water, sediment, and agricultural chemical yields. Major model components include weather, hydrology, soil temperature, crop growth, sediment, nutrients, pesticides, and land management. SWAT has a history of continuous development over past 30 years and has been successfully applied extensively at a variety of watershed scales in many regions across the globe (Gassman et al., 2007). The model divides the UMRB into 131 subwatersheds, which are further delineated into over 2,500 hydrologic response units (HRUs) based on land use, soil type, and management categories. SWAT performs daily mass balance at HRU level and then the resulting flow generation, sediment and chemical yields are summed across each subwatershed and finally routed through main channels and reservoirs to the watershed outlet. HRUs were developed using detailed crop rotations and an array of nutrient and tillage management schemes to more accurately reflect current practices in the UMRB and better facilitate policy analyses for the region, by using land use and other data from the 1997 U.S. Department of Agriculture's National Resource Inventory (USDA-NRI) database (http://www.nrcs.usda.gov/technical/NRI/) and other USDA surveys. A calibration and validation of the UMRB modeling system is reported in Jha et al. (2006).

The calibrated UMRB modeling system has been used to examine suites of hypothetical scenarios of reducing nonpoint source pollution. Evolutionary algorithms are combined with the UMRB modeling system to establish a frontier of least cost combinations and location of conservation practices to achieve various nutrient reductions. Results will be presented describing the tradeoff relationship between nutrient reduction and the corresponding cost of placing selected sets of conservation practices in the UMRB.

The effects of potential future climate change on the frontier selection will also be discussed. The North America Regional Climate Change Assessment Program (NARCCAP) recently started to produce high resolution climate change scenarios by nesting multiple regional climate models (RCMs) within multiple atmospheric ocean general circulation models (AOGCMs) forced with future emissions scenarios (http://www.earthsystemgrid.org/forward.htm?forward=narccap). We will use this high resolution climate prediction to quantify the possible impact of future climate change on nonpoint source pollution reduction strategies. Weather information from these climate models will be applied to the modeling system. This modeling work will be very useful for policy makers and stakeholders to explicitly see the tradeoffs between nutrient reduction and the placement of conservation practices under the baseline condition as well as future climate scenarios. This work could also be used to guide the design and implementation of conservation policy.

Advances in Tracking Nutrient Sources in the Mississippi and Atachafalaya River Basin Using the SPARROW Model

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Increased use of nutrients in past decades, although benefiting society through food and energy production, has increased reactive nitrogen (N) and phosphorus (P) loads in streams, contributing to eutrophication and seasonal hypoxia in many coastal ecosystems globally. In the United States, elevated nutrients in the Mississippi and Atchafalaya River Basin (MARB) have contributed to hypoxia in coastal waters of the northern Gulf of Mexico. Effective management of Gulf hypoxia requires an improved understanding of the sources of nutrients as well as the management practices and climatic and landscape properties that control nutrient delivery to the coast. This is especially challenging in large watersheds, such as the MARB, where land use and environmental conditions are diverse and coastal waters are separated from sources by hundreds to thousands of kilometers. This presentation describes recent applications of the U.S. Geological Survey SPARROW (SPAtially Referenced Regression On Watershed attributes) model to the 3 million km^2 MARB. SPARROW uses a hybrid statistical and process-based approach that includes non-conservative transport, mass-balance constraints, and water flow paths to track the mean annual flux of nutrients in terrestrial and aquatic ecosystems. Monitoring records and spatially explicit geospatial datasets inform the specification and estimation of the model, leading to an improved understanding of watershed processes and model uncertainties. We highlight results from two recently published studies. The first reveals important differences in the sources and transport of N and P that affect their delivery to the Gulf. Although agriculture contributes most of the nutrients to the Gulf, corn and soybean cultivation is the largest N source (52%), whereas P originates primarily from animal manure (37%). Atmospheric deposition is the second leading N source, with urban sources contributing less than 12% of both nutrients. Model results indicate that N and P delivery is strongly influenced by hydrological and biogeochemical processes (e.g., water travel time, denitrification, storage) that scale with stream size, whereas P displays large local- and regional-scale differences in delivery caused by reservoir trapping. In the second study, a statistically robust method was developed for identifying ‘‘high priority’’ inland watersheds for managing nutrient delivery to the Gulf. The method provides a probabilistic ranking of MARB watersheds that accounts for uncertainties in model predictions of delivered nutrient yield to the Gulf (kg km^{-1} yr^{-1}). Watersheds are ranked according to their probability of belonging to a specified high-priority class of watersheds (e.g., the “top 150”) with the highest delivered nutrient yields. Uncertainties in rankings and yields indicate that substantially more watersheds can be confidently excluded from the “top 150” class than included (e.g., 513 of 818 watersheds can be excluded with 90% confidence for N, whereas only 11 watersheds can be included at the same confidence level). The findings suggest that nutrient-reduction efforts will need to target a larger set of high-priority watersheds in the MARB (e.g., "top 250") to effectively reduce nutrient loadings to the Gulf. The SPARROW-based ranking procedure provides a robust and informative method for evaluating the effectiveness of alternative watershed priorities.

Modeling wetland functions and services using SWAT

Ann van Griensven, M. Hidalgo

Many wetlands are dependent on river basin processes, and at the same time, scientists have recognised the important role of wetlands in the river basin: they are important zones for groundwater re-charge, they temper high flows and are therefore very important to limiting flooding. By purifying the water, wetlands also play a very important role for water quality. However, the underlying processes are often not very well known or are poorly quantified. This is especially true for many wetland-rich basins in developing countries that are either poorly gauged or even ungauged.

The freely available GIS maps for DEM, Soil Maps and land use maps are very useful for setting up catchment models but they are not very helpful for wetland characterisation. Finally, wetlands are delineated by combining slope calculation using the DEM and manual evaluations using Google Earth.

The following adaptations were done to the SWAT model in order to simulate the wetlands:

(1) Inclusion of deviation of water from groundwater and/or river towards the wetlands(threshold based).

(2) Switching to hydrological processes for saturated soils during flood periods.

Role of spatial aggregation on sediment processes in SWAT

Emily Boyd, Mazdak Arabi

This paper presents a computational framework for quantifying the impacts of watershed delineation on the complexity, performance, and identifiability of sediment processes in a watershed model. Sediment yields from a watershed have important implications for water quality and water resources. Water quality issues arise because sediments serve as carriers for various pollutants, such as nutrients, pathogens, and toxic substances. Watershed models are often used to model sediment transport through the watershed and provide information on abatement strategies and their location for pollutant control. Accurately representing sediment processes in a watershed model is reliant upon a reasonable hydrologic network representation.

Currently, watershed delineation and extraction of stream networks are accomplished with GIS databases of digital elevation models (DEMs). The most common method for extracting channel networks entails the a-priori specification of a critical source area that is required for channel initiation. There are no established guidelines on how to select the critical source area, and the nature of the channel network is very sensitive to this value. As a result, the channel network can be viewed at multiple scales within the same watershed. Thus, for the same watershed and DEM data, users may obtain markedly different channel networks, and subsequently the watershed model results and nonpoint source control strategies could be affected as well.

The proposed computational analysis, comprised of multivariate and tree regression analyses, is linked with the Soil and Water Assessment Tool (SWAT) to determine the optimum channel network extent that provides the best model performance. The tradeoff between computation time, performance and complexity of SWAT will be investigated using ten different water configurations.

Validation of the SWAT Model for Sediment Prediction in a Mountainous, Snowmelt-dominated Catchment

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Federal and state agencies across the United States are currently tasked with Total Maximum Daily Load (TMDL) development to ensure compliance with the Clean Water Act of 1972. In the northwestern part of the country, the TMDL effort is particularly challenging due to the complicated nature of expansive watersheds, steep mountainous topography, and orographic precipitation. This is especially true for sediment, which is a primary pollutant of concern. Modeling, in combination with field source assessments, has historically been used to estimate watershed sediment yields and associated source contributions. However, even with widespread use of these methods, little has been done to validate the sediment prediction performance of modeling tools in forested mountain regions. The purpose of this paper is to present an eight-year simulation period (1985-1992) for the Lamar River in Yellowstone National Park, Wyoming USA where daily suspended sediment discharges are compared with simulated loads from the Soil and Water Assessment Tool (SWAT). Based on Nash-Sutcliffe efficiencies of >0.81 and >0.86 and for daily and monthly streamflow, and > 0.51 and >0.78 for daily and monthly sediment, as well as simulated and observed streambank erosion contributions of 76 and 72 percent respectively, findings suggest that SWAT is a suitable tool for simulation of sediment yield in mountainous snowmelt-dominated catchments. Information gleaned from this study is applicable to the high-elevation areas of Idaho, Montana, and Wyoming, USA, or those with similar hydrophysiographic constraints.

An Earth-Surface Landscape Evolution Model with a Biological Life Signature

LJ Thibodeaux

In geomorphology, the traditional continuity equation model has provided a useful framework upon which to examine important questions about landscape evolution through time. However, it has advantages and disadvantages. Key advantages include the ability to quantitatively reproduce observed landscape features and mathematical simplicity. This approach has led to some significant findings that have led to a better understanding of the factors driving landscape evolution. The disadvantages are nonetheless significant, particularly the use of a single, empirically-determined parameter for describing the many competing factors that direct the evolution of landscape shape changes. The approach also oversimplifies reality in that it lacks direct inclusion of theoretical terms and formulations that can realistically account for on- and near-surface layer soil transport processes.

We have developed a revised theoretical approach to the formulation of landscape evolution models. It commences with a new derivation, from first principles, of the soil surface continuity equation using a three-dimensional, thin, surface-plane volume element as its basis. The resulting solutions retain the key forecasting feature of the original—the prediction of landscape surface elevation as a function of time and position.

The model can be formulated to include a wide range of surface and near-surface processes, such as soil bioturbation, gravity-driven down-slope soil creep, surface mound erosion, and source-soil erosion. Hillslope landscape profiles displaying an up-slope convex shape and a down-slope concave shape are inherent in the newly derived continuity equation. Numerical landscape shape evolution results for idealized hillside initial conditions are readily obtained and allow for comparison of the relative magnitude and significance of several soil transport processes.

Field-Scale Targeting of Cropland Sediment Yields Using ArcSWAT

Prasad Daggupati, Aleksey Sheshukov, Kyle Douglas-Mankin, Philip Barnes, and Daniel Devlin

Soil erosion and sedimentation are fundamental water quality and quantity concerns throughout the United States. Agricultural fields are known to be a major contributor of sediment into surface waters. Our objective was to demonstrate a method using Arc SWAT to identify specific fields with the greatest soil erosion potential, quantify soil loss reductions from specific conservation practices, and use these values to target $270k in one-time payments to farmers for conservation practice implementation. Black Kettle Creek subwatershed (8,000 ha) of Little Arkansas Watershed (360,000 ha) in south central Kansas was identified as a major source of sediment. An ArcGIS toolbar was developed to post-process SWAT output to generate sediment, nitrogen, and phosphorus yields for individual fields. Individual fields were ranked based on sediment yields, and the top ten percent were selected for conservation practice implementation. A local watershed staff member solicited farmers of these fields in decreasing rank order until $270k in contracts was committed. Results will be presented of modeled field and watershed sediment-yield reductions and cost per unit reduction from the Arc SWAT targeting strategy. These results will be compared to other spatial-targeting strategies using RUSLE and other GIS-based methods.

Development and Application of a WASP Model on a large Texas Reservoir to Assess Eutrophication Control Strategies

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The Tarrant Regional Water District developed and calibrated an 11-year WASP-Eutro model for Cedar Creek Reservoir, a 32,000 acre drinking water supply and recreation reservoir located near Fort Worth, Texas that is demonstrating eutrophication by high median Chl'a' (26.3 ug/L), increasing trends in Chl'a' (3.8% APR), and large diurnal shifts in dissolved oxygen and pH. Cedar Creek was partitioned into 22 segments with up to 3 vertical segments in the main pool. Loading to the reservoir was divided into 4 categories: 1) watershed, 2) 9 wastewater treatment plants (5.6 mgd), 3) atmospheric loading and 4) internal NH_4 and OPO_4 sediment flux. Daily inflows for and watershed loading for the model were developed by an independent SWAT model of the 1007 square mile watershed. State variables included: ammonia, nitrate-nitrite, organic nitrogen, dissolved phosphorus, organic phosphorus, oxygen and biological oxygen demand. Wastewater treatment plant loading was based on one year of weekly plant nutrient and flow data. Atmospheric loading was based on periodic rain sampling adjacent to the reservoir. Internal flux was estimated from hypolimnetic accumulation during stratification. Calibration was based on conformity of median observed and predicted water quality data over the 11-year period for individual sites and by assessing the general longitudinal profiles in the reservoir. Sensitivity analysis of these 4 loadings revealed that the reservoir's Chl'a and total phosphorus were most influenced by the watershed or NPS load. Internal flux was the next most influential load. The impact of internal flux relative to its actual mass or percent of the phosphorus budget emphasizes that location and timing are important components of loading. Estimates of the reduction in NPS necessary for a significant reduction in Chl'a' were in the area of 30%, while estimates of reductions in OPO_4 flux to significantly reduce Chl'a' were in the area of 75%. While it appears a watershed management program aimed at reducing phosphorus loading by at least 30% will reduce reservoir euthrophication internal loading is a large question mark in future predictions.

Integrating Swat Modeling and Economic Considerations to Develop an Economic-Based Watershed Management Plan

M. Edward Rister, Ronald D. Lacewell, Allen W. Sturdivant, Taesoo Lee, Raghavan "Srini" Srinivasan, Balaji Narasimhan, Clint Wolfe, David Waidler, Darrel Andrews, Mark Ernst, and Jennifer Owens*

A multidisciplinary team is addressing watershed management for improved water quality for Tarrant Regional Water District (TRWD) in north-central Texas. A critical component of this research involves identifying a portfolio of Best Management Practices (BMPs) capable of reducing (and/or preventing) Phosphorous (P), Nitrogen (N), and Sediment annual inflows into the Cedar Creek Reservoir. Extensive GIS mapping of the 645,000-acre Cedar Creek watershed (on a 30 m^2 grid basis) using detailed soil type, slope, land use, and other attributes provided the basis for identifying numerous applicable BMPs with potential effectiveness in sub-watershed areas. The Soil and Water Assessment Tool (SWAT) was used in the modeling process. The assorted nuances of each individual BMP required individual economic budget(s) be constructed for each BMP, independent of other BMPs. Subsequently, the Net Present Value of all costs and returns over the expected useful life for each BMP were calculated and transformed into an Annuity Equivalent (a.k.a. life-cycle costs) which facilitated accurate relative comparisons of costs across BMPs. TRWDs objectives are to minimize the cost of watershed management, while meeting the targeted reductions in P, N, and Sediment annual inflows into the reservoir, which are required to meet environmental quality concerns. Each BMP is an alternative management strategy representing unique activities available to the TRWD. The technical nutrient/sediment reduction performance of each BMP and the cost per unit of P, N, and Sediment reduction contribute toward meeting TRWDs objectives. Constraints affecting the optimal solution include (a) initial financial investment funds; (b) annual operating, maintenance, and capital replacement budgets; and (c) potential contributions of P, N, and Sediment reductions from each of seven categories of land use – Cropland, Pasture and Rangeland, Urban, Channel, Watershed, Reservoir 'In-Lake', Construction, and Waste Water Treatment Plants. An appropriate analytical framework which considers all of these issues simultaneously is linear programming (LP). In addition to a base analysis, several sensitivity scenarios have been analyzed for the Cedar Creek Watershed. Frequent interaction with stakeholders and TRWD management contribute to the robust value of the implications of the results toward eventual implementation of an economic-based watershed management plan.

Assessment of cost-effective BMPs to reduce total phosphorous level using SWAT in Cedar Creek Reservoir, TX

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Cedar Creek Watershed, TX is located in the upper part of Trinity River basin, TX with the drainage area of 2,600 km^2. Water quality in the reservoir has been a concern in that Chlorophyll-a concentration in the reservoir has been increasing at an average rate of 3.9% annually since 1989. In order to preserve the lake water quality and to meet the future water demands, the problems of water quality degradation by sediment and nutrients have been studied by Texas Water Resources Institute, Texas A&M University, and TRWD (Tarrant Region Water Distrct).

This study focuses on the assessment of the cost-effective BMPs (Best Management Practices) selected from the economical analyses in Cedar Creek Reservoir, TX as a part of the North Central Texas Watershed Protection Plan. Total phosphorous reduction goal was set as 35% at the reservoir from the stake holder process. Then, the effectiveness of each BMP was estimated using SWAT model that was calibrated and validated, while its 'most likely adoption rate' of each BMP was surveyed. Economical analyses ranked each BMP by the cost effectiveness. The BMPs were implemented in the model by the order of the largest cost-effectiveness BMPs for the watershed, and they were implemented in the subbasins or HRUs by the highest phosphorous loading. When the first BMP implementation was not satisfied for reduction goal, the second BMP was implemented on top of the first one. Using this accumulated BMPs impacts analyses, total 8 BMPs were selected and implemented in the model in order to reach the 35% of total phosphorous reduction goal. Series of subbasin maps were created in order for visual demonstration of phosphorous loading reduction from each subbasin.

Utilizing SWAT to Enhance Stakeholder-based Watershed Protection Planning

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SWAT Modeling is used by watershed planners to account for land use, soils, erosion, and nutrient sources. Model outputs work in conjunction with other formats such as WASP to demonstrate and predict conditions in reservoirs thus allowing for a full watershed analysis. These traditional uses of the SWAT model have typically been the domain of project planners and technical advisory groups. The emergence of stakeholder-based watershed planning efforts allows for a new opportunity to utilize watershed modeling to allow stakeholders to participate in a more meaningful and result-based decision making process to drive management efforts.

Perhaps one of the most valuable aspects of SWAT modeling as demonstrated by the Cedar Creek Watershed Protection Planning effort is the potential for the model to illustrate and predict watershed conditions in a manner that is easy to distinguish for the lay-person. The capability of the SWAT model allows for the development of what if scenarios in which best management practices can be applied to varying land use classification in order to depict necessary pollution reductions thereby letting sound science based information to drive stakeholder based decision making crucial to watershed protection planning.

From the onset of public involvement, Cedar Creek Watershed stakeholders have been provided with mapping of current watershed conditions, as well as pollutant loadings by type and sub-basin. Utilizing mapped data, stakeholders were able to discern the areas of the watershed producing excessive loadings of sediment and nutrients and to make appropriate recommendations for management measures based on prioritizing areas of concern and funding available. Spatial scientists modeled several scenarios of various best management practices to reach the targeted pollutant reduction goal. This information coupled with economic performance data produced by Texas AgriLife Extension has allowed project planners to develop a schedule of implementation sensitive to time and budgetary constraints.

Migrating a Complex Environmental Modeling System from a Proprietary to an Open Source GIS Platform

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The MapWindow development team in collaboration with Idaho State University, the EPA and Texas A&M University have developed a new open source water assessment tool named Open Soil and Water Assessment Tool (OpenSWAT). This is a continuous, time series model useful for modeling the hydrology and point source pollutants of large and small scale watersheds. This model is useful for hydrologists, engineers, and resource managers to answer important questions related to watershed management, such as predicting pollutant concentrations and stream-flow characteristics. This project is instrumental for extending existing technologies like the Better Assessment Science Integrating Point & Nonpoint Sources (BASINS) program created by the EPA, and serving as a critical link to the open source SWAT editor created by Texas A&M University. This paper discusses the performance, operations, limitations, and assumptions involved with this new software tool.

SWAT Application Tool Development for Water Resources Management at County Level in Beijing, China

Jingshan Yu

In order to provide technical tool for the Integrated Water and Environment Management Project (IWEMP) supported by GEF in Beijing, China, a SWAT application tool is developed at county level based on SWAT core operation file swat2005.exe. Predefined stream networks and sub-basins were integrated to the tool for solving the problem of delineation on plat areas.

Simulation results of water balance were in good agreements with evepotranspiration, runoff, ground water levels in early studies. It demonstrates that the SWAT is also adaptable for the plat areas, and can be used as an effective tool for the agricultural water resources management.

ArcMap Tool for Pre-processing SSURGO Soil Database for ArcSWAT

Aleksey Sheshukov, Prasad Daggupati, Ming-Chieh Lee, and Kyle Douglas-Mankin

The Soil Survey Geographic (SSURGO) database provides the highest resolution available for county-wide soil data in the United States. AVSWAT and ArcSWAT are developed for using soil input prepared in a format of the State Soil and Geographic (STATSGO) database. The available SSURGO extension tool currently works only with AVSWAT but not with ArcSWAT. The purpose of this study was to develop an extension tool to ArcMap GIS capable of processing the SSURGO soils into a modified STATSGO format readable by ArcSWAT, and to demonstrate the function and utility of the extension tool by comparing ArcSWAT results using STATSGO vs. SSURGO data. The process consisted of data filtering into a database format compatible with SWAT template soils dataset, appending new soils to a user soil dataset, preparing a watershed specific soil lookup table, and creation of a soil GIS layer for SWAT input. All these steps were automated and contained within a user-friendly interface programmed as an Extension to ArcMap GIS. A comparison of using STATSGO vs. SSURGO soil input datasets to the SWAT model was conducted on several watersheds in Eastern Kansas.

A Web-Based Interface for SWAT Modeling on the TeraGrid

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The Soil and Water Assessment Tool (SWAT) is a river basin scale model developed by the USDA Agricultural Research Service (ARS). It is widely used by researchers in various scientific domains to study the impact of land management practices on water quantity, sediment, and water quality in large watersheds over long periods of time. Currently most users run SWAT tests on their own desktop or laptop computers. While this is adequate for some, users who need to complete a large number of SWAT runs or calibration of the SWAT model for complex watersheds require more powerful computational and storage resources. In this paper we describe an effort to make the SWAT model easily accessible and useable to a larger class of users through a web portal interface. The SWAT portal allows users to run SWAT simulations using the distributed resources provided by the TeraGrid - a national cyberinfrastructure for high end computing funded by the National Science Foundation. This portal supports three types of SWAT simulations: regular simulation, auto calibration, and sensitivity analysis. It provides an intuitive interface for users to configure one or multiple SWAT cases, submit these runs as computation jobs to the TeraGrid, monitor job status, visualize results and download output. This TeraGrid based SWAT portal uses a shared community account to submit jobs to the TeraGrid resource, thus eliminating the need for users to know the details of TeraGrid allocation request and usage. Any user with a browser can connect to this portal over the Internet and benefit from the resources on the TeraGrid. This paper describes the design and implementation of the SWAT portal as well as several case studies by our early users and our future plan to improve the SWAT portal.

A Multi Model and Multiscale, GIS Oriented Web Framework Based on the SWAT Model to Face Issues of Water and Soil Resource Vulnerability

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The latest advances in computer technology offer computing and storage resource distributed over a wide geographical domain, available from fast and secure networks, providing important services, applications and advanced visualization tools. The new paradigm is based on an integrated and collaborative approach where the complexity of the technology is transparent to the end user, and interdisciplinary working groups and skills can be enhanced. On this basis, the development and use of enabling technologies (e.g. RDBMS with spatial extension, AJAX technologies, GRID / cloud computing, etc.), allows to imagine new approaches for the management and the exploiting of data and physical resources available.

The BASHYT (Basin Scale hydrological Tool - http://www.eraprogetti.com/bashyt) is a innovative web-based Collaborative Working Environment (CWE) to quantify human and natural impacts on water body receptors, based on the SWAT model. It permits to simulate and analyze the integrated water cycle (water balance and quality status of surface water bodies at different space and time scales), through a carefully rigorous methodology (DPSIR framework) and to produce reports on environmental states by means of standardized procedures. The CWE framework can be thought as an easy to use open, interoperable, scalable, and extensible development framework for constructing spatially enabled Internet applications. The software supports a WEB based live programming environment making the programming features available to developers with almost-zero learning curve. This increases developer productivity by reducing scaffolding code when developing web, GUI, database, GIS or applications. We expect to improve model usability to aid in making management decisions and watershed-scale (multi-scale) modeling to address more realistically the fate of multiple pollutants in multiple environmental media. In particular we will show an application to estimate an agricultural drought index and a distributed file system solution to run and store SWAT simulations for virtually unlimited basins for a continental scale application.

Effect of climate change on low-flow conditions in Ruscom River watershed, Ontario

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Climate changes in recent decades indicate that there are going to be extreme weather conditions in future including extended periods of dry days. These climate conditions are likely to affect the streamflows. The objective of the present study is to understand and predict the effect of climate change on the low-flows from the Ruscom River watershed. The watershed is one of the sub-watersheds draining into Lake St. Clair on the Canadian side.

Soil and Water Assessment Tool (SWAT) model was implemented to simulate hydrologic regime in the watershed. The model was calibrated and validated for the streamflow from the Ruscom River watershed using the observed monthly flow data. LARS-WG weather generator was used for the generation of daily future weather data at local scale using the Canadian Regional Climate Model (CRCM) outputs under SRES A2 scenario for the period, 2041-2070.

The Nash-Suttcliffe efficiency and r^2 for streamflow predictions were found as greater than 0.74 during calibration and validation periods. Under the projected climate scenario, the future mean monthly minimum and maximum temperatures can be increased by 3.2 ^oC and 3.6 ^oC, respectively compared to the temperatures in base period, 1961-1990. The average annual precipitation would also increase by 8%. Flow duration curves generated from the SWAT simulated streamflow indicated that low-flows in the Ruscom River would be increased in winter and summer but decreased in fall due to the possible climate change. Based on frequency analysis, the annual minimum monthly flow of 5-yr return period could be reduced by about 50%.

Consequences of Climate Change on Water Yield in Mountainous Snow-Dominated Colorado Watersheds

Pranay Sanadhya, Mehdi Ahmadi, Mazdak Arabi

The snow-dominated mountainous watersheds of Colorado have experienced a decrease in snowpack, earlier snowmelts, reduced summer flows and increased peak winter flows, arguably as a result of the climate change in recent years. The present work investigates the changes in water yield and streamflow time series in response to the changing climate in five major Colorado watersheds. The Soil and Water Assessment Tool (SWAT) was used to simulate hydrologic processes in the watersheds. First, a formal sensitivity analysis was carried out to identify the most important SWAT parameters in these snow-dominated systems. Then, the model was calibrated and validated for monthly streamflows over a 20-year period from 1978-1998. Results showed a good fit between measured and simulated streamflow values with Nash-Sutcliffe efficiency coefficient ranging from 0.53 to 0.87. Finally, the variations in hydro-climatic variables were modeled using the Intergovernmental Panel on Climate Change (IPCC) scenarios for temperature and precipitation variations. The calibrated SWAT model simulations corresponding to each IPCC scenario were performed for the 2000-2050 period. It is evident that these scenarios point to a decline in water yield and an alteration of the timing of snowmelt driven flows, though the magnitude of the decline remains highly uncertain.

Changes in Plant Phenology and Physiology Under Climate Change and Related Impacts on Regional Water Resources

Fred F. Hattermann, Frank Wechsung, Friedrich-Wilhelm Gerstengarbe, Shaochung Huang and Valentina Krysanova

Vegetation plays a major role in the regional water balance of the most semi-humid and semi-arid regions worldwide. Wherever enough water is available, climate change stimulates net primary production via temperature increase and CO_2 fertilization. Plants are located at the interface soil to atmosphere and connect deeper horizons with the surface. Changes in plant phenology and physiology should therefore have a strong impact on the regional water resources. However, there is an ongoing discussion about the possible extent of these impacts, and especially about the impacts of changes in plant physiology on runoff generation: plant stomata open less widely under increased carbon dioxide concentration, which reduces transpiration and thus increases runoff. At the same time, plants start growing earlier in spring and the landscape is covered by green vegetation longer into fall.

The aim of this study is to investigate the possible response of the regional water balance to changes in plant phenology and physiology under climate change and to quantify the inherent uncertainty.

Application of SWAT to climate-driven low flow (drought) frequency analysis

Jae Ryu

Extreme hydrologic events, such as floods and droughts, continue to threaten the regional economy as well as the security of water resources. Droughts, in particular, have a wide range of impacts on major industries, agriculture-related business sectors, and the general public. Although societal vulnerability to droughts associated with climate change and variability has been highlighted in scientific communities, few studies have focused on addressing the missing links between climate sciences and water resources management to better understand the impact of climate change. Suitable hydrologic measurements in the context of climate change, therefore, are necessary to help water managers promote adaptive water management and policy decisions in a changing climate. In this study, the low flow frequency analysis has been conducted by means of assessment tools using SWAT to measure the likelihood of climate-driven hydrologic droughts in the selected area. The missing attributes justifying environmental gains from several climate scenarios are also discussed to provide useful insights for water suppliers and managers on some aspects of successful mitigation and adaptation strategies against climate change.

Simulating the Effects of Climate Change and Energy Crop Production on Water Balance and Water Quality of the Parthe Catchment (Germany) using SWAT

Michael Strauch

Changes in climate and agricultural management can significantly affect hydrology and nutrient dynamics in river basins. In order to predict the impact of such changes on the water balance and water quality in the intensively cropped Parthe catchment in Central Germany, i) regional climate scenarios and ii) scenarios of changed agricultural management practices are implemented into the Soil and Water Assessment Tool (SWAT, Arnold et a. 1998). The SWAT model was calibrated and validated using stream flow data from two UFZ stream gauge stations for the period from 1992 to 2007. For the same period the sensitivity of the model response to climate changes was tested by iterative increase and decrease of observed climate data (precipitation ± 10% and temperature ± 1.5°C). As climate change data regional climate scenarios (for SRES A1B and B1) from project WEREX IV (Spekat et al. 2006) were used. Given the scenario-based warming trend up to 2 °C to year 2100 and partially reductions of precipitation up to 10 % we established for several future decades significant decreases in groundwater recharge and stream flow (20 – 50 %) relating to the reference period 1992 - 2007. In spite of large uncertainties associated with the chain of models (General Circulation Model – Regional Climate Model - SWAT) the need for sustainable river basin management as adaption to climate change could be figured out.

Accounting for climate change impact was only one part of the study. Moreover, scenarios for different types of bioenergy production were developed, namely for i) Biodiesel from expanded cultivation of rapeseed and ii) Biogas via two-culture system due to Scheffer (1998). Furthermore one scenario was developed that addresses only food production. Rather than forecasting future land use patterns, the aim of this study was to compare different options of energy crop production with regard to their specific effects on catchment hydrology and water quality. The simulations were carried out for the period from 1992 to 2007 under observed climate. While expanded cultivation of rapeseed caused very high nitrate losses, the chosen two-culture system for biogas production was not accompanied by perceptible increases in nitrate leaching relative to the food scenario. The suitability of SWAT for implementation of energy crop systems is crucial. But the study depicts the behavior of model simulations in such topics, and tendencies relevant to future watershed management can be derived from the results.

Setting up SWAT to Quantify Water-Related Ecosystem Services in a Large Data-Scarce Watershed in East Africa

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The SWAT model is set up and calibrated in order to quantify water-related ecosystem services in the 43'000 km^2 Pangani Basin in Tanzania/Kenya. The starting assumption that an ecosystem service is realized where resource availability matches stakeholder demand requires modelling at fine spatial detail and compatibility of model outputs with socio-economic data. Uncertainty assessment is an imperative due to the limited data availability and quality. By a) improving input data through combination of datasets from different sources, b) using the modified model version SWAT-P, c) developing a more flexible subbasin delineation process, and d) using the SUFI-2 algorithm for calibration and uncertainty assessment, and additionally including uncertainty in time series inputs, a model of the basin could be set up that produces spatially detailed outputs compatible with socio-economic information and planning units. Calibration of monthly discharge in the upper basin yields satisfactory preliminary results with Nash-Sutcliffe coefficients of >= 0.5 at most gauges, on average 68% of measured data bracketed in the 95% prediction uncertainty, and an average width of this uncertainty range of about 0.7 standard deviations of measured data.

Adapting SWAT to a Lowland Catchment and Using Model Results for Ecohydrological Assessments

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Aquatic freshwater habitats are strongly influenced by human activities along the water course but also by agricultural management within the river catchment. In order to find suitable measures to improve habitat quality ecohydrological models can help to assess the impact of environmental stressors. For a comprehensive analysis landscape processes as well as instream processes have to be modelled in a satisfying resolution. Additionally scenario analyses have to be possible to support sustainable river basin management.

Our study area is located in Northern Germany, in a gently rolling landscape with predominant agricultural land use. The Kielstau catchment (50 km², river length of 17 km) has been subject of several campaigns of river straightening, so that the water course is partly artificial. On the other hand it still contains river reaches with a meandering river course and trees along the shore. The water and matter balance of the catchment is influenced by agricultural drainage in from of tile drains and ditches. The crop rotations are dominated by winter cereals, maize and oil seed rape. In our study we chose macro-invertebrates as an indicator for the ecological status of freshwater habitats.

As basis for our ecohydrological modelling system we used the river basin model SWAT2005 (ARNOLD et al., 1998) to evaluate water and sediment balances as a function of land use within the catchment. In order to include the flow velocity regime and the water depth profile as well as substrate stability of the river bed, a two-step hydraulic model cascade is applied. HecRAS (USACE, 2006) is used to depict the whole river reach and the 2 dimensional hydraulic ADH model (BERGER & TATE, 2007) for selected areas only. The ecological submodel which is connected to an autecological database (EURO-LIMPACS, 2009) uses the model outputs to assess the habitat suitability on distributed GIS-maps with knowledge-based parameter functions.

For the successful application of SWAT in the lowland catchment it was of particular importance to include agricultural tile drains and depressional storage volumes. An ArcGIS script has been developed to derive the necessary SWAT input parameters from high-quality topographic data for modelling the depressional areas as potholes. After that, hydrologic modelling results showed a good agreement between measured and simulated runoff in the Kielstau catchment.

Application for SWAT Model to Small Agricultural Catchment in Poland

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Poland is obliged to implement the WFD – Water Frame Directive (2000/60/WE) by the end of 2015 like other UE countries. The main objective of the Directive is to provide normative quality of all water resources (surface, underground and coastal sea waters). To reach this goal reduction of water polluter emission to environment is needed. Our project focuses on pollution from agricultural sources which share in global pollution is high and growing still. As a pilot area, where the WFD is going to be implemented, small agricultural Zglowiaczka river catchment was chosen. In 2004 almost the whole catchment was designated as a Nitrate Vulnerable Zone (NVZ) according to Nitrate Directive of European Union (91/676/EE). The NVZs were designated on the basis of the results of water monitoring system. If the nitrate concentration in surface water was above the allowable value of 50 mg $\cdot dm^{-3}$ NO^{-3} and if the source of the pollutions was or could be agriculture, the area was designated as a NVZ.

The state monitoring for the Zglowiaczka river catchment is conducted in three points along the river. In each of these three points, nitrates concentration periodically significantly exceeds (mostly in spring and autumn) the allowable value of 50 mg $NO^{-3}\cdot dm^{-3}$. The highest average monthly values of nitrates concentration in years 1990–2007 occur in February, March and April, which indicates on agricultural as a source of pollution. During the rest of the year nitrates concentration is below the allowable value.

As a NVZ, Zglowiaczka river catchment is the area where reduction of nitrogen run-off from agricultural lands to water resources is especially needed. The main topic of the research carried out in the polish-norwegian project is to propose different means for reduction of migration of P and N to surface waters, with the use of the SWAT model. In the paper is presented a conception of creating buffer zones using SWAT model.

Buffer zones could be one of the solutions for improvement of water quality in Zglowiaczka river. The efficiency of reduction nutrition load to the surface water is a function of buffer zone width and proper design. The increased width of the buffer zones reduces the arable land, which is expensive. In the article we considered fitting the buffer zone width, depending on the flow rate of water flowing from the fields to the stream.

Using SWAT model interface a map of potential flow was generated, in the conditions of intensive precipitation. The next step was distribution over the whole Zglowiaczka catchments, places with high density of the temporal streams network. It was done using GRASS program. The vector lines of temporal streams were changed on raster format with resolution of 30 m. The map of stream “density” was done by assigning the raster number which is the sum of raster in the neighbourhood (radius of neighbourhood smaller or equal 25 raster). The choice of the most endangered subbasins was done on base of visual evaluation of the surface flow density map.

It is visible in the results that filter strips on endangered areas are far more effective and therefore more required. If the width of the vegetated buffer strips is not sufficient, it will not attain the desired effectiveness. Conversely, if the width is too great, it will cause agricultural land waste, preventing farmers' interest in cooperating with environmental preservation efforts. For the above reasons, it is important to set a reasonable width range. According to the results we are suggesting wider buffer zones in endangered subbasins and narrow in other subbasins.

Development and Evaluation of An Algorithm for Generating Field Based Output From SWAT

Dharmendra Saraswat

SWAT model subdivides a watershed into hydrological response units (HRUs), which are delineated based on homogenous land cover and soil properties. Though HRUs can be spatially located in the watershed, their responses are not tied to any particular field. In this paper, we have discussed the development of an algorithm that allows mapping of SWAT simulations from HRU level to common land unit (CLU) level. The algorithm was tested on an agriculturally dominated, Second Creek watershed in AR. The results show that model response can be tracked at the field level using CLU data.

Combining a Conceptual Hydrologic Model (SWAT) and a Hydrodynamic Model (Telemac 3D) to Simulate Reservoir Dynamics in Eagle Creek Reservoir, Indiana.

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Eagle Creek reservoir, in the southern portion of the Eagle Creek watershed, is one of the major sources of drinking water supply in the Indianapolis area, IN. However, agricultural practices and growing urbanization in this region have posed major threats to the water quality in the reservoir (e.g. blue green algae blooms; atrazine loadings). Currently, a 3-D hydrodynamic model Telemac-3D, based on finite element modeling, is being built to understand some of the hydraulics of the reservoir that impact the various water quality parameters in the reservoir. One of the main challenges in calibrating and validating the hydrodynamic model have been in obtaining realistic and accurate estimates of various inflows. This paper examines the advantages of coupling the hydrologic model Soil and Water Assessment Tool with Telemac-3D to estimate average daily inflows from overland flow and tributaries, and use the estimated inflows in Telemac-3D to simulate the hydraulics in the Eagle Creek reservoir. Preliminary results are presented that show the various benefits and disadvantages of coupling the two different kinds of modeling methodologies.

Influence of Uncertainties in Nitrate-N Monitoring Data on SWAT Model Calibration and Evaluation

Martin Volk

Simulation models are powerful tools to evaluate the impact of land management scenarios on water quantity and quality at the watershed scale. Model-based predictions of water quality (e.g. nutrient loads) require measured nutrient flux data for model calibration and evaluation. As a consequence, uncertainties in the monitoring data resulting from sample collection and load estimation methods influence the calibration and thus the parameter settings which affect the modelling results.

The overall goal of our study was to investigate the influence of uncertainty in nitrate-N monitoring data on model calibration, model parameter settings, and model evaluation.

To investigate this influence, we compared three different time-based sampling strategies: periodic grab samples taken on regular time intervals corresponding to i) biweekly and ii) monthly intervals and iii) daily composite samples (limited from 2000-2001). Furthermore, we used ten most commonly applied load estimation methods to calculate nitrate-N loads.

For our study we used the river basin model SWAT (Soil and Water Assessment Tool) on the intensively managed loess-dominated Parthe watershed (315 km²) in Central Germany.

The results show that nitrate-N load estimations show a wide range with respect to i) the water quality sampling strategy, ii) the applied load estimation methods and iii) the period of interest and its hydrological characteristics. The percentage deviation of mean load estimations for the sub-monthly and monthly data sets as related to the mean estimation value of the daily composite data set, ranges from -6.7% for the monthly data set in 2001 up to a maximum of 64.5% for the sub-monthly data set in 2000. The deviations of the results for each individual sampling strategy using different estimation equations also show wide ranges in some cases (max. 57.3%/67.7% for the sub-monthly/monthly data sets in 2001).

To determine the influence of uncertainty in nitrate-N monitoring data on model calibration, we calibrated SWAT based on the mean monthly loads from daily composite data set because it is assumed to give best estimated load results. Afterwards we compared the simulated results with the mean estimated loads obtained from the sub-monthly and monthly monitoring strategies.

Test results in general show that the quality of simulation decreased with the use of either the sub-monthly or monthly data sets. By using the same parameter settings with sub-monthly and monthly data set the Nash-Sutcliffe-Efficiency dropped from 0.52 to 0.42 and 0.31, respectively. Considering the different results that were obtained from the chosen monitoring strategy and load estimation method, we recommend both the implementation of optimised monitoring programs and the use of more than one load estimation method to improve water quality characterisation and provide appropriate model calibration and evaluation data.

Multi-Objective Calibration to Improve Pesticide Simulations

Ann van Griensven, Dimitri Solomatine, Samwel Zakayo*

Hydrologic distributed models like the Soil and Water Assessment Tool (SWAT) describe many processes and hence are comprised of a handful of parameters. This somewhat presents a difficulty in calibrating such models. These models are increasingly being employed by engineers and managers to simulate various watershed management scenarios.

This study investigated the application of multi-objective algorithm known as NSGAX, to generate Pareto optimal sets. Initially the Nil catchment model was developed in SWAT for the simulation of pesticide concentrations. A sensitivity analysis was carried out from which a total of nine most sensitive flow parameters were identified for an autocalibration process. The results indicated that SWAT model simulated well the daily streamflow of the Nil catchment for a nine-year period and a seven-year period pesticide (atrazine) observation data.

As a next step, multi-objective optimization was set up and implemented by linking the NSGAX tool with the developed Nil SWAT model. The results indicate that the Pareto front is located in a small area of the total objective space which implies that there is a relatively small trade-off between pesticide calibration and flow calibration.

An improved pareto-front was found by including equations for direct pesticide losses, or by including pesticide parameters in the calibration.

A Framework for Sensitivity Analysis of Distributed Watershed Models

Barmak Azizimoghaddam, Mazdak Arabi

This paper presents a framework for sensitivity analysis (SA) of the SWAT model. The proposed framework reconciles a local SA, a regression-based SA, and Morris's screening method with two global techniques: Fourier Amplitude Sensitivity Test (FAST) and Method of Sobol. We aim to examine and compare the computational requirements, efficiency and reliability of these techniques, and establish guidelines for their appropriate use. The sensitivity analysis framework was linked with SWAT to study flow processes in the Cache la Poudre River Basin in Colorado and the Wildcat Creek watershed in Indiana. The importance of the objective function of the analysis was also examined. Results underlined the advantage of using FAST and method of Sobol for obtaining an accurate quantitative estimate of the main effects of model parameters as well as the effects of interactions between parameters. However, several replications of these global methods revealed the instability of sensitivity measures an inadequate number of computational samples, especially when a large number of parameters are considered. This paper puts forth a procedure for the combined use of these methods to perform sensitivity analysis of distributed watershed models.

How To: Understanding SWAT Model Uncertainty Relative to Measured Results

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Watershed models are being relied upon to contribute to most policy-making decisions of watershed management, and the demand for an accurate accounting of complete model uncertainty is rising. Generalized likelihood uncertainty estimation (GLUE) is a widely used method for quantifying uncertainty in hydrological models because of its ease of use and versatility in adaptation. In this paper, we examine the assumptions of GLUE and how they can be used to gain an understanding of the different parts of model uncertainty using the hydrologic model SWAT. Although GLUE, like other uncertainty methods, makes no attempt to account for the inherent uncertainty in model structures, structural uncertainty is addressed by evaluating GLUE uncertainty bounds for predictive capacity and the uncertainty range required to achieve this predictive capacity. It is found that while parameter uncertainty is overestimated using both formal (Bayesian) and informal likelihoods, formal likelihoods have the ability to reduce these overestimations with increased information and provide a more accurate understanding of the structural uncertainty inherent in SWAT.

Multisite-Multivariate Calibration of Watershed Models

Mahdi Ahmadi, Mazdak Arabi

Over the last two decades, watershed models have been increasingly embedded in decision making processes to address a wide range of hydrologic and water quality issues. These models have evolved from lumped to distributed while operating on shorter time steps so that they can utilize input data at finer spatiotemporal resolutions. With the incorporation of more input and output factors has come an escalation in the level of structural complexity of watershed models. This study aims to evaluate the efficiency and applicability of single- and multi-objective optimization techniques for parameter estimation of the SWAT model for multiple output variables at various locations within a watershed. Three evolutionary algorithms including Shuffled Complex Evolution (SCE-UA), single-objective Genetic Algorithm (GA) and multi-objective GA (MOGA) were used to calibrate streamflow, nutrients, and pesticides processes at various temporal scales in Eagle Creek watershed in Indiana. The efficiency of these methods were investigated using different objective functions including root mean square error, coefficient of determination and Nash-Sutcliffe efficiency coefficient for the output variables as well as the baseflow component of the stream discharge. Results indicated that while flow processes can be reasonably ascertained, parameterization of nutrient and pesticide processes of SWAT at multiple locations presents a challenge. The examined auto-calibration algorithms provide a systematic approach for parameter estimation and will significantly reduce the subjectivity and time requirements of the manual calibration exercises.

Bacteria Modeling with SWAT for Assessment and Remediation Studies – A Review

Claire Baffaut, Ali Sadeghi

A module to simulate bacteria fate and transport in watersheds was first tested in SWAT 2000 and fully integrated into the SWAT 2005 code. Since then, few investigators have utilized SWAT to model bacteria or pathogens fate and transport in spite of bacteria being a major impairment of streams and rivers in the United States. In this paper, bacteria modeling applications from Missouri, Kansas, and Georgia in the U.S. and from France and Ireland were reviewed, highlighting the modeling successes and the challenges.

These applications include watersheds that range from 16 km^2 in Georgia to 3,870 km^2 in Missouri. In all cases, land use included agricultural (cropland and pastures) and forested land with a mix of point and nonpoint sources. Nonpoint sources included indirect (manure deposited on land) as well as direct (direct contributions from cattle or wildlife to the streams). In some cases, urban and residential contributions were taken into account. The equations of the model were reviewed to highlight assumptions, possibilities, and limitations. Strategies to represent the different sources were determined and compared. Changes to the model's code that were necessary to handle contributions from urban areas were reviewed. Calibration methods, parameter sensitivity, and goodness of fit were compared. Research needs were identified in the areas of data collection, process understanding, and modeling efforts.

Predicting In-Field Decay and Edge-of-Field Transport of Fecal Indicators

Michelle Soupir

Understanding of how bacteria survive in the environment, release from fecal matter, and transport along overland flow pathways is needed for models such as SWAT to identify sources of pathogens in a watershed. We investigated the fate and transport mechanisms of two pathogen indicators, *E. coli* and enterococci, from grazed lands. Pathogen indicator concentrations in fresh fecal deposits were monitored during four seasons until cells could no longer be detected. First order kinetics approximated *E. coli* and enterococci decay rates with regression coefficients ranging from 0.70 to 0.90 while predictions were improved with higher order approximations that included temperature, solar radiation, rainfall and relative humidity.

Transport mechanisms of pathogen indicators were examined by analyzing runoff samples from small box plots and large transport plots. The box plot experiments examined the partitioning of pathogen indicators in runoff from highly erodible soils while the transport plot experiments examined partitioning at the edge-of-the-field from well-managed and poorly-managed pasturelands. Attachment of *E. coli* and enterococci to particulates present in runoff was evaluated through the application of rainfall to small box plots containing different soil types. Partitioning varied by indicator and by soil type.

In general, enterococci had a higher percent attached to silty loam (49%) and silty clay loam (43%) soils while *E. coli* had a higher percent attached to loamy fine sand soils (43%). At least 50% of all attached *E. coli* and enterococci were associated with sediment and organic particles ranging from 8 to 62 μm in diameter. Much lower attachment rates were observed in runoff samples collected at the edge-of-the-field, regardless of pastureland management strategy. On average, 5% of *E. coli* and 13% of enterococci were attached to particulates in runoff from well-managed pasturelands.

A second transport plot study found that on average only 0.06% of *E. coli* and 1% of enterococci were attached to particulates in runoff from well-managed pasturelands, but percent attachment increased slightly in runoff from poorly-managed pasture with 3% of *E. coli* and 1.2% of enterococci attached to particulates.

Watershed-Scale Fate and Transport of Bacteria Using the Arc-SWAT Model

Mehran Niazi

It is often difficult to precisely determine sources of fecal bacteria contamination, but Bacteria Source Tracking (BST) can help identify non-point sources of fecal bacteria such as livestock, humans and wildlife. The research performed has included a field sampling campaign to collect flow, water quality and BST samples bi-weekly since June 2007 to support development of a Soil and Water Assessment Tool (SWAT) model to investigate the fate and transport of species specific fecal contamination.

The case study is located in Salem County, in southern New Jersey. Over 90% of the land uses are agriculture (including several dairy farms), forest and urban; these are the main sources of bacterial pollution. The presumed sources are livestock, wildlife and humans, respectively.
A SWAT model has been calibrated for the Salem river flow over a one and half year period at the watershed outlet and nine upstream sampling sites. The Nash-Sutcliffe Efficiency Index (E) has been used to evaluate the accuracy of the model simulation compared to measured flow. The E index for calibrated flow ranges from 0.45 at the outlet to -1.8 at a sampling point located upstream. Calibration and validation for water quality are currently underway.

Including Sediment-Associated Bacteria Resuspension and Settling in SWAT Predictions of Microbial Water Quality

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Streambed sediments have been shown to serve as environmental reservoirs for bacteria, including pathogenic strains. The Soil and Water Assessment Tool (SWAT) has been augmented with bacteria subroutine in 2005. Bacteria die-off is the only in-stream process considered in the current SWAT. The purpose of this work was to evaluate the potential significance of bacteria resuspension and settling for the SWAT microbial water quality simulations. In the newly developed submodule, bacteria were partitioned into free-floating and sediment-associated bacteria. Only sediment-associated bacteria were allowed to settle with depositing sediment while both bacteria were involved in sediment resuspension. The SWAT with the bacteria resuspension-settling submodule was applied to the Little Cove Creek watershed, Pennsylvania, with forestry, dairy pastureland, and field crop land uses. Streamflow, *E. coli* in water and streambed, and weather have been monitored for two years. *E. coli* in streambed was the model input, and was approximated with a log-scale sine curve function from monitored data. Observed *E. coli* in streambed peaked in summer to the values of $2 \cdot 10^5$ CFU/g whereas in winter they decreased to $2 \cdot 10^2$ CFU/g. Hydrologic parameters were calibrated with the monitored streamflow, and model performance was evaluated with monitored *E. coli* in stream water. The sediment-associated bacteria resuspension explained the *E. coli* persistence in stream water while surface runoff was the important source for the peak *E. coli* in stream water. Results indicated that improvements in sediment-associated bacteria transport components in SWAT could strengthen SWAT capability to predict bacteria fate and transport in streams.

Simulation of Landscape Processes in SWAT

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River basin management requires a spatially distributed representation of basin hydrology and nutrient transport processes. To accomplish this, the SWAT model was modified to assess runoff processes across the landscape. The model structure more closely reflects the complex controls on infiltration, runoff generation, run-on, and subsurface flow without requiring large computational resources or detailed parameterization. Four landscape delineation methods were compared including: 1) Lumped with one representative soil, land use and slope, 2) HRU methods using lumped soil and land use combinations with no reference to landscape position and no routing of flow across the HRU's, 3) Catena method routing across a representative divide, hill slope and valley bottom, and 4) Distributed (grid) method routing across one ha grid cells. All methods were calibrated to measured flow data at the ARS Riesel Brushy Creek (Station G) watershed with similar results (daily flow N-S coefficients varied from 0.63-0.67). Although the lumped method had compared validation statistics, it was not able to simulate landscape processes. The grid method provided considerable spatial detail, but is still too computationally intensive for simulating large river basins. The catena method may provide realistic simulation of landscape processes while being efficient enough to simulate large river basins.

Simulation of a Heavily Buffered Watershed using the SWAT Landscape Model

David D. Bosch, Jeff G. Arnold, and Martin Volk*

Accurate representation of landscape processes in natural resource models requires distributed representation of basin hydrology and transport processes. To better represent these processes, SWAT was modified to represent runoff processes occurring in different parts of the landscape. The SWAT landscape model consists of a three component system, hill-top, upland, and near stream sections. The model addresses flow and transport across hydrologic response units prior to concentration in streams, and is capable of simulating flow and transport from higher landscape positions to lower positions within a single river basin. The SWAT landscape model was tested using data collected from a heavily vegetated riparian buffer system near Tifton, Georgia, USA. The watershed has been well characterized, with significant information concerning the hydrologic and water quality impacts of the stream buffers. Simulations of surface runoff, lateral subsurface runoff, and groundwater flow for the upland divide, hillslope, and floodplain were generated. Model results indicated that surface runoff was dominated by the upland divide while groundwater flow was dominated by the hillslope and the floodplain. These results agree with general observations from the watershed. Evapotranspiration estimates from the model were not sensitive to the changes in vegetation occurring in the three different landscape positions. While additional calibration and testing is necessary, the results are encouraging. The results demonstrate the applicability of the model to simulate filtering of surface runoff, enhanced infiltration, and water quality buffering typically associated with riparian buffer systems.

Integration of Tropical and Sub-Tropical Wetlands in Regional Catchment Modeling

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Hydrological processes in tropical and sub-tropical wetlands differ often substantially from those in temperate zones, where wetlands are subject to management and regulation and where the natural plant cover has been altered to facilitate agricultural production.

A key pattern in most tropical and sub-tropical river basins is the strong seasonality of the flow regime, especially in areas which have a monsoon type of climate. Large areas are inundated in the raining season, and the additional water surfaces increase evapotranspiration and groundwater recharge and change the entire runoff pattern. However, these wetlands are temporal, and the conditions change totally during the drought season.

Aim of this study is to conceptually understand the role of wetlands under such conditions and to find a methodology to integrate tropical and sub-tropical wetlands in regional hydrological modelling.

SWAT Application for Adaptation Strategies in Cocibolca Basin

*Patrick Debels, Charles Jones, Raghavan Srinivasan, and Jorge Escurra**

The Lake Cocibolca (8000 km^2) is the primordial storage of drinking water for facing future water scarcity problems. Nicaraguan water authorities are concern of contamination and storage capacity reduction of the Lake. Previous studies indicated erosion, sedimentation and contamination from current agriculture practices are the major causes of eutrophication which are caused by increment of nitrogenous and phosphorous.

SWAT was applied for the Cocibolca basin, located in Nicaragua and Costa Rica, in which historic information of weather data (11 years), land use, land slope, soil characteristics, vegetation, and water quality were analyzed to simulate runoff, sediments and nutrients loads formulating the baseline condition (current) set of results. In addition, using the baseline condition, a sensitivity analysis of several climate change scenarios was performed. This analysis consists of simulated effects on mean runoff and sediment loads from increment of annual temperature and increment/reduction of precipitation from the MAGICC-SCENGEN model. As conclusions, adaptation strategies, such as construction of infiltration canals and modified agriculture practices, are proposed.

A Targeting Strategy for Cost-Effective Implementation of Watershed Plans

Heather B. Hill, Mehdi Ahmadi, Mazdak Arabi

Sound management of watershed systems requires striking a balance among conflicting economic and environmental interests. This study develops and demonstrates a technology, dubbed the eRAMS, for targeting critical areas within a watershed that are most susceptible to erosion and contaminant transport for implementation of conservation systems. The eRAMS systematically assesses the tradeoffs between environmental benefits and the costs of various combinations of conservation practices. The tool is comprised of a multi-objective genetic algorithm, a BMP cost module, the SWAT model, and a BMP representation component. The reduction in pollutant loads from BMP implementation is derived from SWAT simulations. After SWAT was calibrated and corroborated for three watersheds in Indiana, the eRAMS was applied to find the combination of conservation practices that will achieve the water quality targets at the lowest cost. Various formulations of objective and constraint functions of the optimization engine were compared: one that achieves maximum reduction of pollutant loads within a specified budget, one that minimizes the total watershed cost while constraining pollutant loads to a target value, and one that maximizes the pollutant reduction to cost ratio while being constrained to both the total watershed cost and the water quality target values. For each case, the optimal set of management actions and a blanket application of each management practice were evaluated over a range of practice adoption percentages. The range of solutions obtained in this study enables a thorough evaluation of the most efficient and reliable targeting strategies for implementation of conservation practices.

Development of a Tool to Estimate Best Management Practices (BMP) Efficiency Using SWAT

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Best management practices (BMPs) have been proven to effectively reduce the Nonpoint source (NPS) pollution loads from agricultural areas. However effective watershed management requires obtaining optimal locations for the placement of BMPs in the watershed that produces maximum reduction in pollutant loads for a least amount of net cost for implementation of the BMPs. A genetic algorithm based optimization technique in combination with the estimates obtained for the BMP efficiency using the SWAT model are used to achieve the goal. In order to obtain the BMP efficiency for a BMP (or a set of BMPs), the particular BMP is modeled in SWAT by modifying input parameters from the base line SWAT model setup (with no BMPs implemented). This task has been accomplished by developing a BMP SIMulation (BSIM) tool in Matlab™ using the GUIDE toolbox. BUSIM requires users to provide any BMP that is desired to be implemented in the watershed and accordingly modifies the parameters in the SWAT input files. The tool is tested for implementation in Wildcat Creek Watershed located in north central Indiana. The various BMPs that can be implemented in the watershed for NPS pollution control are nutrient management plans; tillage practices, such as conservation till and no till; vegetative practices such as contour farming; and structural practices, such as terraces, grade stabilization structures.

Water Quality Impacts of Agricultural BMPs in a Suburban Watershed in New Jersey

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Neshanic River watershed is a 31-square miles headwater watershed located in Hunterdon County, New Jersey. It has only 40 percent of agricultural lands and represents typical natural resource conditions and water quality problems in suburban New Jersey. While the water quality issues have been greatly attributed to rapid urban sprawl and stormwater runoff, the pollution contribution from agricultural practices are often overlooked. In this application, Soil and Water Assessment Tool (SWAT) is used to evaluate the potential water quality impacts of the agricultural best management practices (BMPs) in this suburban watershed. The watershed was delineated into 25 subbasins and 625 Hydrological Response Units (HRUs) based on a 10-meter digital elevation model (DEM), NRCS Ssurgo Soil data, 2002 land use/cover classification and a detailed crop pattern survey. The watershed hydrology is calibrated using the 2001-2002 two-year stream flow data observed in a USGS station within the watershed. Three agricultural management scenarios (Baseline, Best Case and Worst Case) were developed through interviews and meetings with farmers and natural resource conservation professionals in the watershed. The specific water quality parameters are sediments, the total P and N losses. The modeling results provide essential information to evaluate the potential of achieving water quality improvement through cost-effective allocation of agricultural BMPs to reduce agricultural water pollution in this suburban watershed and to facilitate the discussions on the pollution load reduction allocation among agricultural and urban communities.

Evaluation of BMPs Effectiveness on Water Quality in an Intermittent Italian River

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The EU Water Framework Directive 2000/60 requests that a River Basin Management Plan must be developed for principal river basins, including the Candelaro watershed in South Italy. The preliminary investigation of the Apulia Region Authority on the ecological and chemical status of this river lead to classify water quality status as "moderate". Based on this assessment, some measures to be adopted to reduce water pollution in the Candelaro river have been identified by the River Authority.

The objective of this study was to evaluate, using a modelling approach, the long-term impacts of the implementation of some Best Management Practices (BMPs) and waste water reuse in part of the cultivated areas.

Major sources of pollution in the Candelaro basin are nutrients produced by point and nonpoint sources. The anthropic pressure on environment is very strong in the basin since there are many waste water treatments plant (WWTP) discharges and a large area under intensive agriculture. The river shows a remarkable intermittent behaviour: wet periods are followed by drought periods during which the river dries up almost completely. Flash floods are quite common in late spring and autumn which affect in different ways water quality.

In this study the Soil and Water Assessment Tool (SWAT) has been applied to identify the subbasin were the pollution load is higher and to study water quality dynamics during period of high and low flow. Then BMPs have been simulated to study their effect in reducing pollution from non point sources.

Conservative tillage operations, presences of buffer strips along the edge of channels and field vegetative strip along the perimeter of fields have been simulated and their effectiveness on water quality has been evaluated compared to baseline simulation.

Also a waste water reuse scenario has been simulated in which the effluent of six municipal treatment plants have been considered as irrigation sources allowing a reduction of fertilizers in the correspondent cultivated areas.

The results are presented as percentage of nutrients load reduction at watershed scale.
This study showed that a basin scale model, as SWAT, can be very helpful in the decision process before the development of a River Basin Management Plan. The evaluation of effectiveness of different measures to be adopted, in relation to the different landscape and climate characteristics of the river basin, can help to find appropriate solutions for achieve a good chemical status of surface water.

Evaluating Effectiveness of Unconfined Livestock BMPs using SWAT

Aleksey Sheshukov, Kyle Douglas-Mankin, and Prasad Daggupati

Innovative market-based approaches for environmental management, such as Best Management Practice (BMP) auctions, recently have gained more attention due to their cost-effectiveness and practical success dealing with specific pollution problems. In a BMP auction, agricultural or livestock producers submit their own BMP proposals that are ranked based upon the quantity of pollutant reduction per dollar, and winning bids are awarded accordingly to achieve the greatest environmental impact for the least cost. As an example, $70,000 is committed to be awarded to producers through an auction in the Lower Marais des Cygnes watershed (410,700 ha), located at the Kansas and Missouri border with almost half of its land used for livestock operations. This study presents a field-scale modeling approach to assess effectiveness of livestock BMP proposals using Soil and Water Assessment Tool (SWAT). A pasture field used to represent an actual bid was divided into floodplain, riparian buffer, and multiple grazing land areas having unique land characteristics similar to the Hydrologic Response Units (HRU) in SWAT. Multiple sets of grazing operation scenarios with a wide range of applied stocking rates within each pasture area were simulated by running the SWAT model in a Lower Marais des Cygnes watershed for 17 years. The collected annual average nutrients loads for every HRU in the watershed that represents a floodplain, a grazing land or a riparian buffer were statistically analyzed, and the least-square error trends were determined. Given the unique pasture features in each submitted bid, including pasture geometry, land characteristics, and management operation schedule, the BMP effectiveness index was calculated based on the pollutant load values interpolated from the trend charts and an expert-formed ranking table. A stand-alone user-friendly interface was developed to help the bid evaluation expert team pre- and post-process individual BMP proposals.

Effective Parameters for Simulating Important Biofuels Crops and Grasses

Jim R. Kiniry and Mari-Vaughn V. Johnson

Process-based models such as SWAT and ALMANAC require realistic plant parameters to effectively simulate growth and production of plant species or communities. These models have become particularly important with recent interest in biofuel simulation. With appropriate parameters, SWAT and ALMANAC can simulate traditional crops such as maize and sorghum, as well as switchgrass and miscanthus. This talk will describe published results and ongoing essential research aimed at deriving the key eco-physiological parameters so that biofuel plant species may be better simulated by models such as SWAT. These parameters include leaf area index (LAI), light extinction coefficient (k), radiation use efficiency (RUE), base temperatures and degree days, and optimum nutrient concentrations at various growth stages. Improved parameter development will directly improve model simulation of land conversion to various biofuel cropping systems by SWAT. Model results will be critical for evaluating the economic, nutrient, and water impacts of converting large areas to biofuel production.

Agronomic Considerations for Simulating Switchgrass for Biomass Energy

Rob Mitchell, K.P. Vogel

Switchgrass (*Panicum virgatum* L.), a perennial warm-season grass native to North America, is a prime candidate for dedicated biomass energy for many regions of the USA. USDA-ARS in Lincoln, NE, has conducted switchgrass research since the 1930's. Plot-scale research has been conducted on switchgrass establishment, fertility requirements, and response to harvest date in numerous environments in the Great Plains and Midwest. Switchgrass production parameters such as economics, net energy, carbon sequestration, temporal and spatial biomass variation, and harvest and storage management have been evaluated at the field-scale on marginal land in the central and Northern Great Plains.

For example, switchgrass biomass across all farms was produced for an average farm gate cost of $60 per US ton, and produced 13 times more energy as ethanol than would be required as energy from petroleum and produced 540% more renewable than non-renewable energy consumed when properly managed. Additionally, after five production years soil organic carbon was sequestered at a rate of 2.9 Mg C ha^{-1} yr^{-1} in the top 120 cm of soil. The information from these studies on economic feasibility, net energy, C-sequestration, sustainability, and best agronomic production practices forms the basis on which large scale modeling of switchgrass production for bioenergy can be based.

Switchgrass Genetics: Status, Future Directions, and Implications for Simulations

Kenneth P. Vogel

Switchgrass (*Panicum virgatum* L.) is a C4 perennial grass that is native to most of North America except for the areas west of the Rocky Mountains and north of 55^0 N. lat. It is a polymorphic species with two distinct ecotypes, lowland and upland and with two major ploidy levels, tetraploid and octaploid. Switchgrass reproduces with seeds, tillers, and rhizomes and roots can reach depths of 3m. Lowland types are found on flood plains and other areas subject to inundation while upland types occur in upland areas that are not subject to flooding. Lowland types are taller, more coarse, generally more rust (*Puccinia* spp.) resistant, have a more bunch-type growth and have greater biomass yield potential. All switchgrasses are determinate, photoperiod sensitive grasses and require short days to induce flowering. The photoperiod requirements for switchgrass strains or cultivars are based on the latitude where the parent germplasm evolved. In nature, flowering is induced by decreasing day length during early summer.

In North America, moving northern ecotypes south provides them a shorter than normal day length during summer months and they flower early. The opposite occurs when southern ecotypes are moved north. They remain vegetative longer and produce more forage than northern strains moved south. When grown in the central Great Plains, switchgrasses from the Dakotas (northern ecotypes) flower and mature early and are short in stature while those from Texas and Oklahoma (southern ecotypes) flower late and are tall. The photoperiod response also appears to be associated with winter survival. Southern types moved too far north will not survive winters because they stay vegetative too late in the fall.

As a general rule, switchgrass germplasm should not be moved more than one USDA Plant Hardiness Zone north of its area of origin because of the possibility of stand losses from winter injury. Adaptation range varies with cultivar. The growth and development of a switchgrass plant depends upon its genotype (parent germplasm origin) and the location where it is evaluated. The development of switchgrass is location-dependent because flowering depends on photoperiod and also on growing-degree-days (GDD) which measure accumulated heat or photosynthesis energy. The physiological development of switchgrass as determined using a maturity staging system is highly correlated to day-of-the-year (DOY) and GDD in temperate climates such as the Great Plains of the USA. In the Central Great Plains, photoperiod as measured by DOY was more predictive of physiological development than GDD indicating the photoperiod is the primary determinant of switchgrass development but photosynthesis or heat units can modify the developmental response.

In addition to photoperiod, the other factor that determines specific adaptation is response to precipitation and the associated humidity. Cultivars from the more arid Great Plains states may be more susceptible to foliar diseases when grown in the more humid eastern USA. Cultivars developed from eastern germplasm may not be as well adapted to drought stress as those based on western germplasm. Plant breeders will improve biomass yield and quality of switchgrasses for use in bioenergy production systems. It is very difficult to breed for adaptation and the adaptation response of new cultivars is expected to be based on parent germplasm's latitude or Plant Adaptation Region of origin.

Conceptual Chemical Fate and Transport Models for Emerging Contaminants and SWAT Sub-Model Development

LJ Thibodeaux

The concept of environmental chemical fate is imbedded in the Lavoisier species mass balance. This continuity equation provided the means for development of current generation of widely-used, so-called compartmental chemical fate and transport models. The characteristics of these multi-media models are well illustrated by the fugacity-based ones developed at the Trent University Centre for Environmental Modeling and Chemistry. Thermodynamic equilibrium constants, reaction rate kinetics and mass transport coefficients are needed for these models in making realistic chemical fate predictions in time and space. Models of all levels of sophistication, including the Soil & Water Assessment Tool (SWAT), must have the best available data and predictive correlations for estimating these parameters. They must realistically reflect the chemistry, physics and biology of the natural media at the field-scale, ideally. While much has been accomplished, the level of development of transport coefficients, which control the rate of chemical mobility within and between the media compartments, lags behind.
An LSU-Trent U. joint project focused on addressing the state-of –the-art on available transport flux models, data and correlations is nearing completion with publication slated for 2010. The presentation will be on these subjects with the focus being organic chemical contaminants, fugacity-type compartment models, and mass transport data needs with the idea of developing appropriate sub-models for the SWAT.

Irrigation Ditch Facilitated Transport of Veterinary Pharmaceutical Compounds in a Semi-Arid Watershed

Kenneth Carlson, Mazdak Arabi

A rural watershed in Northern Colorado has been studied for several years to understand the fate and transport of veterinary pharmaceuticals. The Cache la Poudre River is the primary watershed drainage with little input from secondary streams due to the arid nature of the area. There is however, an extensive system of irrigation ditches that act to supply and drain water from the many agricultural operations in the watershed. The concentration of veterinary antibiotics in aqueous and sediment matrices was measured in agricultural irrigation ditches bordering several animal-feeding operations and then compared to measured antibiotic levels in the watershed.

In general, higher concentrations of antibiotics were observed in the aqueous phase of irrigation ditches than in aqueous watershed samples, while higher concentrations were measured in river sediment than in irrigation ditch sediment samples. There was a high calculated correlation between precipitation and measured concentration in aqueous samples from the irrigation ditches for five of the ten targeted veterinary antibiotics, indicating that surface runoff could be an important transport mechanism of veterinary antibiotics from field to environment.

Further, environmental loading calculations based on measured concentrations in aqueous samples and flow information clearly showed that much greater mass was present in the irrigation ditches than in the river. This result suggests the likelihood that veterinary antibiotics can be transported via irrigation ditches to the watershed. The transport via surface runoff and likely environmental loading via irrigation ditches identified in this study helps identify the transport pathway of veterinary antibiotics residuals in the environment. We have begun to use this data to calibrate the SWAT model and the preliminary results will be presented at the conference.

Behavior and Redox Sensitivity of Pharmaceutical Residues During Bank Filtration – Final Lessons from the NASRI Project

Dr. Thomas Heberer

The behavior of various pharmaceutical residues during bank filtration was investigated between 2002 and 2005 within an interdisciplinary research project entitled NASRI (Natural and Artificial Systems for Recharge and Infiltration). Transport and the redox sensitivity of the compounds were studied both in column experiments and "on-site" at different field sites in Berlin, Germany, where bank-filtered water is used for the production of drinking water [1-3]. At these field sites, the neighboring surface water used for bank filtration is under the influence of treated municipal sewage water. The concentrations measured for the drug residues in the shallow, young bank filtrate (travel times < one month) were correlated to the prevailing hydrochemical conditions at the field site. The redox conditions and the elimination of the respective drug residues displayed strong seasonal variations. Oxic conditions were only encountered close to the shore and in winter, when temperatures were low. In parallel to the fieldsite investigations, the behavior of the drug residues was also evaluated in the lab during passage through an undisturbed sediment core taken from the lake base at the site (clogging layer). The results from the column study showed that the removal is almost restricted to the upper decimeters of the lake base.

Residues of antimicrobial drugs, analgesics, antiepileptic drugs, lipid regulators and X-ray contrast media were found in the surface water at the field sites. Out of the seven antimicrobial drugs detected in the surface water only three (anhydroerythromycin, clindamycin and sulfamethoxazole) were also found above their limits of quantitation in bank filtrate with a travel time of one month or less with median concentrations. With the exception of sulfamethoxazole, none of the 19 investigated antimicrobial drugs were present in bank filtrate with a residence time larger than one month or in the water-supply well itself. Sulfamethoxazole was the most persistent of all antimicrobial drugs but still removed by more than 98%. Thus, it was only found at trace concentrations in the water-supply well. The degradation of clindamycin and sulfamethoxazole was redox-dependent. Sulfamethoxazole was eliminated more rapidly under anoxic infiltration conditions while Clindamycin was eliminated more efficiently under oxic infiltration conditions. All macrolides were readily removable by bank filtration both under oxic and anoxic conditions. Nevetherless, a preference for an improved degradation under oxic or anoxic conditions was also observed for several macrolide antibiotics. [2]

Some analgesic drugs and their polar metabolites including phenazone, 4-acetylaminoantipyrine (AAA), 4-formylaminoantipyrin (FAA) and 1,5-dimethyl-1,2-dehydro-3-pyrazolone (DP) were eliminated more efficiently under oxic conditions, whereas 1-acetyl-1-methyl-2-dimethyloxamoyl-2-phenylhydrazide (AMDOPH) was not eliminated at all. While phenazone elimination was observed as being almost complete during aerobic rapid sand filtration in the waterworks, the compounds were found to be more persistent under anoxic field conditions. [3]

The main lessons from the NASRI project were that removal of drug residues at bank filtration sites mainly occurs in the upper (colmation) layer but for a few compounds also in the ground water aquifer. The good removal of hydrophobic pharmaceuticals such as bezafibrate, indomethacin and estrogenic steroids can be explained by hydrophobic sorption and can directly be linked to their high log KOW values. For the polar drug residues, other non-hydrophobic mechanisms (e.g. hydrogen bonds, ion exchange effects) may also be important and a simple relationship between observed removal and log

KOW does not account for such mechanisms. Microbial degradation appears to play an important role and the prevailing redox conditions can be important for the removal rates of the individual compounds. Complete or at least good removal was also observed for antimicrobial drugs and for diclofenac. Phenazone-type drugs, clofibric acid and carbamazepine showed poor or even very poor removal both under oxic but especially under anoxic conditions. Residues of AMDOPH and primidone were little or not at all affected either under oxic or reducing conditions.

Besides its potential to remove microbes and other contaminants from surface water, bank-filtration or other methods used for ground water recharge may also be a useful tool to remove drug residues or to lower their concentrations in water from contaminated raw water sources. Thus, bank filtration can be used for the pretreatment of contaminated surface water but will not be sufficient for a complete removal of all kinds of pharmaceutical residues including their metabolites. However, several drugs are excellent indicators for municipal sewage influences in surface and ground water and to check the removal efficiencies of bank filtration sites. To date, a risk for humans can be almost excluded with regard to the rare positive findings of pharmaceuticals in drinking water usually only occurring at trace levels. However, in view of the precautionary principle and with regard to environmental hygiene, the occurrence of drug residues in groundwater used as drinking water resources is not desirable.

Watershed Scale Chemical Signaling Networks, Endocrine Disruption, and Ecosystem Responses

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Exposure of aquatic organisms to endocrine active chemicals (EACs) through surface water, bed sediments, and food sources and the corresponding ecosystem impacts is a global issue. Reproductive disruption has been shown in a number of species exposed to EACs in stream reaches that are impacted by point-source discharges such as wastewater treatment plant (WWTP) effluents. Although models have been used to evaluate the occurrence and fate of consumer product chemicals such as boron and pharmaceutical compounds, challenges remain in conducting watershed scale investigations including understanding all sources of EACs at the landscape level, identifying the hydrological pathways between the sources and surface water systems, and evaluating ecosystem impacts resulting from spatially and temporally variable chemical exposures. Conceptual models developed for the interactions between anthropogenic chemical input and hydrological, landscape, and biological factors can be tested with numerical models such as the Soil and Water Assessment Tool (SWAT). Located along the Colorado Front Range, the Boulder Creek Watershed is a research site on the environmental occurrence, fate, and effects of emerging contaminants, including consumer product chemicals and EACs. The extensive data on natural and contaminant chemistry, geology, hydrology, and land use on Boulder Creek provides a framework for developing an understanding the implications of watershed scale chemical signaling networks on ecosystem health. The impact of EACs on the Boulder Creek ecosystem has been shown through an integrated series of fish exposure experiments using stream water and WWTP effluent, spatial and temporal chemical characterizations of the water and sediment, and in-stream biological effects investigations, The information and research network on emerging contaminants in the Boulder Creek would be enhanced by applying the SWAT model to evaluate watershed-scale chemical signaling network on endocrine disruption and other ecosystem health issues.

Modeling Upland and Channel Sources of Sediment in the Le Sueur River Watershed, Minnesota

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The Le Sueur River Watershed (LRW) drains 2,850 km^2 in the Minnesota River, and generates 302,000 t/yr of sediment which contributes to sedimentation and turbidity impairments in Lake Pepin and the Mississippi River. The Le Sueur River watershed accounts for about 7% of the area, but 53% of the Total Suspended Solids (TSS) leaving the Minnesota River Basin (Water Resources Center, 2008). Sediment sources in the LRW are spatially heterogeneous, and include slumping river bluffs, ravines, stream banks and eroding upland agricultural lands. The objective of our research was to use the Soil and Water Assessment Tool (SWAT) to quantify the contribution of upland areas to sediment loads at various locations within the Le Sueur River Watershed. Predicted upland sediment loads were compared to measured stream sediment loads to indirectly estimate the sediment contributions from channel sources of sediment, including river bluffs, ravines and stream banks.

The SWAT model was calibrated and validated from 2000-2006 in the Beauford sub-watershed, where the landscape has no bluffs or ravines. The calibrated model was applied to the entire LRW in order to estimate sediment losses from upland regions of the watershed. The contribution of the channel sources was estimated by difference from the amount measured at the outlet of the LRW. SWAT model simulation results for 2006 showed that upland agricultural regions of LRW sub-watersheds contribute 14% of the total annual sediment yield. By inference, the remaining 86% of the sediment load arises from river bluffs, ravines and eroding stream banks.

In-Stream Water Quality Processes in SWAT with Different Routing Methods and Adapted Water Quality Modules for Daily or Sub-Daily Time Steps

Ann van Griensven

Integrating Nitrogen and Phosphorus with Carbon Cycling in SWAT

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Carbon plays a pivotal role in the cycling of nutrients in the soil-plant-water-atmospheric continuum, with the cycling of nitrogen, phosphorus and carbon in the soil intimately intertwined. The soil organic matter (SOM) is a complex mixture of living organisms, decomposing organic materials, and charcoal, with a varying degree of association with the soil mineral fraction, and with a wide range of turnover rates. Fractionating SOM into components with defined, measurable, and modelable properties has been a challenge for soil biologist and modelers alike. In this paper we introduce a one-pool SOM sub-model linking nitrogen, phosphorus, and carbon in the SWAT model. Inputs to this pool are from stabilized organic components (humified) from crop residues from aboveground and dead roots, manure or other organic amendments. The fraction of the decomposed inputs that are stabilized as SOM depends on the layer SOM content and the soil texture. The C:N and C:P ratios of the newly formed SOM depend on the C:N and C:P ratios of the inputs and on the availability of mineral N (nitrates and ammonia) and mineral P. The SOM decomposition rate has a strong dependence on the layer SOM – the higher the SOM the higher the decomposition rate. Tillage accelerates the SOM turnover rate of the mechanically disturbed layers. The magnitude of the rate enhancement is tool-specific and decreases with time as a function of the soil layer moisture content. The SOM pool does not include explicitly organic matter of pyrogenic origin, and may not represent adequately the properties of SOM in organic soil horizons or seasonally flooded soils. The algorithm does not include a process causing the often observed lower C:N ratio of SOM with depth. Preliminary testing has shown that the model represents appropriately SOM cycling in agricultural soils in temperate climates. Future testing and improvements of the model should emphasize tropical soils, subtropical climates with different types of vegetation, and organic horizons.

Assessing the Impact of Point and Diffuse Sources Pollution on Nitrate Load in a Rural Lowland Catchment using the SWAT Model

*Lam Quang Dung, Britta Schmalz, and Nicola Fohrer**

The aims of this study are the evaluation of the SWAT model (Soil and Water Assessment Tool) performance in simulating flow and the prediction of the impact of point and diffuse sources pollution on nitrate load based on the current agricultural practices and sewage disposals in a rural lowland catchment. The study area Kielstau catchment with a size of approximately 50km^2, which is characterized by low hydraulic gradients, near-surface groundwater, and flat topography, is located in North German lowlands. The water quality is not only influenced by the predominating agricultural land use in the catchment as cropland and pasture, but also by six municipal wastewater treatment plants. Diffuse entries from the agriculture resulting from fertilizers as well as punctual entries from the wastewater treatment plants are implemented in the model set-up.

The results of this study show good agreement between simulated and measured daily discharges with the Nash-Sutcliffe efficiency and the determination coefficient of 0.75 and 0.78 for the calibration period (1998-2004); 0.78 and 0.84 for the validation period (2004-2008). The Nash-Sutcliffe efficiency of the model for daily nitrate loads is 0.64 and 0.76 for the calibration period (June 2006- October 2007) and validation period (November 2007-October 2008), respectively.
These statistical results revealed that SWAT model performed satisfactorily in simulating both the flow and nitrate load in a daily time step in lowland catchment of Northern Germany.

Numerical Analyses on Seasonal Variations of Nutrient Salts and Load Discharges in Abashiri River Basin

Hiroaki Somura

Impact assessments of land-use change, population growth/decrease and watershed development to water quantity and quality are one of the most important topics in a basin. As well, integrated managements of water environment from a river basin to downstream such as a lake are also very important for conservation and sustainable use of its resources. In recent years, water quality in a lake is tried to improve until under environmental standard by emission control of pollutant loads to a lake and rivers through putting an adequate sewage system in place and development of laws, though water quality in a lake have not been improved well as we expected. One of the reasons is considered to be pollutant loads discharged from non-point sources such as agricultural land. When considering watershed management and improvement of water environment in a lake, both information of a lake and rivers will be necessary. Thus, we applied the Soil and Water Assessment Tool (SWAT) model to the Abashiri River Basin for obtaining information related to river basin hydrology and influence of the hydrology to downstream Lake Abashiri. The Abashiri river basin is located in the eastern part of Hokkaido region, Japan. The catchment area of the River basin is about 1,100 km^2. Forest is dominant in the area. Over 80% of the area is forest and less than 20% is used for agriculture in the basin. In this stage, we paid attention to agricultural activities in the basin and estimation of seasonal variation of nitrogen and phosphorus by the SWAT model. First of all, information about cultivated crops, timing of plowing and fertilizer application were investigated in the basin. Then, the information was treated as input data for the model. In this basin, it is grasped that a large amount of fertilizers of nitrogen and phosphorus was applied in April and May which are period of snow melting and start of crop cultivation, and September which is a beginning of cultivated period of winter wheat. Moreover, seasonal variations of nutrient salts were relatively well simulated by the model and annual load discharges from river basin to the Lake Abasihi were estimated.

The CEAP National Cropland Assessment: Conversion of Crop Management Survey Data into APEX Simulation Input

Jay D. Atwood

A 10 percent subset of the National Resource Inventory (NRI) points classified as cropland was selected for inclusion in the CEAP Crop Management Survey. The farm manager for the farm field containing each point was identified and an attempt was made to collect three years of comprehensive management data for that farm field. After all survey data preparation and screening procedures were applied, the resulting dataset contained approximately 19,000 samples. In addition to the NRI points classified as cropland, APEX simulation datasets were prepared for all points classified as CRP in the 2003 survey period. Along with simulation of CRP cover for the CRP points, simulations representing alternative cropping scenarios were developed, using data from the cropland point samples. Soil and weather data were also assembled for all selected NRI points. The major data procedures applied to each sample to build an APEX input data set included the following:

- Determination of crop rotation to be repeated during the 42-year simulation and editing of the data to conform, e.g., use only two years of report for a corn-soybean rotation;
- Assignment of specific crop and machine labels for cases where report had only generic information;
- Resolution of cases of split fields or management during one or more years of the reporting period;
- Addition of data as needed for simulation of reported grazing, irrigation, and straw removal;
- Correction of mis-coding and reporting of dates, units, and quantities; and
- Determination of fertilizer quantities for samples with obvious missing data.

Integrating APEX Cropland Output with SWAT Watershed Simulations

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The Conservation Effects Assessment Project (CEAP) national assessment is to quantify the environment benefits of conservation programs at regional and national level including both on-site and instream water quality benefits. The complexities of nature in this scale suggest modeling as an efficient and necessary method. A subset of National Resources Inventory sample points was selected to serve as "representative fields" simulated using the Agricultural Policy Environmental eXtender (APEX) model. Statistical sample weight associated with each sample point was used to aggregate the modeling results to 8-digit watershed outlets, which were then passed to Hydrologic Unit Model for the United States/Soil and Water Assessment Tool (HUMUS/SWAT) for estimating the offsite effects of conservation practices. Since each 8-digit watershed in the United States was treated as a sub-basin in HUMUS/SWAT and the two models were run separately at the 8-digit level, two major steps were made in both models: calibration of water yield at the 8-digit watershed level and development of sediment delivery ratios (SDR) for transporting sediment from cultivated cropland (simulated using APEX) and uncultivated land uses (simulated SWAT) to the 8-digit outlet. This article was to address: why using APEX for CEAP field-level cropland modeling; APEX simulation of conservation practices; calibration of APEX for water yield; and SDR development within APEX. Calibration and SDR procedures were developed and applied for the Upper Mississippi river basin. APEX predicted and observed annual average water yields were in good agreement as evidenced by R^2 value of 0.82. The mean SDR varied from 0.30 to 0.46, which are reasonable comparing to literature values.

Effectiveness of BMPs in Controlling Nonpoint Source Pollutant Losses from a CEAP Watershed

Indrajeet Chaubey

Due to intensive farm practices, non-point source pollution has become one of the most challenging environmental problems in agricultural and mixed land use watersheds. The NPS pollution problem can be controlled by implementing various best management practices (BMPs) in the watershed. However, before such practices are adopted, their effectiveness at various spatial and temporal scales must be evaluated. There is also a need to quantify how various BMPs when implemented simultaneously interact with one another in controlling NPS pollution. The objective of this research was to evaluate a suite of BMPs in a pasture dominated watershed in controlling sediment and nutrient losses. A total of 171 different BMP combinations incorporating grazing and pasture management, riparian and buffer zones, poultry litter and commercial litters application were evaluated for their effectiveness using the Soil and Water Assessment Tool (SWAT) model. The SWAT model was evaluated using detailed farm and watershed scale data. The stochasticity in weather was captured by generating 250 various possible weather realizations for a 25-year period, using measured historical climate data for the watershed. Preliminary evaluations indicate that a number of the BMPs can be effectively adopted to improve water quality and to minimize NPS pollution in the watershed.

Little River Watershed Conservation Practice Assessment with SWAT

David D. Bosch, J. Cho, G. Vellidis, R. Lowrance, T.C. Strickland

The Conservation Effects Assessment Project (CEAP) was initiated in 2003 to quantify the environmental impacts of USDA conservation practices at the watershed scale. One of the goals of the project is to assess the ability of physically based watershed scale models to simulate the effects of conservation practices. The SWAT model was selected to quantify the impact of historical practices on hydrology and water quality in the Little River Experimental Watershed (LREW). Hydrology and water quality data have been measured for more than 30 years within the watershed. The LREW is one of fourteen benchmark watersheds for CEAP, representing a typical Coastal Plain Watershed.

The objective of this study was to evaluate alternative scenarios for implementing conservation practices within the watershed. To achieve this objective, SWAT was calibrated and validated, considering cause and effect relationships between measured water quality trends and documented conservation practices. Sensitive pollutant source areas were identified based on simulated pollutant loads from upland areas. Alternative scenarios were developed and areas for conservation practice applications were continuously increased from the most to the least sensitive pollutant source areas. Finally, the critical point at which no further improvement was observed was indentified. The study will be useful for maximizing the efficiency of conservation practices on improving water quality using restricted resources.

ARS CEAP Watershed Assessment Study Overview

John Sadler, Mike Shannon, and Mark Walbridge*

The Conservation Effects Assessment Project, CEAP, is comprised of two parts. The National Assessment, led by NRCS, is described earlier in this session. The Watershed Assessment Study, led by ARS, provides research results and empirical support to the modeling studies at watershed scales and enables cross-location research on problems at larger scales. For Croplands, the WAS encompasses research in14 watersheds at Kimberly ID, Temple TX, El Reno OK, Columbia MO, Ames IA, West Lafayette IN, Columbus OH, University Park PA, Beltsville MD, Tifton GA, and Oxford MS. Modeling studies within WAS are being done at those sites plus Ft Collins CO and Corvallis OR. From these watersheds, spatio-temporal research data are being formatted for and stored in STEWARDS (Sustaining the Earth's Watersheds – Agricultural Research Database System), which has extensive metadata describing both the methods and locations of the data collection sites. ARS is committed to providing public access to these data and encourages cooperative model studies and other hydrologic analyses based on the valuable research asset.

Comparison of Flow Calibration Using NEXRAD and Surface Rain Gauge Data in ArcSWAT

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The value of watershed-scale, water quality models to ecosystem management is increasingly evident as more programs adopt these tools to help assess the effectiveness of different management scenarios on the environment. The USDA-Conservation Effects Assessment Project (CEAP) is one such program which was established to quantify the environmental benefits from conservation practices implemented under USDA conservation programs.

The Choptank River watershed, located in Maryland on the Eastern Shore of the Chesapeake Bay, is a special emphasis watershed under the CEAP program. Several of its tributaries have been identified as "impaired waters" under Section 303(d) of the Federal Clean Water Act due to high levels of nutrients and sediments.

The Soil and Water Assessment Tool (SWAT) was utilized to build a model for the German Branch (GB) watershed (~50 km^2), a non-tidal tributary basin of the Choptank River. The overall goal of the project is to determine the effectiveness of cover crop programs to reduce nutrient loadings to the Choptank River; however, the initial steps to build the GB model are presented here.

Climate is the driving force of any water quality model; therefore effort was put into assessing the effects of alternative sources of climate data. Both surface rain gauge measurements and Next Generation Weather Radar (NEXRAD) precipitation data were used to determine any significant differences in model performance. Sensitivity, calibration, and validation analyses were conducted on the hydrology component of the GB model. The optimal water balance obtained in this study is an essential precursor to acquiring realistic sediment and nutrient results in forthcoming GB modeling efforts.

Application of SWAT in Hydrologic and Nutrient Transport Modelling of the Lake Winnipeg Watershed

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The quality of water in Lake Winnipeg, Canada, has deteriorated during past three decades as a result of excess nutrient loading from non-point sources in the watershed. While nutrient transport from non-point sources to the lakes is driven by complex hydrologic and biochemical processes, snowmelt driven hydrologic response plays a key role in nutrient delivery to the lakes. This paper presents the first part of a study on the application of SWAT (Soil & Water Assessment Tool) for hydrologic modelling of two representative sub-catchments of the Lake Winnipeg watershed; namely, the upper Assiniboine catchment (area 13500 km^2) in the province of Saskatchewan and the Morris catchment (area 4300 km^2) in the adjacent province of Manitoba. Both catchments are dominated by agricultural land use and are considered particularly suitable for understanding the impacts of climate variability and change on non-point nutrient loadings to the lake. We analyze the effects of two gridded precipitation inputs: North America Regional Reanalysis (NARR) data and Gridded Climate Dataset for Canada (GCDC) in discharge simulation of both catchments. The calibrated model results indicate that, although SWAT is able to simulate overall discharge reasonably well with the both datasets, the GCDC precipitation inputs resulted in a better simulation of discharge dynamics compared to NARR. The results of the models suggest that the type of precipitation input has an important influence on SWAT model simulation results, even in a snowmelt dominated catchment.

Spatio-temporal variation of surface-groundwater interactions in a small watershed, South Korea

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The intensity and direction of groundwater–surface water exchange flux are controlled by the groundwater head gradient, hydraulic conductivity and riverbed geometry. The spatial heterogeneity of these factors and the subsequent variability of the impact of these interaction processes affect the water balance in the watershed. However, detailed studies concerning the spatio-temporal variability of the extent and intensity of surface-groundwater interactions have been extremely limited. In this study, assessment of the amount of water exchange flux was carried out by applying the integrated SWAT-MODFLOW model to upper-mid stream of Anyangcheon, the representative urban stream through Anyang city, South Korea. The effluent stream characteristics were found in this watershed, namely, baseflow was annually discharged except heavy rainy periods. The intensity and the spatial extent of surface-groundwater interactions in different sub-watersheds were simulated on a daily basis.

Assessing the Benefit of Improved Precipitation Input in SWAT Model Simulations

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The importance of better input data, model structure and parameterization for good process-based predictions are well recognized in the hydrological modeling. Although the physically based semi-distributed model Soil Water Assessment Tool (SWAT) offers a range of possibility for defining the model structure and input data, the input of climatic data is still very simple. SWAT uses the data of gauge located nearest to the centroid of the catchment, which may not always represent overall catchment climatic conditions. This eventually influences the model parameterization process and quality of the predicted results. This paper uses areal precipitation obtained through interpolation and compares the model performance (observed versus simulated hydrograph) using the normal SWAT precipitation input procedure (station precipitation). The model was applied to mountainous, semi arid catchments in the Karkheh basin, Iran. Daily time series data from October 1987 to September 2001 were used for the model calibration (1987-94) and validation (1994-01). The model performance was evaluated at daily, monthly and annual scales by using a number of performance indicators. The comparison suggests that the use of areal precipitation is likely to improve model performance at smaller spatial scales, i.e., sub-catchments representing tertiary level streams (having drainage area in the range of 600 to 2,300 km^2). Whereas reasonably good simulations can be achieved for larger scales representing the Karkheh River and its major tributaries (drainage area of greater than 5,000 km^2) under both precipitation scenarios.

Influence of Changed Land Use on River and Surface Flow in Small Flysch Catchments in Slovenia

Matjaž Glavan

Geology, soil and topology characteristics were, in combination with changed social structure of the research areas, led to changes in agricultural land use (e.g. abandonment of agricultural land, afforestation, intensive vineyarding, agromelioration). Together with climate changes this also led to the changed physical and chemical processes connected with water (e.g. river flow, erosion, infiltration, evapotranspiration, leaching of nutrients). Typical Flysch geology for these areas consists of repeated sedimentary layers of sandstones, marl, slate and limestone which can quickly crumble under the influence of precipitation and temperature changes; this kind of geology also accelerates surface runoff. Due to the inappropriate land management we could witness very strong erosion processes. The main objective of the research is to identify long-term effects of changed agricultural land use on the surface flow of the flysch type catchments of the river Dragonja in Slovenian Istria and the river Reka in Goriška Brda, thereby contributing to the understanding of hydrological processes in flysch catchments and to suggest guidelines for the development of catchments to reach good quality state of watercourses or to preserve current state. This paper is presenting sensitivity analysis, calibration and validation for the base scenario and final hydrological parameters outputs (river flow, surface flow) for the base (2007) and past (1830) scenario. Further work will concentrate on future scenarios of agricultural land use, to show what kind of the long-term environmental responses can be expect under changes of climate and agri-environmental policy.

Conservation Practice Modeling Guide for SWAT and APEX

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The use of computer driven soil and water modeling systems has enhanced the ability of environmental managers, researchers, government officials, and urban planners to analyze current conditions and predict future impacts of land use changes. Despite the innovation of these technologies, modelers are often required to account for the changes in pollutant and sediment loadings resulting from the implementation of approved conservation practices such as rain gardens and pervious pavement.

This parallel development of computer modeling and conservation practices calls for the creation of a comprehensive guide to modeling that will allow traditional and new constituencies the convenience of a single source for information to feed water quality planning efforts. The establishment of a conservation practice manual based on the prominent Soil and Water Assessment Tool (SWAT) and Agricultural Policy EXtender (APEX) models proposes to meet this need. By assembling the existing data for practice design, efficiency, application, and model inputs into a user-friendly manual, the modelers and other beneficiaries will no longer need to engage in lengthy and exhaustive research to determine the conservation practices that will allow for the desired pollutant reductions.

Development of a Simple Conservation Practice Evaluation Tool using SWAT

Michael White

Conservation planners need an assessment tool to accurately predict nutrient, sediment, and bacteria losses from agricultural lands to evaluate the impact of management decisions and the establishment of conservation practices on water quality. The Soil and Water Assessment Tool (SWAT) has been widely used to evaluate conservation practices, but is too complex for extensive use by conservation planners. PPM Plus is a simplified SWAT interface developed to evaluate conservation practices in the state of Oklahoma. PPM Plus was validated using 283 years of field scale data collected under natural rainfall throughout the southern United States. These extremely diverse data included pasture, small grains, and row crop fields with rainfall ranging from 630 to 1390 mm/yr, with and without manure application.

A new version, the Texas Best Management Practices Evaluation Tool (TBET) is currently under development to service the state of Texas. TBET supports additional conservation practices and reduced data requirements, and will be validated more extensively. TBET will be used to evaluate conservation practices subsidized with state and federal funds to establish pollutant reductions attributable to these programs. These tools allow conservation planners to take advantage of a powerful water quality tool typically reserved for use by engineers and scientists.

Modeling Nutrient Loads From Poultry Operations in the Toledo Bend Reservoir and Sam Rayburn Reservoir Watersheds of East Texas

Carl Amonett

The Soil and Water Assessment Tool (SWAT) was used to quantify the effects of conservation practice application on nutrient and sediment loadings to streams, rivers, and lakes in two east Texas watersheds. Sam Rayburn Reservoir and Toledo Bend Reservoir, created in 1965 and 1966, respectively, were designed to control floods, generate hydroelectric power, and conserve water for municipal, industrial, agricultural, and recreational uses. Both lakes are very popular for fishing and boating.

Most of the Texas commercial poultry industry is located in the contributing watersheds of these reservoirs. A combined total of approximately 262,615,000 birds are produced annually along with about 273,600 tonnes of manure. A total of 674 Water Quality Management Plans (WQMPs) on 35,591 ha were developed with the poultry producers over the last 15 years. Technical and financial assistance was provided by planning technicians from the Texas State Soil and Water Conservation Board and from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS).

A database was prepared of the 674 farms with detailed field level management data for each of the 3,675 fields. Conservation and management practices, soil test results, waste application schedules, off-site manure application and spatial locations were included. The farm field boundaries were digitized and the 2001 National Land Cover Dataset (NLCD) land use grid was modified with eighteen additional SWAT land use classes to facilitate modeling.

Major conservation practices simulated with SWAT were waste utilization, nutrient management, pest management, ponds, buffer practices (field borders, filter strips, riparian forest buffers), pasture and hayland planting, prescribed grazing, forage harvest management, critical area planting, waste storage facility, tree establishment, fencing, brush management, heavy use area protection and firebreaks.

Model prediction performance was evaluated by the mean, root mean square error (RMSE), and Nash-Sutcliffe simulation efficiency (Ens). Sam Rayburn flow was calibrated and validated to six stream gauges. Ens values were from 0.64 to 0.82. Toledo Bend flow was calibrated to seven stream gauges, with Ens values ranging from 0.60 to over 0.80. Predicted sediment was calibrated to reservoir hydrographic surveys. Nutrient calibration/validation was made to limited grab sample data collected from 1998 through 2005 (usually four samples per year).
Two scenarios were modeled: (I) current conditions prior to development and application of WQMPs, and (II) after WQMP application. Results were presented as percentage reductions in nutrient and sediment loadings at three levels: farm, subbasin and watershed.

The NRCS Water Resources Assessment Team (WRAT) located at the Blackland/Grassland Research and Extension Center conducted the model simulations.

Modeling Environmental Benefits of Conservation Practices in Richland-Chambers Watershed, Texas

Pushpa Tuppad, C. Santhi, and Raghavan Srinivasan

The effectiveness of conservation practices (CP) is site specific due to variations in soil, topography, landuse, and climate. There is a substantial investment in conservation programs by the government, especially through 2002 farm bill. For the most part, implementation of CP by the farmers is voluntary. Though these conservation programs are widely recognized to preserve/enhance water quality and conserve natural resources, more study is necessary to quantify their environmental benefits at different spatial scales and geographic locations. Evaluation of these conservation practices for their impacts on water quality is crucial in terms of time, technical, and financial resources. Simulation models are promising tools to assess environmental benefits but no clear guidelines exist on representing various CPs. Moreover, non-availability of long-term and continuous monitoring data limits BMP field validation efforts.

The objective of this study is to demonstrate a modeling methodology to determine the long-term effectiveness of CPs (or best management practices (BMPs)) on surface runoff, and sediment and nutrient loads at the field and watershed levels. The study area is Richland-Chambers Watershed (RCW) (5,157 km^2) in the upper Trinity River Basin, TX. The Soil and Water Assessment Tool (SWAT) model is calibrated and validated for the pre- and post-BMP periods for flow, sediment, and nutrients. The CPs simulated include terraces, contour farming, conservation cropping, conversion of agricultural land to pasture, prescribed grazing, range management, brush management, and critical area planting. The environmental benefits of these CPs are presented as percentage reductions in long-term annual average sediment, total nitrogen (TN), and total phosphorus (TP) loading at the field and watershed levels. Among all the BMPs simulated, 'critical area planting' practice produced the greatest reduction in sediment and TN. Agricultural land converted to pasture and brush removal followed by pasture planting with prescribed grazing and nutrient management were also highly effective in reducing (98%) sediment yield at the field level. Considering all the areas on which a type of CP was implemented, we get a range in pollutant reduction because of the variability in soils and slope and weather. Collectively, these BMPs resulted in 0.9%, 2.4%, and 2.5% reduction in sediment, TN, and TP, respectively at the watershed outlet. This study provides guidance on simulating various CPs within SWAT model and systematic quantification of how the suite of BMPs reduces sediment, nitrogen, and phosphorus loadings in a watershed from field level to watershed outlet.

Metal Transport in SWAT

Cole Rossi

The SWAT model simulation capabilities are being upgraded by adding metals that impact natural aqueous and soil systems. The model will include a mass balance for dissolved and adsorbed/exchangeable species. A database will be included that references the reactions and log equilibrium constants for the free ions and charged complexes that are of greatest concern to the aqueous and soil environments (Fe, Al, Ca, Hg, Cu, Mn, Pb K, Na). Soil reduction-oxidation processes will be included to reflect the impact of waterlogged soils that can have an affect at the watershed scale. The addition of particle sizes already being incorporated into SWAT will assist in the representation of the soil-chemical equilibria. The organic carbon content, clay content, and pH of the environment through which water passes will be included as impact factors when the data are available.

Transport and Retention of Heavy Metals in Soils: An Overview

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Heavy metals are considered as potential pollutants to the soil and groundwater environment mainly due to various industrial activities and anthropogenic factors. Mining, industrial waste and sewage sludge disposal on land often contain appreciable amounts of heavy metal such as Hg, Cu, Zn, Cd and Ni and thus create a risk for crop lands, as well as animals and humans. Understanding the fate and transport of heavy metals in the soil environment is a prerequisite in identifying dominant mechanisms governing their release and potential mobility in the soil system. The ability to predict the transport of heavy metals in the soil is a prerequisite in minimizing surface and subsurface leaching losses, managing land disposal of wastes and fertilizer applications. Such predictive capability requires knowledge of the physical, chemical as well as biological processes influencing heavy metal behavior in the soil environment. Moreover, research is needed for the application of mechanistically based arsenic transport models in making regulatory decision and designing remediation strategy.

In order to assess the potential mobility of heavy metals in the soil, models that account for their reactivities or retention with the soil matrix are needed. Heavy metal retention and release reactions in the soil environment include ion exchange, adsorption/desorption, precipitation/dissolution, and other mechanisms such as chemical or biological transformations. Retention and release reactions are influenced by several soil properties, including bulk density, soil texture, water flux, pH, redox potential, soil organic matter, carbonate content, iron and aluminum oxides, type and amount of dominant clay minerals, among others.

In this presentation, models that govern retention reactions and transport of heavy metals in the soil are presented. Models of the equilibrium type are first discussed then followed by models of the kinetic type. Retention models of the multiple reaction type including the two-site equilibrium-kinetic models, the concurrent- and consecutive multireaction models, and the second-order approach will be presented. In addition, competitive type models such as equilibrium and kinetic ion exchange type and Sheindorf-Rebhun-Sheintuch Freundlich are also are presented.

Selected experimental retention and transport results for heavy metals such Hg Cu, Pb, Cr, Cd, and Zn are illustrated for the purpose of model evaluation and validation. Several heavy metals such as Hg are strongly sorbed due to strong affinities to the soils. Results of Hg retention adsorption indicated was rapid and highly irreversible sorption where the amounts released or desorbed were often less than 1% of that applied. Moreover, the removal of soil organic matter resulted in a decrease of mercury adsorption in all soils. Transport studies indicated that mercury breakthrough curves (BTCs) exhibited erratic patterns and Hg is best regarded as strongly retained and highly "immobile" in soils. This is likely due highly stable complex formation (irreversible forms) and strong binding to high affinity sites. Limited mobility was observed in a column packed with sand material where symmetric BTC was obtained. Arsenic (As(V)) is considered strongly retained which exhibited kinetic behaviour where the rate of As(V) retention was rapid initially and was followed by gradual or somewhat slow retention behaviour with increasing reaction time. Release or desorption were hysteretic in nature which are indications of lack of equilibrium retention and/or irreversible or slowly reversible processes. A multi-reaction model (MRM) with equilibrium and kinetic sorption successfully described the adsorption kinetics of As(V) in medium textured soils.

Other heavy metals such as Cd and Ni are generally considered weakly bonded with low affinity to soils. A consequence of weakly bonded heavy metals is that competition may result in their enhanced mobility in the soil environment. Generally, competing ions strongly affect heavy metal retention and release in soils. Competitive sorption experiments indicated that both Ni and Cd adsorption isotherms exhibited strong nonlinear behavior with similar overall patterns and their sorption correlated well the cation exchange capacity (CEC). Moreover, Cd sorption by two acidic soils was greater than Ni, whereas for the neutral soil Ni sorption was greater than Cd.

Evaluation of a SWAT Parameterization Strategy for Pesticide Concentration Predictions without Site-Specific Calibration

Michael Winchell

The Soil and Water Assessment Tool (SWAT) is a powerful tool for evaluating watershed scale water quality, including the fate and transport of pesticides. One limitation to applications of SWAT in pesticide exposure risk assessments has historically been the need to develop and calibrate the model to site-specific data. This has made the application of SWAT to large numbers of watersheds impractical due to the limited availability of site specific calibration data, and the considerable effort required to calibrate an individual watershed.

In order for SWAT to be an efficient and practical tool for large scale risk assessments, an approach was developed to define an initial model parameterization that enabled acceptable prediction of pesticide concentrations for 20 watersheds of less than 100 square miles across the Midwest Corn Belt. The parameterization approach used datasets which are readily available at the national scale for the U.S. in order to examine the potential of the technique for national assessments. Following an evaluation of model performance from the initial parameterization, regional parameter adjustments were developed to identify the potential performance improvements that could be achieved through limited calibration. This presentation will focus on important choices made in SWAT parameters for the initial parameterization and the selection and identification of parameters for the regional calibrations.

Modeling the Fate and Transport of Pesticides in Agricultural Watersheds Using SWAT

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Transport of pesticides in agricultural watersheds is an important consideration in the development of nonpoint source pollution control strategies. However, modeling the fate and transport of pesticides at the watershed scale is usually hampered by numerous challenges including the spatial variability of the rate and timing of pesticide applications within the watershed and the sparsity of observed data. In order to address these challenges, several methods for incorporation of pesticide management operations in the Soil and Water Assessment Tool (SWAT) were examined to simulate the transport of atrazine in three Indiana watersheds. After calibrating and corroborating flow and pesticide processes in the study area, information on intra-seasonal planting dates was used to temporally assign the timing of tillage, nutrient application, and pesticide application to the cropland in the watersheds. Three different approaches were taken to schedule pesticide applications: a one-day application over the entire watershed, a temporally incremental application over the entire watershed, and a spatially and temporally incremental application in the watershed. A detailed comparison of observed and simulated pesticide load time series for each approach indicated that accurate representation of application dates was imperative. By using a spatially and temporally distributed application of pesticides, a more realistic pesticide simulation for the watershed was achieved. The enhanced modeling strategy will allow for a more effective planning and placement of management actions for the mitigation of pesticide loads.

Migration of SWAT 2005 in to Open Modeling Interface (OpenMI) and its Application on the Simulation of Sediment Transport in the Blue Nile

Getnet Betrie, Ann van Griensven, Stef Hummel, Arthur Mynett*

Integrated catchment management has arisen because managing environmental processes independently does not always produce sensible decisions in a wider view. However, most existing models tend to address only single issues. One of the powerful tools which can address such issue is the Soils Water Assessment Tool (SWAT). SWAT is a physical process based model which simulates hydrology and soil erosion at large catchment scale. The routing module for flow and sediment does not use Saint Venant equation and could not capture the backwater effect that is caused hydraulics structures such as dam. Subsequently, it does not capture the sediment deposition process that is caused by flow velocity reduction. Therefore, the SWAT model was migrated into Open Modeling Interface Environment (OpenMI) in order to link with hydrodynamic model which can capture the backwater effect.

In order to migrate SWAT into OpenMI complaint some modification was done the source code. Firstly, the initialization procedure was structured into one function than several modules. Secondly, SWAT was modified to run one time step from the beginning to the end of simulation. The last modification made to SWAT code was to split the sediment into sediment fractions such as clay, silt and sand to consider their role in sediment transport formula. Similarity on the number of out files printed and their content between the OpenMI compliant and original SWAT models showed that success of migration. A case study was undertaken by linking OpenMI-SWAT with SOBEK one dimensional hydrodynamic river model to model flow routing processes in the Blue Nile river basin. Comparison of observed and simulated flow result showed good fit at Roseries and Sennar dams, in lower Blue Nile.

Annual Freeze/Thaw Temperature Cycles in Soils on the Canadian Boreal Plain: Comparison of SWAT Predictions to Measured Data

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One of the key elements in modelling the impact of changing forest cover on surface water quantity and quality is to understand how annual freeze/thaw cycles affect soil temperature in forested watersheds. The focus of this study is to verify the suitability of the algorithms utilized by the Soil and Water Assessment Tool (SWAT) to predict soil temperature for a range of disturbed and undisturbed forest land classification types on the Boreal Plain of Canada. As part of the Forest Watershed and Riparian Disturbance project, instrumentation was installed at five site types across the study area that included burned, harvested, conifer, deciduous and wetland forest. Soil temperature and moisture were measured hourly at depths of 0.1, 0.5 and 1.0 m in the soil profile. The SWAT temperature algorithms were used to predict soil temperatures and timing of the annual freeze/thaw cycle at these depths, based upon average daily air temperature, soil characteristics, vegetation biomass, snow cover and solar radiation. Predicted daily soil temperatures were compared to measured values for each of the five site types. The algorithms utilized by SWAT were able to reproduce seasonal trends in soil temperatures adequately for the spring, summer and autumn seasons, with only a slight increase in the lag coefficient parameter. During winter months, the SWAT algorithms tended to predict soil temperatures that were consistently lower than measured data. Further development to the SWAT soil temperature algorithms is required to better represent the important insulating effect of snowpack.

Improved physically based approaches for Channel Erosion Modelling in SWAT

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Soil erosion from the overland region and routing of eroded sediment through the stream channel is an important component of SWAT model. Soil erosion is computed using the Modified Universal Soil Loss Equation (MUSLE). Based on the sediment load reaching the stream channel and the stream power (sediment carrying capacity of water), either channel erosion or sediment deposition can occur. In the previous version of SWAT (SWAT 2005), a simplified version of the original stream power equation developed by Bagnold was used to compute the maximum amount of sediment that can be transported based on peak channel velocity. However, this simplified model may not be suitable for all the river basins or the bed materials transported. Hence, in the current version of SWAT, four new sediment routing models have been added. In these four models, bank erosion and bed erosion are calculated separately based on the shear stress exerted by the moving water on the channel bank and bed respectively. Channel deposition is calculated based on the particle size and its fall velocity. In the previous version, only channel erosion or deposition can occur at a time. In the current version, some deposition can occur simultaneously with erosion as in reality. Soil erosion from the overland region is partitioned into various particle sizes, similar to EPIC model, and they are routed through ponds, reservoirs and channels. Hence, deposition could be calculated based on the particle size. Flood plain deposition of sediments is also modelled when the water overtops the stream bank and enters the flood plain.

Integration of a Simple Process-Based Snowmelt Model into SWAT

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Many of the spatial hydrologic modeling systems common today use variants on a site calibrated temperature-index (TI) approach for modeling snowmelt. Justification for using TI over process-based snowmelt models is due to the complexity as well as the large number of forcing variables required for running the models, as it is often hard to find reliable temperature and precipitation over a watershed of interest. Unfortunately, TI approaches require long historical periods of meteorological and hydrologic data to calibrate, which makes the search for historical temperature and precipitation data even harder, as now there is the added requirement of finding representative meteorological and stream flow gages with long and consistent temporal coverages.

For this article, we integrate a previously published process-based snowmelt model that requires only daily minimum and maximum temperature data, into the Soil and Water Assessment Tool (SWAT). We compare two scenarios over four watersheds representative of four distinct regions of the US. In the first scenario, we examine how well each model performs in each region given a long historical period to calibrate the TI approach. Second, we consider the case of limited historical data, and compare the performance of the snowmelt models using single year histories for calibration. With the results, we develop the justification for including process-based snowmelt models as an option for this and other spatial hydrologic modeling systems.

Evaluation of Different Spatial Discretizations Schemes in the Hydrological Response of an Andean Watershed

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The ability of a model to represent a basin depends on the efficiency with which the model is able to represent the different processes that happens on it. In order to simulate the hydrology of a basin, it is possible to use a lumped or distributed model. The present work objective is to analyze how the combination of different slope definitions during the Land use/Soil/Slope definition step, influence the results obtained in a modeling exercise done at the Lonquimay river basin in Chile. The watershed was delineated taking into account eight different contributing areas, after this the definition of land use, soil and slope was done considering three slope classes definition (single, 2 classes and 3 classes), next HRU were defined considering: Dominant land use and soil and different combination of soil over land use. SWAT model was run 128 times and simulated monthly flows were compared with observed flows using different statistical indicators. Best results are obtained when the basin is divided in three sub-basins and two classes of slope are considered. As sub-basin number is incremented there is a need of a larger relation between Nº of sub-basins and Nº of HRUs to obtain better results. This kind of analysis is relevant in countries were data availability is scarce, because sometimes during the set up of a model an over discretization is done which not necessarily improve results.

Application of BMP Design for Inshore Alluvial Plain River system in North Jiangsu, China

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River system in north Jiangsu Plain was manually divided into three sub-systems. Three generalized river systems were manually established in this area, an inshore alluvial plain (2,374km^2) with extremely dense river system (1.56km/km^2), less than 8 meters' difference in elevation and overloaded fertilizer application (1,062.91kg/ha). Based on the generalized river systems, stream flow and phosphorus transportation processes were constructed and calibrated with Soil and Water Assessment Tool (SWAT 2005) from 2003 to 2008. Spatial distribution of water flow and TP were calculated. The BMP simulation was designed in order to reveal the responses between different fertilizer rates and P nutrients yield in three land use types.

Calibration results presented acceptable precision (R^2>0.62, NS>0.34). This meant the manually design watersheds and generalized river systems were capable to represent local hydrological features. The spatial distribution showed a higher water and TP yield in east and lower in west. The Scenarios' results indicated that soluble P is the most sensitive nutrient in the three forms of P nutrients.

Integration of Satellite Data in the SWAT Watershed Water Quality Model: A Case Study of Roxo Reservoir Watershed, Portugal

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Various research on Roxo watershed have shown cases of the eutrophic nature of the Roxo reservoir.The processes that influence nutrients sources, transport, and delivery from watershed to lakes and reservoirs are most efficiently evaluated using computer models such as the Soil Water Assessment Tool (SWAT). This research evaluates the capability of the *"SWAT"* model (WQ) in simulating stream flow and nutrient (nitrogen and phosphorous) transport from watershed to surface water (Roxo reservoir). Effort was made to calibrate and validates the SWAT model in Roxo reservoir watershed for hydrologic component because nutrient (N & P) fluxes are believed to be influenced by water fluxes. This research examines the impact of different rainfall forcing methods on the Soil Water assessment Tool (SWAT) hydrology/water quality model.

ArcSWAT2005 interfaced with ArcGIS 9.2 was used to extract and process the input parameters which include a digital elevation model (DEM), land cover and soil map GIS data layers. Three types of rainfall forcing, which include the SWAT weather generator, point gauge and satellite observation rainfall data were used for simulation. A comparison was made between the simulation outputs and the result shows that the point gauge rainfall input to be better than the weather generator and satellite rainfall forcing. After analyzing cold simulation results, the gauge simulation was chosen for hydrologic model calibration. The model was calibrated and validated for stream flow in one location at the outlet of the catchment using monthly time steps. A sensitivity analysis was carried out to help determine the parameters to adjust during the calibration. Of these parameters, the most sensitive were the Curve number (CN), threshold depth of water in the shallow aquifer required for return flow to occur (Gwqmn), base flow alpha-factor (Alpha_Bf), threshold depth of water in the shallow aquifer for 'revap' to occur (Revapmn), soil evaporation compensation factor (Esco) and available water capacity of the soil layer (Sol_Awc). Statistical indicators like the Natsh-Sutcliffe (NSE) and Percentage bias (PBIAS) as well as graphical techniques and plots of 1:1 line were used to evaluate the SWAT model performance. In general simulations matched observed stream flow as the NSE estimates gave good range of values (about 0.77) for calibration period (2001-2004) and validation (about 0.64) for the period 2005-2007. A strong correlation was found between observed and simulated stream flow as the regression R 2 of the 1:1 plots gave 0.77 and 0.75 for calibration and validation respectively.

Challenges in Calibrating a Large Watershed Model with Varying Hydrogeologic Conditions

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A watershed model of the Lake LBJ, Texas three million-acre watershed was developed and hydrologically calibrated in ArcSWAT as part of the Lower Colorado River Authority's (LCRA) Colorado River Environmental Models (CREMs) project. Lake LBJ is one of the Central Texas Highland Lakes, which are run-of-river reservoirs in the Colorado River basin managed by the LCRA, and is a major water supply and hydroelectric power source for several surrounding communities. The CREMs project was designed to diagnose existing water quality problems and issues, discern water quality trends, and predict the consequences of various management decisions and associated actions on the water quality of the Highland Lakes, the Lower Colorado River, and its tributaries. The modeling tools, which will ultimately include watershed and lake models of Lake Travis, Lake LBJ, Inks Lake, and Lake Marble Falls, are being designed to provide information needed by LCRA to support policy decisions that proactively and effectively protect the integrity of the water resources in the Lower Colorado River basin.

The Lake LBJ watershed includes portions of both the karstified Cretaceous limestone of the Edwards Plateau in the west and the Llano Uplift in the east, which is composed of Precambrian and Paleozoic crystalline rocks. Additionally, average annual rainfall varies in the region from less than 20 in. in the upper, western portion of the watershed to more than 30 in. in the lower, eastern portion. The geologic and rainfall transitions within the watershed have resulted in two hydrologically distinct regions with differing groundwater characteristics, soil development, and vegetative cover. Curve number values due to variations in soil types and land cover were set for each sub-region within the watershed based on basin conditions. The primary challenge faced in this project was to account for the differences in the hydrogeologic properties of the karst system of the Edwards Plateau and an extensive, northeast trending fracture system in the Llano Uplift. In order to address the differences in hydrogeologic transport of water between the Edwards Plateau and Llano Uplift areas within the watershed, the calibration focused on the treatment of groundwater recharge and discharge. The most useful parameters in the calibration proved to be groundwater delay (GW_DELAY), the effective hydraulic conductivity of the main channel (CH_K2), and percent recharge to the deep aquifer (RCH_DP). For example, the combination of a relatively long GW_DELAY (365 days) and an increased CH_K2 (1.5 mm/hr) in the Edwards Plateau region of the watershed approximated the contribution of spring flow to the Llano River. Also, a RCH_DP value of 0.80 for the Llano Uplift region accounted for losses to the fractured, crystalline rock aquifer, whereas the value for the Edwards Plateau was only 0.55.

The Lake LBJ watershed model results will not only be used for future calibrations of sediment and nutrients within the watershed, but also, due to the absence of some calibration data and the existing inter-basinal hydrologic similarities, many of the calibrated parameters will be extrapolated to the Inks Lake and Lake Marble Falls watershed models. Ultimately, the output of the three watershed models will be linked to the three corresponding CE-QUAL-W2 lake models.

SWAT Water Balance: Development and Application of a Physically Based Landscape Water Balance in the SWAT Model

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The Soil and Water Assessment Tool (SWAT) uses the popular Curve Number (CN) method to determine the respective amounts of infiltration and surface runoff. While appropriate for engineering design in temperate climates, the CN is less than ideal in some situations (e.g. monsoonal climates, areas dominated by variable source area hydrology). The CN methodology is based on the assumption that moisture content distribution in the watershed is similar for each runoff event, a questionable assumption in many regions. To predict runoff, the CN routine was replaced with a physically based water balance in the code base. To compare this new water balance SWAT (SWAT-WB) to the original CN based SWAT (SWAT-CN), several watersheds in the headwaters of the Blue Nile in Ethiopia and in the Catskill Mountains of New York State (NYS) were initialized. Prior to any calibration of the models, daily streamflow Nash-Sutcliffe (NSE) model efficiencies improved from 0.03 with SWAT-CN to 0.33 with SWAT-WB, presumably because water deficits are better modeled. Moderate calibration (parameterization) based on soil properties in the watersheds resulted in vastly improved model performance for both models. However, SWAT-WB streamflow predictions were significantly better in the Ethiopian watersheds (NSE 0.74 vs 0.61), and resulted in nearly identical predictive accuracy in the NYS watershed (NSE 0.68 vs 0.67).These results suggest that replacement of the CN with a water balance routine in SWAT significantly improves model predictions in monsoonal climate such as Ethiopia, while providing equally acceptable levels of accuracy under more typical US conditions, with minimal calibration. Further work will investigate the implications of the model selection on the spatial distribution of processes in the watersheds.

Development of Effective Management Plan For A Small Watershed Using AVSWAT

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In the present investigation an effort has been made to identify the critical sub watersheds a small watershed for development of best management plan using a hydrological model namely AVSWAT2000. Total 180 combinations of various management treatments including crops (Rice, maize ground nut and soybean); tillage (zero, conservation, field cultivator, mould board plough and conventional practices) and fertilizer levels (existing, half of recommended and recommended) have been evaluated. The investigation revealed that rice cannot be replaced by other crops like groundnut, maize, mungbean, sorghum and soybean since comparatively these crops resulted in higher sediment yield. The tillage practices with disk plough has been found to have more impact on sediment yield and nutrient losses than conventional tillage practices for the existing level of fertilizer. Sediment yield decreased in case of zero tillage, conservation tillage, field cultivator, moldboard plough, conservation tillage as compare to conventional tillage. Lowest NO_3-N loss was observed in zero tillage in all the fertilizer treatments, where as field cultivator, moldboard plough and disk plough resulted increased in NO_3-N loss. As compare to conventional tillage the losses of soluble phosphorus were increased in moldboard plough. The losses of organic nitrogen were also increased as fertilizer dose increased. After zero tillage the conservation tillage preformed better in all the fertilizer treatments as per loss of organic nitrogen and organic phosphorus is concerned. It can be concluded that the sediment yield was found to be the highest in case of disk plough followed by moldboard plough, field cultivator, conventional tillage, field cultivator and least in zero tillage practices, where as the nutrias losses were found to he in different order with tillage practices, resulted highest nutrient losses in disk plough tillage practices. In view of sediment yield and nutrient losses, the conservation tillage practice was found to he the best as the sediment yield is less than the average soil loss where as nutrient loss is within the permissible limit.

Improving the Snowmelt Simulation by SWIM in the Experimental Basin of Upper Danube

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Snow is sensitive to climate changes and it is an important indicator in the climate impact assessment. In SWIM, the snowmelt and meltwater outflow is simulated by the simple degree-day method at the subbasin scale. However, this method is not sufficient to simulate the spatially distributed snowmelt and the runoff generation processes, especially for the snow-dominated regions. In this study, the upper Danube (Germany) was chosen as the experimental basin, and the simulated river discharge at the gauge Hofkirchen as well as the maximum snow water equivalent in the basin were compared with the observed values. The modifications on the SWIM snow module are 1) snow process is simulated at the hydrotope scale, and temperatures for each hydrotope is corrected based on the elevation; 2) more snow melt and runoff generation processes are included. As a result of these modifications, the river discharge was better simulated for the snow melting period in Alps, and the maximum snow water equivalent map of this basin became more precise with distinct characteristics in mountains and valleys.

Climate Change Impact on Hydrology and Water Resources in the White Volta River Basin, West Africa

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The White Volta river basin, West Africa, has enough water resource to meet current demands but there are many challenges including high spatial and temporal variability in rainfall, global climate change, deforestation, land degradation and high population growth. To have enough water for future use, the resource has to be managed sustainably, which among other things includes an understanding of how climate change will impact on hydrology and water. For this purpose, the Soil and Water Assessment Tool (SWAT) was applied to the basin to simulate the hydrology and to estimate the impact of future climate change on water resource. The model was calibrated and validated using measured river discharge data from the river discharge gage at Nawuni, for the period 1980-2000. Impact of climate change on water resource was estimated by simulating river discharge of the baseline (1990-2000) and future (2030-2039) time slices and comparing their mean annual values. The climate series used for simulating the future discharge reflected monthly changes in precipitation and temperature forecasted by the meso-scale climate model MM5, which has been downscaled from ECHAM4 scenario IS92a. The results show that SWAT is able to accurately reproduce the river discharge in the White Volta Basin. The coefficient of determination and Nash-Sutcliffe model efficiency were found to be, respectively, higher than 0.8 and 0.7, for both the calibration and validation periods. Compared to the present, the future mean annual river discharge and the annual coefficient of variation of the discharge in the basin are expected to increase by 33% and 52%, respectively, as a result of climate change.

The Use of Global Databases in Developing SWAT Applications to Sub-Saharan Africa and South Asia for Large-Scale Hydrological and Crop Simulation: Preliminary Results of Data Preprocessing and Harmonization

Hua Xie

A water management project was recently initiated to identify promising investment options for agriculture in Sub-Saharan Africa and South Asia. A focus of this project is to assess the impacts of smallholder irrigation on water resources and agricultural productivity. The SWAT model provides an integrated framework for hydrological and crop simulation, and is selected as the modeling tool in this endeavor. The development of large-scale SWAT applications to Sub-Saharan Africa and South Asia countries relies on the use of global databases and involves intensive data processing and harmonization activities. The data from global databases are evaluated, harmonized and processed so that they are compatible for use for SWAT modeling. The preliminary results of data preprocessing and data harmonization in the context of building SWAT models for assessing the suitability of smallholder irrigation in Sub-Saharan Africa and South Asia will be presented. The experience from this study will also be helpful in developing other SWAT applications in developing countries.

Satellite Data and New Methodologies for SWAT Validation in Euthrophication Studies

Pedro Chambel Leitão

Watershed modeling is data intensive in terms of input and also in terms of calibration validation data. For many users the processes of getting data is so time consuming that they consider modeling watersheds almost an impossible mission. The SWAT model is a watershed model that has made a compromise between the available data and the input required, in such way that it is possible to apply it to almost everywhere in the world, even though there isn't always the best data available.

This paper describes the experience of applying SWAT in Maranhão watershed in Portugal, which drains to Maranhão reservoir. Strategies for calibration/validation of model included not only the use of direct measurements (like flows) but also other sources of data, in order to overcome some data constrains.

For example, the available data on concentration of Nitrogen and Phosphorous is frequently not sufficient to validate the water quality processes estimated by SWAT. For example in the case of Maranhão, less than 10 measurements were made per year. However they could be enough to produce global nutrient balances based on measurement of river concentration and river flows. This global nutrient balances based on river measurements compared with SWAT model nutrient balance, can be a first step to validate model processes. In this case, global balance showed that much of the available nutrients that were expected to arrive at the monitored point are being retained somewhere in the basin. This is probably related with the high number of small reservoirs (less than 5 ha) spread throughout the watershed.

A test was made to evaluate if SWAT concentrations (used as input) could improve CeQualW2 results. With the two models connected it was possible to reproduce some of the algal blooms that were detected in the Maranhão reservoir measurements.

One of the most promising new sources of data to calibrate SWAT are satellites. In this study, for example, SWAT LAI results were compared to LAI from EUMETSAT Satellite. The comparison with EUMETSAT LAI showed that SWAT delays the peak of LAI (with the maximum only in July-August) while EUMETSAT show a maximum around May. Considering the main differences of LAI are happening in the low precipitation season, they are not influencing significantly the flows (and consequently the water quality).

Spatiotemporal Variability of Nutrient Processes under Changing Climate

Maya Motorova, Mahdi Ahmadi, Barmak Azizimoghaddam, Mazdak Arabi

While a significant shift in climatic conditions is evident around the world, the response of hydrologic and water quality processes at the watershed scale defies answers. For example, changing temperature and moisture conditions may alter the rate and timing of denitrification processes in soils, and the nutrient cycle in streams. This study presents a computational analysis to systematically evaluate the spatiotemporal variability of critical nutrient processes under varying climatic conditions over the coming decades. In the analysis, model parameters are treated as surrogates for natural processes that they represent. A sensitivity analysis is applied in conjunction with the SWAT model to reveal the importance of flow and nutrient processes at daily, monthly, seasonal, and annual time steps. The magnitude of spatial variability is evaluated at different stream locations with various morphological and hydrological characteristics. First, SWAT was calibrated and tested for daily streamflows, nutrient and pesticide loads over a twenty year period in the St Joseph River watershed in Indiana, where flow and water quality data at various locations are available. While applying various climatic forcings (i.e., precipitation and temperature) derived from Intergovernmental Panel on Climate Change (IPCC) scenarios, shifts in critical nutrient processes in soils as well as in the channel network were evident. The implication of such transitions on implementation of management actions for nutrient loads reduction is discussed.

A Post Processing Tool to Assess Sediment and Nutrient Source Allocations from SWAT Simulations

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Throughout the United States, distributed parameter hydrologic simulation models have been have employed to assist state and federal agencies in the development of Total Maximum Daily Loads (TMDLs) for impaired stream systems. These models have the capability of estimating point and non-point source pollutant load allocations at various spatial and temporal scales within a watershed. In recent years the Montana Department of Environmental Quality (MDEQ) has employed the Soil and Water Assessment Tool (SWAT) to assess sediment, nitrogen, and phosphorus load allocations for impaired stream systems throughout Western Montana. To develop these assessments requires multiple simulations with SWAT, retrieval of output files from the model, and subsequent labor intensive computations. A post processing tool was recently developed by MDEQ to facilitate the computation of sediment and nutrient load allocations simulated by SWAT for 303d listed streams. To develop these pollutant load allocations, the model is run three times to generate the necessary information to compute load allocations for a particular impaired stream system within a delineated SWAT project. Output retrieved from these runs includes the output.hru (hydrologic response unit) file and the output.rch (channel reach) file associated with the total load, the total load less bank erosion, and the total load less point source load. Data retrieved from the output files are in turn input to the post processing tool to compute average monthly or seasonal sediment and nutrient load allocations from the landscape associated with the various land cover types present within the impaired stream system. The tool also computes the average monthly or seasonal sediment and nutrient load allocations associated with bank erosion, point sources, and non-point sources present in that stream system. This newly developed post processing tool holds considerable promise in reducing the time required to develop pollutant load allocations for specific stream systems within large, complex watersheds typically encountered in Montana.

Land Use Resolution Impact on Modelling Water Quantity and Quality - Tagus Watershed

David Brito, Pedro Chambel-Leitão, Mário Caetano, Ramiro Neves

Maranhão is a water reservoir in Tagus watershed in Portugal, used mainly for irrigation. Maranhão watershed drains a total area of 2290 km2.

Tests were made on land use map resolution on water quantity and water quality in Maranhão watershed. The tasks consisted of using three different land use maps from satellite sensors with different resolutions - MERIS – 300m resolution; AWIFS – 60m; LISS – 20m. These maps were used to estimate diffuse source loads with SWAT model. Land use, soil characteristics (texture, conductivity, etc), digital terrain model and products (slope, river network, etc.) and meteorology are the main forcing inputs to the SWAT model.

The differences from MERIS (300 m resolution) to the AWIFS (60 m resolution) consist in the reduction of about 60% the area with non irrigated crops and around 50% reduction in agro-forestry. The decrease of these classes increased pasture areas and orchard/vineyards producing a wider range of land uses in the watershed, consequence of the higher resolution map.
SWAT hydrodynamic was validated against field data in flow stations in the watershed. The comparison between modeled and measured flow in a monthly basis produced high correlation between 83% to 88% and high model efficiencies from 0.70 to 0.84.

Hydrodynamic simulations using different land use maps showed that the land use differences did not produce almost visible changes in flow results or in water balance in the watershed.
Land use resolution in Maranhão watershed was proven to have impact on water quality. Simulations showed that fertilized area in the watershed (variable in land use maps) can be of great impact on diffuse load estimation. The coarser resolution map (MERIS, with higher fertilized areas) resulted in almost double of the diffuse loads (and erosion) of the finer resolution maps (AWiFS and LISS). Moreover, the predominant path for nutrient load in Maranhão watershed is the transport in superficial flow (around 70% for nitrogen and almost all the phosphorus) and particularly associated with erosion (particles adsorbed to fine sediments).
Land use resolution in Maranhão watershed does not seem to be important for water budget but seems to be an important issue on diffuse load and erosion estimation.

Modeling River Flows and Sediment Dynamics for the Laguna de Santa Rosa Watershed in Northern California

Dave Bubenheim

Use of the SWAT Model to Evaluate the Sustainability of Bioenergy Production at a National scale

*Latha Baskaran, Henriette I. Jager, Raghavan Srinivasan, Peter Schweizer**

With the recent attention towards bioenergy as an alternate source of energy, there is a need to ensure a sustainable future for such an energy system. Two aspects of sustainability are production and ecological protection. On the one hand, we require long-term potential for profitably producing energy crops or residues. On the other hand, we require that no harm is done to ecosystems influenced by bioenergy production. The Soil and Water Assessment Tool (SWAT) is an important tool in our efforts to quantify both sides of this equation at a national scale. To address production, we have made progress in estimating yields of perennial crops, thus far focusing on switchgrass within its natural range, the eastern US. To date, we have estimated the geographic distribution of potential switchgrass yield for twelve major hydrologic regions of the eastern United States. We performed separate SWAT runs for each 2-digit hydrologic region assuming that all areas (excluding regions identified as water in the 2001 National Land Cover Data) were converted to Alamo switchgrass, which is a lowland variety. This analysis, when compared with the ORNL database of switchgrass field trials revealed qualitatively similar geographic patterns, with a need for latitudinal adjustments in growth parameters. To address ecological protection, we plan to use the SWAT model to forecast changes in water quality, fish and mussel richness as a result of changes in landscape to incorporate bioenergy crops. Thus far, we have implemented the SWAT model for the Arkansas-Red-White region, which drains into the Mississippi River. This analysis was carried out at the scale of 8-digit hydrological units. The 2008 cropland data layer was used as the base land cover for most of the study region. We identified two sub-watersheds for sensitivity analysis and calibration, one with mostly forest cover and the other with a relatively large percentage (~15%) of agricultural lands. Future plans include repeating our SWAT analysis with calibrated parameters and forecasting changes in water quality for future bioenergy landscapes as forecasted by the POLYSYS model. Only by evaluating energy and environmental implications of landscape changes can we make informed decisions about bioenergy at the National scale, and the SWAT model will enable us to reach that goal.

Assessing Impacts of VAF system and Practices on Soil and Water at a Sub-Watershed Scale using SWAT Model: Case study in Nghia Trung Sub-watershed, Binh Phuoc Province, Vietnam

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During recent years, emerging water and soil problems threaten the livelihood of local people and the sustainability of the whole watershed ecosystems in Vietnam. Day by day there are a lot of water resources is polluted and soil is lost because of degradation of forest or land use change. This study is aimed at assessing factors contributing to reservoir sedimentation, water quality using land use factors in Nghia Trung Sub-watershed as case study. It is especially important in the Nghia Trung Sub-watershed where the soil is highly erodible and forest conversion for agricultural cropping is in serious condition. This study was also focused on how soil loss and water quality was impacted when land use in the watershed resource is changed. The SWAT model was applied to evaluate the effect of main input data of SWAT (land use, soil, human practices) to soil loss and water quality in Ong Thoai reservoir, Nghia Trung Sub-watershed.
The output of SWAT model indicated that land use change and deforestation impacted surface flow and sediment yield in Ong Thoai reservoir, Nghia Trung sub-watershed. The precipitation between 2002 and 2007 does not much different but the surface flow (631.37) at year 2007 about 1.36 times compare with surface flow (466.50) at year 2002, and also sediment yield at year 2007 about 5.78 ton/ha compare with 3.56 ton/ha at year 2002. This figure is also shown that 127 ha forestland about 12 percent of studied area in 2002 was converted to cashew, rubber in 2007 which is cause surface flow 1.36 times increasing and also sediment yield in Ong Thoai reservoir 1.62 times increasing. The cashew has only 27.52 ha about 2.81% the research area but without weeding sediment was reduced about 0.576 ton/ha and surface flow was reduced about 14mm.

GIS Based Spatial Precipitation Estimation for SWAT

Xuesong Zhang, Raghavan Srinivasan

Precipitation is one primary input into SWAT. In this study, we present two Geographic Information System (GIS) based tools that can automatically estimate spatial precipitation using rain gauge data and Next Generation Weather Radar (NEXRAD). These tools include multivariate Kriging methods (e.g. Simple Kriging with varying local means, Kriging with External Drift, Regression Kriging, and Collocated Kriging) for combining rain gauge data and NEXRAD and uni-variate methods (nearest neighborhood, inverse distance weighted, Simple Kriging, and Ordinary Kriging) for interpolating rain gauge data. The performances of the methods mentioned above are evaluated in several watersheds. The sensitivity of streamflow and sediment load modeling to spatial precipitation estimated using different methods is examined. Further information on the availability of these GIS tools is also provided.

SWAT Development for Simulating Flow and Pesticide Movement in a Large Claypan Watershed

Claire Baffaut, E. John Sadler, Robert N. Lerch, Newell R. Kitchen, Kenneth A. Sudduth

The Mark Twain Lake/Salt River Basin is located in northeastern Missouri and is the source of water to Mark Twain Lake (MTL), a public water supply that serves 40,000 people. At the outlet of MTL, the basin drains 6417 km^2, including ten major watersheds that range in area from 271 to 1579 km^2. The basin is characterized by flat to gently rolling topography with a predominance of claypan soils that result in high runoff potential. The claypan soils are especially vulnerable to soil erosion, which has degraded soil and water quality throughout the basin, and to surface transport of herbicides.

SWAT modeling efforts started with the intensely studied and monitored Goodwater Creek Experimental Watershed, a 73 km^2 in MTL watershed. Modifications of the code were needed to improve the simulation of saturated conditions above the claypan, which cause excess runoff and subsurface lateral flow. The ability to use planting records was added, allowing specification of planting and herbicide application dates that matched real ones over a large area and long period.

Results showed improvement of calibration and validation results for flow and atrazine. The model was used to estimate the effectiveness of several practices that impact herbicide transport including incorporation, filter strips, and reduction of application rates. Further work includes the application of the model to the whole MTL watershed, the simulation of nutrient and sediment transport, and the estimation of the impact of land-use changes brought about by biofuel production.

Streamflow, Sediment, and Nutrient Simulation of the Bitterroot Watershed Using SWAT

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The Department of Environmental Quality has employed the Soil and Water Assessment Tool (SWAT) to aid in the development of sediment and nutrient total maximum daily loads (TMDLs) for impaired stream systems within the 7300 km^2 Bitterroot Watershed in Western Montana, USA. A revised 2005 version of SWAT that consisted of a modification to consider losses of organic nitrogen and phosphorus due to bank erosion was used to perform simulations on the watershed. Parameters that govern streamflow, sediment, nitrogen (N), and phosphorus (P) in SWAT were calibrated in a distributed fashion for seven regions within the Bitterroot. A dryer than normal four year period of record from 2000 to 2003 was used for model calibration while a wetter than normal four year period from 1995 to 1998 was used for model calibration. Based on computed values of percent bias and the coefficient of efficiency as well as graphical comparisons of streamflow, SWAT exhibited an element of robustness in that it performed at least as well under wetter than average conditions (validation period) as compared to dryer than average conditions (calibration period). From the comparison of measured versus simulated average monthly sediment, total N, and total P loads for the calibration and validation periods, SWAT also did a reasonable job predicting sediment and nutrient constituents for the Bitterroot Watershed. Results of model simulations suggest that bank erosion accounts for about 44%, 21%, and 30% of the total sediment, nitrogen, and phosphorus yields from the watershed, respectively. These simulated nutrient yields due to bank erosion are appreciably different from previous SWAT simulations in Montana that have not considered the impact of bank erosion on nutrient transport.

SWAT modeling of Critical Source Area for Runoff and Phosphorus losses: Lake Champlain Basin, VT

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Lake Champlain, located between Vermont, New York, and Quebec, exhibits eutrophication due to continuing phosphorus (P) inputs mainly from upstream nonpoint source areas. To address the Lake's eutrophication problem and as part of total maximum daily load (TMDL) requirements, a state-level P reduction goal has been set by the Department of Environmental Conservation of both Vermont and New York. Unfortunately, remedial measures being undertaken thus far to control the nonpoint P losses have been mostly based on landowner voluntary participation and have not been guided by a systematic technique to implement remedial measures where they are most needed (greater P loss risk) and where they can provide the greatest P loss reduction. Consequently, P reduction goals have not been achieved in most segments of Lake Champlain. The main objective of this study was to identify land uses with the highest P loss - i.e., critical sources areas (CSA) - using a model-based approach. Soil and Water Assessment Tool (SWAT) is used for this objective. This study focuses on the Rock River Watershed, which is one of the highest contributors of P to Lake Champlain. Spread over 71 km^2, the watershed is dominated by dairy agriculture and has fertile periglacial lacustrine and alluvial soils with an old tile drainage system. Performances SWAT-prediction of hydrology, sediment, and P loss are being tested in Rock River Watershed. In this paper, outputs of model calibration, validation, and spatial locations of CSAs of runoff, sediment, and P losses are presented. The identification of CSAs for P loss is expected to support the next phase of our project, which involves exploring cost-effective P management strategies with the highest potential for P loss reduction applicable to the study watershed and Lake Champlain Basin.

Using SWAT as a Tool for Sustainable Landuse Policy Development

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This paper looks at sustainable development from a watershed perspective. The two facets to sustainability – environment and development, are both related and impact each other. The quality and quantity of available water affects human activities, their well-being and their livelihoods. On the other hand anthropogenic activities and land use practices affect the quality and quantity of water available. Watershed management is a very powerful and effective tool to provide a framework and subsequently to measure humanity's progress towards sustainability. This paper builds a framework to measure a "Watershed Sustainability Index" (WSI). It then implements the framework on a watershed in Millsboro Pond watershed in the Southern Delaware and uses SWAT to measure the WSI for four landuse scenarios (created based on recharge potential and riparian widths) in the watershed. It was found that the spatial distribution of land use impacts the sustainability of a watershed. Riparian zones, up to a certain width, improve the sustainability of a watershed. Out of the four scenarios, the current land use may be considered "sustainable" only if environmental issues are given less weightage.

Calculation of Optimal Trade-Offs Between Farm Profit, Water Quality and Fish Diversity

Gerald Whittaker, Remegio Confesor, Jr., Alan Herlihy, William Gerth, Guillermo Giannico, George W. Mueller-Warrant, Stephen M. Griffith, Gary M. Banowetz, Kathryn Boyer, Tiffany S. Garcia, and Brenda McComb*

This paper introduces an integrated modeling system with dynamic links among an economic model, SWAT, a linear program that calculates index numbers and a fish diversity model. The modeling system is implemented using a hybrid genetic algorithm using activity analysis as a local search method, and NSGA-II for calculation of the multiple objective Pareto optimal set. This approach allows communication among the different models during the optimization search, in contrast with other methods that only allow sequential exchange of information. We apply this modeling system to the evaluation of conservation practices used in grass seed production in the Calapooia river valley in Oregon. The output of the optimization is a simulation of the Pareto optimal front containing the optimal trade-offs among three objectives; farm profit, water quality for human consumption, and diversity of fish species. Data envelopment analysis is used to model producer behavior under the assumption of profit maximization (farm profit), which in turn provides inputs to SWAT. A Malmquist index approach is used to calculate water quality from SWAT outputs, and a statistical model relates fish diversity to outputs from SWAT.

Management Scenarios for Reduced Nitrate Loads in a Small Catchment in Brittany (France) – The Problem of Data Scarcity and the Resulting Predictive Uncertainty

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The Soil and Water Assessment Tool (SWAT) has been applied to the Ic watershed, Brittany, France, to evaluate scenarios for reduction of nitrate in stream water. For the simulated period the model showed fair results with a mean index of agreement of 0.64 at the watershed outlet for discharge and nitrate loads.

The management goal for the watershed is the meeting of drinking water threshold at the watershed outlet. An analysis of observed data revealed that nitrate loads would have to be reduced by at least 17% on average to reach that goal. Scenarios investigated cover fertilizer reduction and the introduction of wetland buffer zones. Decreased nitrogen inputs were realized on a) selected subbasins and b) all agricultural fields; wetlands were placed at three model subbasins. Most effective measures were a 50% fertilizer decrease on selected subbasins resulting in a range of 13 - 22 % reduction of nitrate loads with a high uncertainty.
Consequently, none of the tested measures is likely to achieve a sufficient reduction. Combined measures such as enhanced fertilizer management and concurrent introduction of wetlands seem to be the most promising way to approach the drinking water threshold.

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