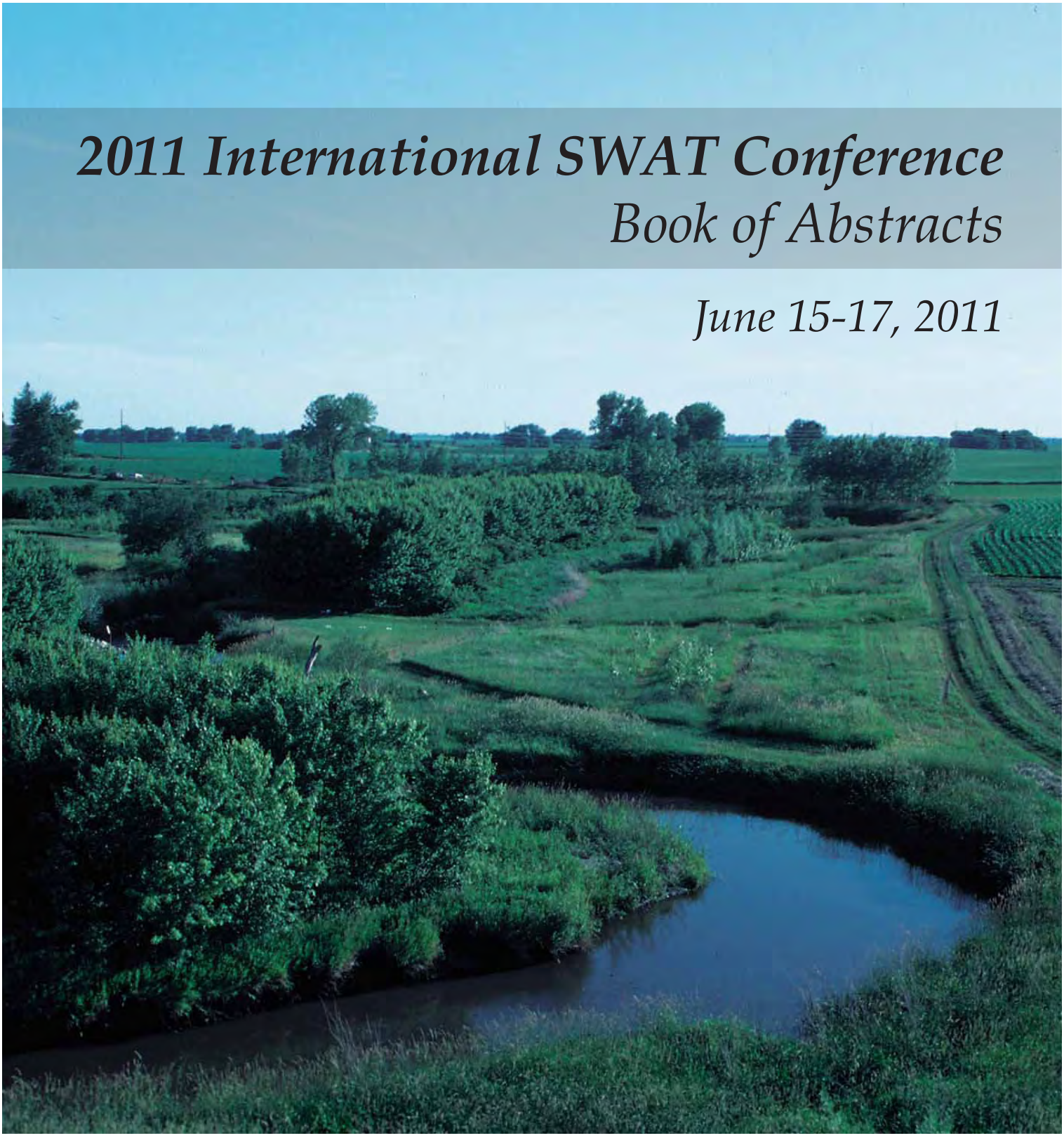
2011 SWAT

University of Castilla La Mancha
Toledo, Spain

2011 International SWAT Conference
Book of Abstracts

June 15-17, 2011



2011 International SWAT Conference - Book of Abstracts

Prepared by:

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Raghavan Srinivasan, Texas AgriLife Research, USA

2011 SWAT

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2011 SWAT

Foreward

The organizers of the 2011 International SWAT Conference want to express their thanks to the organizations and individuals involved and their preparation and dedication to coordinate a successful conference. We would also like to thank the Scientific Committee for their support in preparing the conference agenda and allowing for scientists and researchers around the globe to participate and exchange their scientific knowledge at this conference.

Organizations that have played a key role include:

- *United States Department of Agriculture - Agricultural Research Service*
- *Texas AgriLife Research*
- *Texas A&M University*
- *University of Castilla La Mancha. Campus of Fábrica de Armas*

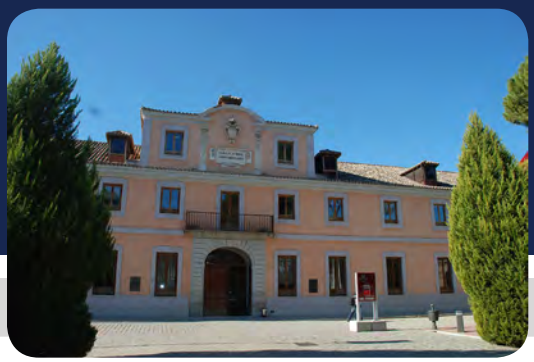
We would especially like to thank conference sponsors for making this conference possible:

- *Jacobs Engineering Group Inc.*
- *The Madrid Institute for Advanced Studies in Water Technologies IMDEA Water*
- *The Ministry of Science and Innovation, Spain*
- *ARNAIZ Consultores*
- *United States Department of Agriculture - Agricultural Research Service*
- *Texas AgriLife Research*
- *Texas A&M University*
- *University of Castilla La Mancha. Campus of Fábrica de Armas*

A special thank you to the University of Castilla La Mancha and Dr. José María Bodoque del Pozo and for his countless hours and efforts to host the SWAT Community. On behalf of the SWAT Community, we extend our sincere gratitude to you and your university for the kind invitation and welcoming hospitality.

The following Book of Abstracts contains abstracts for presentations covering a variety of topics including but not limited to large scale applications; climate change applications; model development; environmental applications; hydrology; best management practices (BMPs); sensitivity, calibration and uncertainty; pesticide, bacteria, metals and pharmaceuticals; biofuel and plant growth; and more.

The Conference Organizers hope you enjoy the conference and continue to view these SWAT gatherings as a positive opportunity for our international research community to share the latest innovations developed for the Soil and Water Assessment Tool.



Wednesday, June 15, 2011

8:30 - 9:30 a.m. **PARTICIPANT CHECK-IN AND REGISTRATION**
Building 37 - Room 0.01

9:30 - 10:30 a.m. **OPENING CEREMONY**
Building 37 - Room 0.01

Moderator: Dr. José María Bodoque del Pozo
University of Castilla La Mancha, Spain

Welcome Address: **Dr. José María Bodoque del Pozo**, *University of Castilla La Mancha, Spain*

Keynote Speakers: **President,** *University of Castilla La Mancha, Spain*

Model Development: **Dr. Jeffrey G. Arnold**, *USDA - Agricultural Research Service, USA*

Closing: **Dr. Raghavan Srinivasan**, *Texas A&M University, USA*

10:30 - 10:50 a.m. **COFFEE BREAK AND GROUP PHOTO**
Building 37 - Restaurant

Wednesday, June 15, 2011

10:50 a.m. - 12:35 p.m. **SESSION A1 - LARGE SCALE APPLICATIONS**
Building 37 - Room 0.08 (Page 1)

Moderator: Indrajeet Chaubey
Purdue University, USA

10:50 - 11:10 a.m.	Elham Rouholahnejad	*Water Resources Status in Danube River Basin*
11:10 - 11:30 a.m.	Benedikt Notter	*Estimating Ecosystem Service Provision for Future Management and Climate Change Scenarios for the Pangani Basin, East Africa*
11:30 - 11:50 a.m.	Hans Estrup Andersen	*Modelling Nutrient Loading of Danish Marine Waters*
11:50 - 12:10 p.m.	Liliana Pagliero	*SWAT Modelling at Pan European Scale: the Danube Basin Pilot Study*
12:10 - 12:30 p.m.	Christine Kuendig	*Impact of the Ratio Between Subbasins and Climate Stations on the Performance of SWAT in the Rhine Basin*
12:30 - 12:35 p.m.	*Discussion & Wrap Up*	

10:50 a.m. - 12:35 p.m. **SESSION A2 - SENSITIVITY CALIBRATION & UNCERTAINTY**
Building 37 - Room 0.09 (Page 6)

Moderator: Ann van Griensven
UNESCO-IHE, the Netherlands

10:50 - 11:10 a.m.	Martin Volk	*Changing Land Management Practices During Model Calibration and Evaluation Periods – Importance, Impact and Interpretation*
11:10 - 11:30 a.m.	Michael Strauch	*Using Precipitation Data Ensemble and Bayesian Model Averaging for Uncertainty Analysis in Hydrologic Modeling*
11:30 - 11:50 a.m.	Karim C. Abbaspour	*SWAT-CUP New Features: Parallel processing, Parameterization, Outlet Visualization*
11:50 - 12:10 p.m.	Hyunwoo Kang	*Evaluation of SWAT Auto-calibration using Diverse Efficiency Criteria*
12:10 - 12:30 p.m.	Hyung Kyung Joh	*The Uncertainty Analysis of SWAT Simulated Stream Flow and Water Quality Applied to Chungju Dam Watershed of South Korea*
12:30 - 12:35 p.m.	*Discussion & Wrap Up*	

10:50 a.m. - 12:35 p.m. **SESSION A3 - BEST MANAGEMENT PRACTICES (BMPs)**
Building 37 - Room 0.10 (Page 11)

Moderator: C. Allan Jones
Texas AgriLife Research, USA

10:50 - 11:10 a.m.	Aaron Mittelstet	*Field Scale Modeling to Estimate the Reduction in Phosphorus and Sediment using a Simplified GUI for SWAT*
11:10 - 11:30 a.m.	Britta Schmalz	*Effect of Best Management Practices on Water Quality in a Lowland Catchment*
11:30 - 11:50 a.m.	José Miguel Sanchez Perez	*Simulated Mitigation Measurements to Reduce Nitrate in Surface Water using SWAT Hydrological Modeling in an Agricultural Watershed, Southwest France*
11:50 - 12:10 p.m.	Hongguang Cheng	*Application of BMPs Design for Inshore Alluvial Plain River system in North Jiangsu, China*
12:10 - 12:30 p.m.	Jenny Sandberg	*The Impact of Land Management on Drinking Water Quality: A Water Industry Application, East of England*
12:30 - 12:35 p.m.	*Discussion & Wrap Up*	

Wednesday, June 15, 2011

12:35 p.m. - 1:40 p.m. **SESSION B1 - MODEL DEVELOPMENT**
Building 37 - Room 0.08 (Page 16)

Moderator: Fred F. Hattermann
Potsdam Inst. for Climate Impact Research, Germany

12:35 - 12:55 p.m.	Stefan Liersch	*How to Integrate Wetland Processes in River Basin Modeling? A West African Case Study*
12:55 - 1:15 p.m.	Darren Ficklin	*Development and Application of a Hydroclimatological Stream Temperature Model within SWAT*
1:15 - 1:35 p.m.	Gordon Putz	*Soil Temperature Damping Depth in Boreal Plain Forest Stands and Clear Cuts: Comparison of Measured Depths versus Predicted based upon SWAT Algorithms*
1:35 - 1:40 p.m.	*Discussion & Wrap Up*	

12:35 p.m. - 2:00 p.m. **SESSION B2 - ENVIRONMENTAL APPLICATIONS**
Building 37 - Room 0.09 (Page 19)

Moderator: Nicola Fohrer
Christian-Albrechts-University, Germany

12:35 - 12:55 p.m.	Julio Issao Kuwajima	*Challenges and Difficulties in Sediment Modeling Applied to Sedimentation Study of the Lobo Reservoir in Brazil*
12:55 - 1:15 p.m.	Raphael Benning	*Using Measurement Data on Water and Matter Fluxes in Small Homogeneous Mountainous Catchments for HRU-parameterization in SWAT*
1:15 - 1:35 p.m.	Jean-Marie Lescot	*Cost-Effectiveness Analysis for Controlling Water Pollution by Pesticides using SWAT and Bio-Economical Modeling*
1:35 - 1:55 p.m.	Itsasne Cerro	*Assessing the Pollutant Transport with SWAT model in an Agricultural Watershed Dominated by an Alluvial Aquifer*
1:55 - 2:00 p.m.	*Discussion & Wrap Up*	

12:35 p.m. - 1:40 p.m. **SESSION B3 - LANDSCAPE PROCESSES & LANDSCAPE/RIVER CONTINUUM**
Building 37 - Room 0.10 (Page 23)

Moderator: Martin Volk
Helmholtz Centre for Environmental Research Germany

12:35 - 12:55 p.m.	Dan Hawtree	*Assessing the Impact of Increased Cultivation of Woody Biomass for Energy Generation Purposes on Water and Matter Balances in Rural Catchments*
12:55 - 1:15 p.m.	Claire Baffaut	*Linking Edge-of-Field Results to Stream Flow and Water Quality: A Comparison Between APEX and SWAT*
1:15 - 1:35 p.m.	Carina Almeida	*SWAT LAI Calibration with Local LAI Measurements*
1:35 - 1:40 p.m.	*Discussion & Wrap Up*	

1:40 p.m. - 3:00 p.m. **LUNCH**
Building 37 - Restaurant

Wednesday, June 15, 2011

3:00 p.m. - 4:25 p.m. **SESSION C1 - PESTICIDES, BACTERIA, METALS & PHARMACEUTICALS**
Building 37 - Room 0.08 (Page 26)

Moderator: Virginia Jin
USDA - Agricultural Research Service, USA

3:00 - 3:20 p.m.	Laurie Boithias	*Modeling Pesticide Fluxes During Highflow Events in an Intensive Agricultural Catchment: the Save River (Southwestern France) Case Study*
3:20 - 3:40 p.m.	Kristin Brassett	*A Mass Balance Approach: Updating the SWAT Pesticide Module for Application to EMCONs*
3:40 - 4:00 p.m.	Nicola Fohrer	*Fate and Transport Modeling of the Herbicides Metazachlor and Flufenacet using SWAT*
4:00 - 4:20 p.m.	Michael Winchell	*A Comparison of SWAT Pesticide Simulations Based on Varying Input Resolutions Using a Minimal Calibration Approach*
4:20 - 4:25 p.m.	*Discussion & Wrap Up*	

3:00 p.m. - 4:25 p.m. **SESSION C2 - HYDROLOGY**
Building 37 - Room 0.09 (Page 30)

Moderator: José María Bodoque del Pozo
University of Castilla La Mancha, Spain

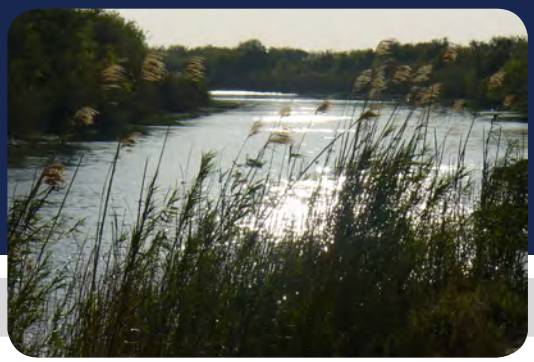
3:00 - 3:20 p.m.	Daniel N. Moriasi	*Hydrologic Evaluation Using Two SWAT Shallow Water Table Depth Algorithms in the South Fork Watershed*
3:20 - 3:40 p.m.	Farida Dechmi	*Application of SWAT Model to a Sprinkler Irrigated Watershed in the Middle Ebro River Basin (Spain)*
3:40 - 4:00 p.m.	Laura Galván González	*Malfunctioning of Stream-Gauge Stations in the Chanza and Arochete Rivers (Huelva, Spain) Detected from Hydrological Modeling with SWAT*
4:00 - 4:20 p.m.	Leticia Palazón Tabuenca	*Application and Validation of SWAT Model to an Alpine Catchment in the Central Spanish Pyrenees*
4:20 - 4:25 p.m.	*Discussion & Wrap Up*	

3:00 p.m. - 4:25 p.m. **SESSION C3 - INSTREAM SEDIMENT & POLLUTANT TRANSPORT**
Building 37 - Room 0.10 (Page 34)

Moderator: Balaji Narasimhan
Indian Institute of Technology, India

3:00 - 3:20 p.m.	Anabela Cândida Ramalho Durão	*Estimation of Transported Pollutant Load in Ardila Catchment using the SWAT Model*
3:20 - 3:40 p.m.	Ricardo Sorando	*Modeling the Pollutant Dynamic in an Intensive Irrigation Agricultural Watershed of a Semi-arid Zone: the Flumen River in Northeastern Spain*
3:40 - 4:00 p.m.	Mario Guevara	*Soil Erosion Modelling in an Agro-forested Catchment of NE Spain Affected by Gullying using SWAT*
4:00 - 4:20 p.m.	Jaehak Jeong	*Development of Algorithms for Sedimentation-Filtration Basins in SWAT*
4:20 - 4:25 p.m.	*Discussion & Wrap Up*	

4:25 p.m. - 4:45 p.m. **BREAK**
Building 37 - Restaurant



Wednesday, June 15, 2011

4:45 p.m. - 5:50 p.m. **SESSION D1 - BIOFUEL & PLANT GROWTH**
Building 37 - Room 0.08 (Page 38)

Moderator: Jeff Arnold
USDA - Agricultural Research Service, USA

4:45 - 5:05 p.m.	Jesus Uresti Gil	*Mapping Sugar Cane Yield for Bioethanol Production in Veracruz, México*
5:05 - 5:25 p.m.	Indrajeet Chaubey	*Improving the Simulation of Biofuel Crop Sustainability Assessment using SWAT Model*
5:25 - 5:45 p.m.	Jesus Uresti-Gil	*Mapping King-grass (Pennisetum purpureum) Biomass Yield for Cellulosic Bioethanol Production in Veracruz, México*
5:45 - 5:50 p.m.	*Discussion & Wrap Up*	

4:45 p.m. - 5:50 p.m. **SESSION D2 - CLIMATE CHANGE APPLICATIONS**
Building 37 - Room 0.09 (Page 41)

Moderator: A. K. Gosain
Indian Institute of Technology, India

4:45 - 5:05 p.m.	Diana Pascual Sanchez	*Climate Change Impacts on Water Availability in Three Mediterranean Basins of Catalonia (NE Spain)*
5:05 - 5:25 p.m.	Maite Meaurio Arrate	*Application of SWAT Model to Evaluate the Impacts on Water Resources of Some Climatic Scenarios in a Catchment of the Basque Country*
5:25 - 5:45 p.m.	Marco Pastori	*Impact of Climate Change on the Water and Nutrient Cycles in the Po River Basin (Italy)*
5:45 - 5:50 p.m.	*Discussion & Wrap Up*	

4:45 p.m. - 5:50 p.m. **SESSION D3 - ENVIRONMENTAL APPLICATIONS**
Building 37 - Room 0.10 (Page 44)

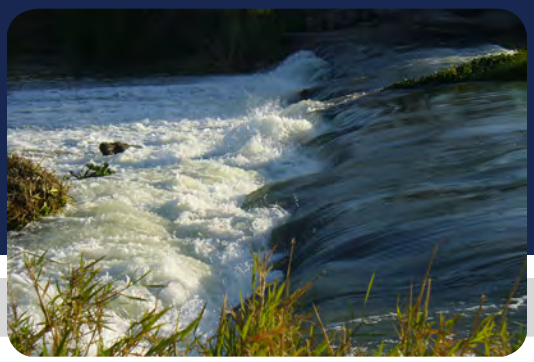
Moderator: Jose Miguel Sanchez-Perez
ECOLAB, France

4:45 - 5:05 p.m.	João Rocha	*Estimating Water Pollution Abatement Cost Functions using the Soil and Water Assessment Tool (SWAT)*
5:05 - 5:25 p.m.	Sven Lautenbach	*Quantifying Trade-offs Between Bioenergy Production, Food Production, Water Quality and Water Quantity Aspects in a German Case Study*
5:25 - 5:45 p.m.	Frederike Schumacher	*Simulations of Water Balances in Different European Climates – Potentials and Limitations of Integrated Forest and Land-Use Impact Modelling*
5:45 - 5:50 p.m.	*Discussion & Wrap Up*	

7 p.m. - 9 p.m. **WELCOME RECEPTION**
Palacio de Lorenzana

Guest of Honor

María José Ruíz García
Dean of the Environmental Science Faculty



Thursday, June 16, 2011

8:30 a.m. - 10:15 a.m. **SESSION E1 - CLIMATE CHANGE APPLICATIONS**
Building 37 - Room 0.08 (Page 47)

Moderator: Valentina Krysanova
Potsdam Inst. for Climate Impact Research, Germany

8:30 - 8:50 a.m.	Minji Park	*Analysis of the Future Climate Change Impact on Vegetation Canopy and the Crop Growth Period*
8:50 - 9:10 a.m.	Shaochun Huang	*Projections of Hydrological Extremes under Climate Change in Germany by Combining Different RCMs with SWIM*
9:10 - 9:30 a.m.	Fred Hattermann	*Modeling Hydro-climatic Extremes and Flood Damages under Climate Change Conditions*
9:30 - 9:50 a.m.	Minh Tue Vu	*Quantifying SWAT Runoff Using Gridded Observations and Reanalysis for Dakbla River, Vietnam*
9:50 - 10:10 a.m.	Mikolaj Piniewski	*Effect of Climate Change on Environmental Flow Indicators in the Narew Basin, Poland*
10:10 - 10:15 a.m.	*Discussion & Wrap Up*	

8:30 a.m. - 10:15 a.m. **SESSION E2 - SEDIMENT, NUTRIENTS & CARBON**
Building 37 - Room 0.09 (Page 52)

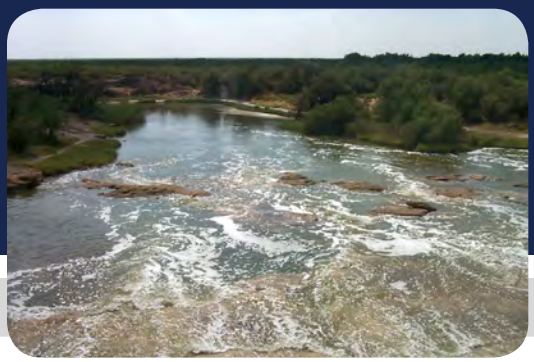
Moderator: Pedro Chambel Leitao
IST-MARETEC, Portugal

8:30 - 8:50 a.m.	Nicola Fohrer	*Coupling SWAT with In-stream Models for an Integrated Assessment of Sediment Transport*
8:50 - 9:10 a.m.	Matjaž Glavan	*Impact of Historically Changed Land Use on the Water Quality of the Rivers Reka and Dragonja, Slovenia*
9:10 - 9:30 a.m.	Katrin Bieger	*Application of SWAT to a Data Scarce Catchment in the Three Gorges Region, China: The Impact of Land Use Change on Sediment and Phosphorus Transport*
9:30 - 9:50 a.m.	Jose María Bodoque	*Sub-hourly Modeling of Sheet Erosion and Sediment Transport using the SWAT Model*
9:50 - 10:10 a.m.	Balaji Narasimhan	*Development and Testing of Improved Physically Based Streambank Erosion and Sediment Routing Routines in SWAT*
10:10 - 10:15 a.m.	*Discussion & Wrap Up*	

8:30 a.m. - 10:15 a.m. **SESSION E3 - HYDROLOGY**
Building 37 - Room 0.10 (Page 57)

Moderator: Taesoo Lee
Texas AgriLife Research, USA

8:30 - 8:50 a.m.	Abdelhamid Fadil	*Hydrologic Modeling of Bouregreg Watershed by SWAT*
8:50 - 9:10 a.m.	Alejandra Stehr	*Using MODIS Imagery to Validate the Spatial Representation of Snow Cover Extent Obtained from SWAT in a Data-scarce Chilean Andean Watershed*
9:10 - 9:30 a.m.	Aouissi Jalel	*Assessment of SWAT Potential Evapotranspiration Options and Data-dependence for Estimating Actual Evapotranspiration and Streamflow*
9:30 - 9:50 a.m.	Gholamreza Rahbar	*The Effects of Floodwater Spreading on Soil Infiltration Rate in Kowsar Aquifer Management Station*
9:50 - 10:10 a.m.	Il-Moon Chung	*Integrated Surface-Groundwater Analysis on Groundwater Dam Effect in Ssangcheon Watershed in South Korea*
10:10 - 10:15 a.m.	*Discussion & Wrap Up*	



Thursday, June 16, 2011

10:15 a.m. - 10:35 a.m. **BREAK**
Building 37 - Restaurant

10:35 a.m. - 12 p.m. **SESSION F1 - MODEL DEVELOPMENT**
Building 37 - Room 0.08 (Page 62)

Moderator: Karim Abbaspour
EAWAG, Switzerland

10:35 - 10:55 a.m.	Ann van Griensven	*A New 'Floodland' Module in the SWAT Codes for the Simulation of Periodically Wet Areas*
10:55 - 11:15 a.m.	Jichul Ryu	*Development of Fully Integrated System for SWAT and REMM Model*
11:15 - 11:35 a.m.	Pedro Chambel Leitão	*Evapotranspiration Forecast using SWAT Model and Weather Forecast Model*
11:35 - 11:55 a.m.	Linh Hoang Ann van Griensven*	*Adaptation to the Sub-Surface Processes in the Soil and Water Assessment Tool*
11:55 - 12:00 p.m.	*Discussion & Wrap Up*	

10:35 a.m. - 12 p.m. **SESSION F2 - INTERNATIONAL SWAT APPLICATIONS REVIEW**
Building 37 - Room 0.09 (Page 66)

Moderator: Philip W. Gassman
Iowa State University, USA

10:35 - 10:55 a.m.	Luis Hamilton Pospissil Garbossa	*The Use and Results of the Soil and Water Assessment Tool in Brazil: A Review from 1999 until 2010*
10:55 - 11:15 a.m.	Marwa Ali	*Application of SWAT Model in Land-Use Change in the Nile River Basin: A Review*
11:15 - 11:35 a.m.	Preksedis Marco Ndomba Ann van Griensven*	*Current Application Trends and Data Challenges Regarding the Use of the Soil and Water Assessment Tool (SWAT) in Africa*
11:35 - 11:55 a.m.	Philip W. Gassman	*The Worldwide Use of the SWAT Model: Technological Drivers, Networking Impacts, Simulation Trends, and Potential Future Constraints*
11:55 - 12:00 p.m.	*Discussion & Wrap Up*	

10:35 a.m. - 12 p.m. **SESSION F3 - URBAN PROCESSES & MANAGEMENT**
Building 37 - Room 0.10 (Page 70)

Moderator: Jaehak Jeong
Texas AgriLife Research, USA

10:35 - 10:55 a.m.	Roger Glick	*Calibration of a Sub-Daily SWAT Model and Validation using Different Land Use Data to Examine the Impacts of Land Use Changes*
10:55 - 11:15 a.m.	Roger Glick	*Applying the Sub-Daily SWAT Model to Assess Erosion Potential under Different Development Scenarios in the Austin, Texas Area*
11:15 - 11:35 a.m.	C. Allan Jones	*Use of SWAT by International Engineering Firms*
11:35 - 11:55 a.m.	Roger Glick	*Applying the Sub-Daily SWAT Model to Assess Aquatic Life Potential under Different Development Scenarios in Austin, Texas*
11:55 - 12:00 p.m.	*Discussion & Wrap Up*	

Thursday, June 16, 2011

12 p.m. - 1:25 p.m. **SESSION G1 - LARGE SCALE APPLICATIONS**
Building 37 - Room 0.08 (Page 74)

Moderator: Antonio Lo Porto
IRSA-CNR, Italy

12:00 - 12:20 p.m.	Narayanan Kannan	*Evaluating the Effects of Conservation Practices on Water Quality in the Ohio-Tennessee River Basin using a Regional Scale Modeling System*
12:20 - 12:40 p.m.	Mike White	*Rapid National Model Assessments to Support US Conservation Policy Planning*
12:40 - 1:00 p.m.	Xiuying Wang	*Assessing Impacts of Rangeland Conservation Practices prior to Implementation: A Simulation Case Study using APEX*
1:00 - 1:20 p.m.	Narayanan Kannan	*Calibration of SWAT Model for Large-scale Applications*
1:20 - 1:25 p.m.	*Discussion & Wrap Up*	

12 p.m. - 1:25 p.m. **SESSION G2 - BEST MANAGEMENT PRACTICES (BMPS)**
Building 37 - Room 0.09 (Page 78)

Moderator: Darrel Andrews
Tarrant Regional Water District, USA

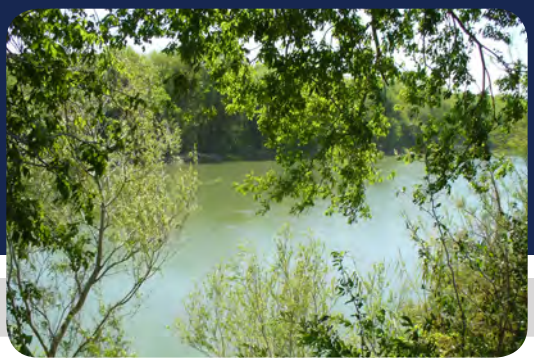
12:00 - 12:20 p.m.	Darrel Andrews	*Utilizing SWAT for Water Supply Planning in Texas*
12:20 - 12:40 p.m.	Taesoo Lee	*Cost Effective Multiple BMPs to Reduce the Total Phosphorous Level in a Reservoir*
12:40 - 1:00 p.m.	Yiannis Panagopoulos	*A Decision Support Tool for a Cost-effective Mitigation of Non-point Source Pollution*
1:00 - 1:20 p.m.	Chung Gil Jung	*SWAT-APEX Modeling of the SRI BMP Scenario Effect in an Agricultural Reservoir Watershed of South Korea*
1:20 - 1:25 p.m.	*Discussion & Wrap Up*	

12 p.m. - 1:25 p.m. **SESSION G3 - SENSITIVITY CALIBRATION & UNCERTAINTY**
Building 37 - Room 0.10 (Page 82)

Moderator: Brett Watson
University of Saskatchewan, Canada

12:00 - 12:20 p.m.	Jiwon Lee	*Analysis of Effects on Validation of Spatiotemporal Changes in Cropping at Agriculture-dominant Watershed*
12:20 - 12:40 p.m.	Maria Ermitas Rial Rivas	*Calibration and Sensitivity Analysis of SWAT for a Small Forested Catchment, North-Central Portugal*
12:40 - 1:00 p.m.	Felix Witing, Martin Volk	*Comparing Different Model Calibration Strategies for Improved Representation of Landscape Conditions in SWAT at the Example of a Large Heterogeneous Catchment*
1:00 - 1:20 p.m.	Shenglan Lu	*Multi-objective Calibration on Flow and Sediment on a Small Danish Catchment*
1:20 - 1:25 p.m.	*Discussion & Wrap Up*	

1:30 p.m. - 3 p.m. **LUNCH**
Building 37 - Restaurant



Thursday, June 16, 2011

3 p.m. - 4 p.m. **POSTER SESSION** (viewing)
Building 37 - Room 0.01 (Page 120)

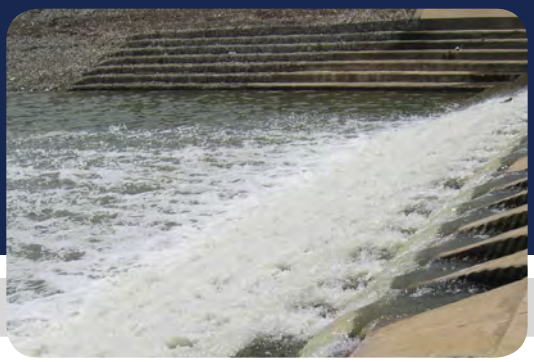
Il-Moon Chung*, Nam-Won Kim, Jitae Kim, Jeongwoo Lee	*Development of Conceptual Model for the Integrated Surface-Groundwater Analysis in Jeju Island*
Ali M. Sadeghi	*The Effect of DEM Resolution on Slope Estimation and Sediment Predictions*
Woo-Yul Jung, Sung-Kee Yang, Jitae Kim*	*Simulation on Runoff of Rivers in Jeju Island using SWAT Model*
Yan Li*, Julian Thompson, Richard Taylor, Hengpeng Li	*Sensitivity Analysis and Calibration of the SWAT Model: Understanding Model Behaviour in Hydrological Studies of the Daning Catchment, China*
Samuel Fournet	*Preliminary Investigation for the Development of a Water Allocation Module in SWIM to Study the Impact of Prospective and Conflicting Irrigation and Water Resources Management Plans in the Inner Niger Delta under Climate Change Conditions*
Julia Tecklenburg	*Investigation of Monsoon Variability and Related Impacts on Hydrological Processes in the Nile Basin under Climate Change Conditions*
Judith Stagl	*Climate Change Impacts on River Flow Regime and Discharge into the Danube Delta including Quantification of Scenario Uncertainty*
Hendrik Rathjens Natascha Oppelt	*Upgrading the Grid-based Discretization Scheme in SWAT*
Luis Jiménez Meneses M. Morales, T. Sanz, M.T. Bellido	*Reduction of the Peak Streamflow as a Result of Vegetation Rehabilitation in the "Yesos of Barrachina" Protected Area*
Jiang Rui	*Modeling the Water Balance Processes for Understanding the Components of River Discharge in a Non-conservative Watershed*
Seyed Zeynalabedin Hosseini	*Estimating Relation Between Vegetation Dynamic and Precipitation in Central Iran*
L. N. Kieu, M.R. Reyes, G. Hoyt, E. Steglich	*Evaluation of the APEX Model for Organic and Conventional Management Under Conservation and Conventional Tillage Systems*
Deniz Özkundakci*, David P. Hamilton, Chris G. McBride	*A Coupled Catchment-lake Model to Simulate Historical, Contemporary and Future Water Quality of a Eutrophic, Polymictic lake*

6 p.m. to 9 p.m. DEPART FOR **CONFERENCE OUTING**
Guided Walking Tour across the historical city

- Please meet at approximately 6 p.m.
to participate in the walking tour
(Please remain in groups of 30 people per each tour-guide)

- Bus will take group to dinner at 9 p.m.

Restaurante Hierbabuena
Callejon San Jose, 17, 45003
Toledo, Spain



Friday, June 17, 2011

9:30 a.m. - 11:15 a.m. **SESSION H1 - SEDIMENT, NUTRIENTS & CARBON**
Building 37 - Room 0.08 (Page 86)
Moderator: Narayanan Kannan
Texas AgriLife Research, USA

9:30 - 9:50 a.m.	María Concepción Ramos	*Runoff and Soil Loss Prediction in a Vineyard Area at Very Detailed Scale using SWAT Model: Comparison Between Dry and Wet Years*
9:50 - 10:10 a.m.	Sanjeev Kumar	*Modelling Nitrogen in Streamflow from Boreal Forest Watersheds in Alberta, Canada using SWAT*
10:10 - 10:30 a.m.	Nadia Bernardi Bonumá	*Integration of a Landscape Sediment Deposition Routine into SWAT Model*
10:30 - 10:50 a.m.	Jim Almendinger	*Use of SWAT to Scale Sediment Delivery from Field to Watershed in an Agricultural Landscape with Topographic Depressions*
10:50 - 11:10 a.m.	Stefan Julich	*Water Quality Modeling in Luxembourgish Watersheds for the Identification and Quantification of Sources for River Water Pollution*
11:10 - 11:15 a.m.	*Discussion & Wrap Up*	

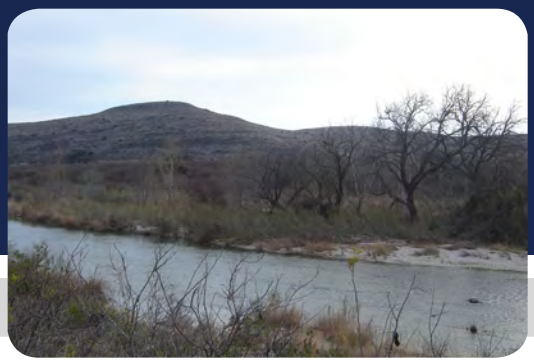
9:30 a.m. - 11:15 a.m. **SESSION H2 - HYDROLOGY**
Building 37 - Room 0.09 (Page 91)
Moderator: Balaji Narasimhan
Indian Institute of Technology, India

9:30 - 9:50 a.m.	Pedro Chambel Leitão	*Modeling Watershed Dynamics in Agricultural/Silvopastoral System of a Semi-arid Zone: Enxoé River in Southeast Portugal*
9:50 - 10:10 a.m.	Fidelis Kilonzo	*Choosing a Potential Evapotranspiration Method in the Absence of Essential Climatic Input Data*
10:10 - 10:30 a.m.	Geun-Ae Park	*Analysis of SWAT Simulated Soil Moisture with the MODIS Land Surface Temperature and Vegetation Index for Soyanggang Dam Watershed of South Korea*
10:30 - 10:50 a.m.	Jaehak Jeong	*Flood Routing for Continuous Simulation Models*
10:50 - 11:10 a.m.	Paul Wagner	*Impacts of Precipitation Interpolation on Hydrologic Modeling in Data Scarce Regions*
11:10 - 11:15 a.m.	*Discussion & Wrap Up*	

9:30 a.m. - 11:25 a.m. **SESSION H3 - LARGE SCALE APPLICATIONS**
Building 37 - Room 0.10 (Page 96)
Moderator: Il-Moon Chung
Korea Institute of Construction Technology, Korea

9:30 - 9:50 a.m.	Eugenio Molina Navarro	*Studying the Viability of a Limno-reservoir using SWAT: The Ompólveda River Basin (Guadalajara, Spain) as a Case of Study*
9:50 - 10:10 a.m.	Pierluigi Cau	*Using SWAT and GETM to Model the Integrated Water Cycle within the BASHYT Environment*
10:10 - 10:30 a.m.	Hua Xie	*Assessing the Application Potentials of Treadle Pump Irrigation Technology in Sub-Saharan Africa*
10:30 - 10:50 a.m.	Dorian Gorgan	*Grid based Hydrological Model Calibration and Execution by SWAT Application*
10:50 - 11:10 a.m.	Tirupati Bolisetti	*Representation of Modeling Errors by AR(1) Process and Uncertainty Analysis of SWAT Model under Bayesian Approach*
11:10 - 11:20 a.m.	Asghar Besalatpour	*Soil Erosion Hazard Prediction using SWAT Model and Fuzzy Logic in a large Watershed*
11:20 - 11:25 a.m.	*Discussion & Wrap Up*	

11:15 a.m. - 11:35 a.m. **BREAK**
Building 37 - Restaurant



Friday, June 17, 2011

11:35 a.m. - 1:20 p.m. **SESSION I1 - DATABASE AND GIS APPLICATION AND DEVELOPMENT**
Building 37 - Room 0.08 (Page 102)

Moderator: Pierluigi Cau
CRS4, Italy

11:35 - 11:55 a.m.	Sudipta K. Mishra	*Understanding Water-Human Interaction through an Intelligent Digital Watershed: Initial Development and Implementation*
11:55 - 12:15 p.m.	A. K. Gosain, Chakresh Sahu	*Geospatial Infrastructure for Water Resources Assessment & Planning*
12:15 - 12:35 p.m.	Dharmendra Saraswat	*SWAT2009_LUC: A Tool to Activate Land Use Change Module in SWAT 2009*
12:35 - 12:55 p.m.	A. K. Gosain, Chakresh Sahu	*SwatCube: An OLAP Approach for Managing Swat Model Results*
12:55 - 1:15 p.m.	Constantino Soru	*A Web Interface to Write the txtinout file for Scenarios Development*
1:15 - 1:20 p.m.	*Discussion & Wrap Up*	

11:35 a.m. - 12:40 p.m. **SESSION I2 - CLIMATE CHANGE APPLICATIONS**
Building 37 - Room 0.09 (Page 107)

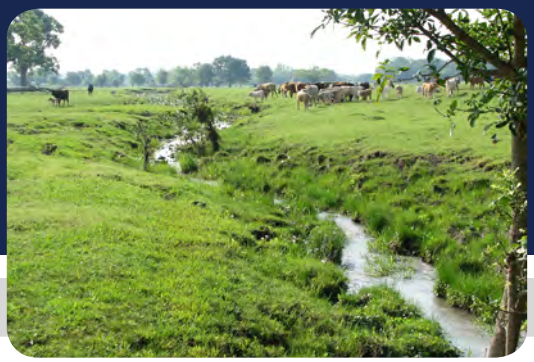
Moderator: Bouchra Haddad
University of Castilla La Mancha, Spain

11:35 - 11:55 a.m.	Imtiaz Bashir	*Evaluation of Climate Change Impacts on the Blue Nile flows using SWAT*
11:55 - 12:15 p.m.	Jong-Yoon Park	*Assessment of Future Climate Change Impacts on Stream and Lake Water Quality using SWAT and WASP model*
12:15 - 12:35 p.m.	Brett Watson	*Comparison of Temperature-Index Snowmelt Models of Varying Complexity in SWAT for Predicting Water Yield in a Cold Region*
12:35 - 12:40 p.m.	*Discussion & Wrap Up*	

11:35 a.m. - 1:20 p.m. **SESSION I3 - ENVIRONMENTAL APPLICATIONS**
Building 37 - Room 0.10 (Page 110)

Moderator: Mike White
USDA - Agricultural Research Service, USA

11:35 - 11:55 a.m.	Aloyce S. Hepelwa	*Economic Valuation and Hydrologic Analysis in View of Sustainable Watershed Management: The Case of Sigi Catchment in Tanzania*
11:55 - 12:15 p.m.	Cristina Yacoub López	*Assessing Hydrologic Impact of Anthropogenic Activities Located at the Upper Part of Jequetepeque River Basin, Peru*
12:15 - 12:35 p.m.	Mojgan Azimi	*Application of SWAT to Model Rangeland Production Dominated by Sagebrush (Artemisia sieberi) in Hable-Rud Basin, Iran*
12:35 - 12:55 p.m.	Sabine Sauvage	*Modelling the Nitrate Dynamics and the Role of Buffer Zones in a Major European Catchment, the Garonne River, in Southwest France*
12:55 - 1:15 p.m.	Rebecca Boger	*Community Based Watershed Modeling in Nigeria*
1:15 - 1:20 p.m.	*Discussion & Wrap Up*	



Friday, June 17, 2011

11:35 a.m. - 1:20 p.m. **SESSION I4 - HYDROLOGY**
Building 37 - Room 0.01 (Page 115)

Moderator: Daniel Moriasi
USDA - Agricultural Research Service, USA

11:35 - 11:55 a.m.	Hyung Jin Shin	*Evaluation of Snowmelt Contribution to Streamflow in a Heavy Snowfall Watershed of South Korea using SWAT Model*
11:55 - 12:15 p.m.	Kazi Rahman	*Runoff Simulation in a Glacier Dominated Watershed of Rhone River using Semi Distributed Hydrological Model*
12:15 - 12:35 p.m.	Philip W. Gassman	*Development of SWAT Hydrologic Input Parameter Guidelines for Specific Iowa Landform Regions for TMDL Analyses and Other Water Quality Assessments*
12:35 - 12:55 p.m.	Maria Luz Rodríguez-Blanco	*Simulation of Stream Discharge from an Agroforestry Catchment in NW Spain using SWAT Model*
12:55 - 1:15 p.m.	Rajesh Nune	*An Assessment of Climatic and Anthropogenic Impacts on a Hydrological System*
1:15 - 1:20 p.m.	*Discussion & Wrap Up*	

1:30 p.m. - 3 p.m. **LUNCH**
Building 37 - Restaurant

3 p.m. - 4:30 p.m. **CLOSING SESSION**
OPEN FORUM FOR SWAT DISCUSSION
Building 37 - Room 0.01

Soil & Water Assessment Tool | SWAT

Water Resources Status in Danube River Basin

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The core environmental problem of the Danube River Basin can be described as ―ecologically unsustainable development and inadequate water resources management" (PCU 1999). The problems are caused by different factors, such as: inadequate management of wastewater/solid waste, ecological unsustainable industrial activities, and inadequate land management and improper agricultural practices.

The Danube Basin with the drainage area of around 801,000 km^2 and 83 million inhabitants, covering parts of 19 European countries, is the major freshwater contributor to the Black Sea. The aim of the modeling approach developed for the Danube River, is to establish a hydrological model of the catchment, rather than individual countries, to obtain accurate knowledge of water availability for water resources management at regional or national level.

In this study we used the program Soil and Water Assessment Tool (SWAT) to develop a hydrologic model of Danube River Basin based on river discharges and crop yield. On the basis of available observation discharge and yield data for the region, the Sequential Uncertainty Fitting program (SUFI-2) was used to calibrate and validate the hydrological model. The results were quite satisfactory for most of the rivers across the region. A reasonable agreement was found between the model simulations and the observations.

Using the calibrated hydrological model, we quantified all water balance component in the basin such as precipitation, evapotranspiration, runoff, infiltration, deep aquifer recharge, and return flow. Based on these, measures closer to water resources concepts such as blue water (water yield plus deep aquifer recharge) green water flow (actual and potential evapotranspiration) and green water storage (soil moisture) at sub-basin level with monthly time-steps were obtained.

The results of this project will provide useful information of current and future status of water in Danube River Basin to support decision makers to meet the challenges posed by water scarcity and climate change across the region as well as regional policies.

The resulting tools and data will allow for the analysis of river basin pressures and their impacts on human and ecosystem well-being by local stakeholders and decision makers. These efforts will also help to identify and provide early warning to vulnerable populations and identify the efforts needed to adapt and to limit negative social, economic and environmental impacts in the future.

Keywords: Large-scale hydrological modeling, SWAT, SWAT-CUP, Uncertainty analysis, Green water, Blue water.

Estimating Ecosystem Service Provision for Future Management and Climate Change Scenarios for the Pangani Basin, East Africa

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The SWAT model is used to estimate ecosystem service provision for future management and climate change scenarios for the East African Pangani Basin. The study starts from the assumption that an ecosystem service is a valued and accessible output from an ecosystem, which makes the explicit consideration of stakeholder preferences, as well as modeling at fine spatial detail, a necessity. A slightly modified version of SWAT2005, SWAT-P, has been calibrated for Pangani Basin using the SUFI-2 algorithm. Information on stakeholder preferences is used to derive indicators of ecosystem service provision from model outputs. The main focus is on the services of water provision for different uses and water regulation, but associated land-based ecosystem services are also considered. Three management and three climate change scenarios are evaluated. The first management scenario gives priority to agriculture, the second to hydropower generation, and the third aims at balancing requirements. Two of the climate change scenarios represent the extremes of available IPCC predictions (i.e. the driest and wettest conditions predicted), while the third assumes no climate change. The results show that not the physical availability of water, but access to water resources and efficiency of use represent the greatest challenges. Current levels of service provision in the water sector can be maintained or even improved with appropriate management. However, the decline in services from natural terrestrial ecosystems (e.g. charcoal, food), due to the expansion of agriculture, increases the vulnerability of residents who depend on such services mostly in times of drought.

Modelling Nutrient Loading of Danish Marine Waters

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The MAFIA alliance (http://www.mafia-alliance.org/) is an interdisciplinary consortium designed to establish a body of knowledge, which can provide a common ecosystem-based decision platform. Based on a series of integrated models, MAFIA aims to develop decision support tools and scenarios that describe the interplay between science and management of agriculture, fisheries, aquatic environments and welfare economics, with principal focus on the Danish marine waters within the Baltic Sea. SWAT has been chosen as a tool to model riverine water and nutrient loads from the drainage basin (121,000 km2 covering most of Denmark and parts of Germany and Sweden) to the sea. High intensive agriculture plays an important role in the drainage basin with 62% of the Danish land area being cultivated. Parameterization of the SWAT model is performed on a very detailed data set, containing e.g. information at the field and farm level of all Danish farms. Concurrently, modifications to SWAT, with particular focus on phosphorus cycling, will be performed and validated based on these data sets. For computational reasons the drainage basin is divided into seven regions, each with individual SWAT models. Model parameters are initially calibrated in seven data rich mini catchments. Subsequently, the calibrated parameters are transferred to the regional models and model performance is evaluated for regional monitoring stations. Our modeling concept and preliminary results will be demonstrated.

SWAT Modelling at Pan European Scale: the Danube Basin Pilot Study

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A harmonised pan European assessment of water resources availability and quality as affected by various management options is necessary for a successful implementation of European environmental legislation. In this context we developed a methodology to predict surface water flow and nutrient loads at pan European scale using readily available datasets. Among the hydrological models available, the Soil Water Assessment Tool (SWAT) has been selected because its characteristic that make it suitable for large scale applications with limited data requirements. This paper presents the first hydrologic results for the Danube pilot basin.
The Danube basin is one of the largest European watersheds covering ca. 803,000 km^2 and 14 countries. Modelling data used included pan European land use and management information, a detailed soil map, and high resolution climate data. The Danube basin was divided into 4663 subbasins of an average size of 179 km^2. A protocol is proposed to overcome the problems of hydrological regionalization from gauged to ungauged catchments and the over-parameterization and identifiability problems present in calibration. The protocol involves cluster analysis for the determination of hydrological regions, sensitivity analysis at subbasin level and multi-objective calibration using SUFI-2 automated calibration of SWAT-CUP.
The proposed protocol was successfully implemented and the modelled discharges captured well the overall hydrologic behaviour of the basin.

Keywords: Large-scale application, SWAT, hydrologic regionalization, sensitivity analysis

Impact of the Ratio Between Subbasins and Climate Stations on the Performance of SWAT in the Rhine Basin

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Climate data is perhaps the most important driving input data in watershed models. As there are often a limited number of observed stations, the watershed models suffer from a chronically large uncertainty with respect to climate data. This uncertainty has profound impact on model calibration of parameters, leading to wrong parameters, and hence, wrong process identification. In this paper, we used the CRU‘s 0.5-degree gridded climate data to test the ratio of the number of climate stations to the number of subbasins. As SWAT only uses one climate station per subbasin, the spatial extend of subbasins may have a significant impact on model performance. The results of this study show that on the local scale, the heterogeneity in precipitation may lead to a substantial difference in runoff. Further downstream, this influence becomes less pronounced. We conclude that the ratio of the number of climate stations to subbasins should ideally be close to one, implying that the subbasin area should be of the same magnitude as the climate station grid size.

Keywords: SWAT, large scale application, Europe, hydrological modeling, climate dataset, delineation threshold

Changing Land Management Practices during Model Calibration and Evaluation Periods – Importance, Impact and Interpretation

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Environmental programs such as the Clean Water Act in the US or the European Water Framework Directive (WFD) were implemented to achieve good ecological and chemical conditions of water quality of groundwater and surface water bodies. Main nutrient input comes from nonpoint source pollution, mainly forced by intensive agricultural activities. Therefore, alternative land management practices are increasingly used as environmental measures to reduce nonpoint source pollution. Simulation models such as SWAT are powerful tools and can be used to evaluate the impact of such environmental measures on water quantity and quality at the watershed scale. However, several problems still exist when using models for spatially explicit simulation and prediction of the environmental impact of land management practices. Beside difficulties of getting an appropriate land management and water quality data base for an accurate calibration and evaluation of the applied model, other problems that still exist are:

i) to implement and estimate changes of management practices within the calibration and validation process,
ii) the regionalisation of management practices

Where i) is especially important when simulating the impact of sudden large-area changes of land management such as for instance the increased cultivation of bioenergy plants, which occurs oftentimes at the cost of conservation and other management practices. The second point is of general importance. To investigate these issues, we used SWAT in the intensively used loess-dominated Parthe watershed (315 km²) in Central Germany. Hence, the overall goal of our study is to investigate the influence of implementation of management practice (spatially and timely) on model calibration and model evaluation. Some of our former analyses have already shown that the model is very sensitive to applied crop rotations and in some cases even to small variations of tillage practices. We will present our i) study results on how different (input-data dependent) adjustments of management scenarios affect model output parameters and give recommendations how deal with the resulted value ranges and ii) suggest methods for regionlisation of management practices.

Using Precipitation Data Ensemble and Bayesian Model Averaging for Uncertainty Analysis in Hydrologic Modeling

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Precipitation pattern in the tropics are characterized by extremely high spatial and temporal variability that are difficult to cover by rain gauge networks. Since precipitation represents the most important input to hydrological models, this amplifies model uncertainties especially in areas with sparse rain gauge networks. In order to investigate the influence of precipitation uncertainty on model parameter and prediction uncertainty in a data sparse region, the integrated river basin model SWAT was calibrated against measured streamflow of the Pipiripau River in Central Brazil. This was done based on an ensemble of different reasonable precipitation data, i.e. (1) measured data of the only available rain gauge within the watershed, (2) a smoothed version of these data derived by the sliding mean, (3) Thiessen Polygons including rain gauges outside the watershed, and (4) Tropical Rainfall Measuring Mission (TRMM) radar data. For each precipitation input model, we determined the best parameter setting and respective uncertainty ranges using the Sequential Uncertainty Fitting Procedure (SUFI-2). With each rainfall input model, it was possible to achieve good or at least satisfactory streamflow simulations. However, the results of our study clearly illustrate that parameter uncertainty increases strongly by using different methods for precipitation dataset generation. Moreover, we obtained improved deterministic streamflow predictions and more reliable probabilistic forecasts by means of simple ensemble-based methods, such as the arithmetic ensemble mean, and more advanced Bayesian Model Averaging (BMA) schemes. The study shows that ensemble modeling with multiple precipitation inputs can significantly increase the level of confidence in the simulation results especially in data-poor regions but also for hydrologic modeling in general.

SWAT-CUP New Features: Parallel processing, Parameterization, Outlet Visualization

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High-resolution distributed hydrological models are being used more and more for identification of the best management practices and other managerial decision making. Hence, it is important that these models are properly calibrated. Some of the challenges in the calibration of large-scale distributed models are: time constraint, parameterization, and correct positioning of the observed outlets. In this paper we discuss the new features in SWAT-CUP, which deals with these issues. As the calibration process may take too long, faster methods are required to maintain proper calibration, validation, and uncertainty analysis. In recent years, the use of grid and cloud computing has become more and more popular. But the use of these systems is not possible for all users and involves much administrative tasks not to mention financial expenses. To address this limitation, we have developed a parallel processing scheme and included it in the SWAT-CUP software. The scheme utilizes maximum capacity of the existing systems and substantially speeds up the calibration process. With a modest financial investment, a system could be build with a large number of processors and RAM, which will make possible running large jobs in an affordable time. Parameterization is perhaps the most important, the most difficult and the most neglected task in model calibration. In SWAT-CUP we provide a detailed scheme that can parameterize a system based on basic physical properties such as soil, landuse, hydrologic unit, slope, and subbasin location. Positioning observed outlets is another important step in SWAT calibration. Wrong positioning provides the analyst with a calibration-nightmare-scenario. Using Microsoft's BING map, a user can now visualize the location of observed outlets to verify their positions as well as get an idea of the surrounding region for better model parameterization.

Keywords: Parallel processing, SWAT-CUP, Parameterization, Outlet visualization, SUFI-2

Evaluation of SWAT Auto-calibration using Diverse Efficiency Criteria

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The appraisals of hydrology model behavior for flow and water quality are generally performed through comparison of simulated and observed data. To perform appraisal of hydrology model, some criteria are often used, such as coefficient of determination (R^2), Nash and Sutcliffe model efficiency coefficient (NSE), index of agreement (*d*), modified forms of NSE and *d*, and relative efficiency criteria NS and *d*. These criteria are used not only for hydrology model estimations also for various comparisons of two data sets; This NSE has been often used for SWAT calibration. However, it has been known that the NS value has some limitations in evaluating hydrology at watersheds under the monsoon climate because this sciatic is largely affected by higher values in the data set. To overcome these limitations, the SWAT auto-calibration module was enhanced with K-means clustering and direct runoff/baseflow modules. However the NSE is still being used in this module to evaluate model performance. Therefore, the SWAT Auto-calibration module was modified to incorporate alternative efficiency criteria into the SWAT K-means/direct runoff-baseflow auto-calibration module. It is expected that this enhanced SWAT auto-calibration module will provide better calibration capability of SWAT model for all flow regime.

The Uncertainty Analysis of SWAT Simulated Stream Flow and Water Quality Applied to Chungju Dam Watershed of South Korea

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SWAT (Soil and Water Assessment Tool) model is a physically-based continuous-time, conceptual, long-term, distributed-parameter model designed to predict of land management practices on the hydrology, sediment and contaminant transport in agricultural district. For this reason, SWAT is increasingly being used to support decisions about alternative water management policies in the areas of land use change, climate change, water rearrangement, and pollution control. To fulfill this applicability of model, it is important that this model passes through a careful calibration and uncertainty analysis. In recent years, many researchers have come up with various uncertainty analysis techniques for watershed models. To determine the differences and similarities of these techniques, we applied three uncertainty analysis procedures to Chungju Dam watershed (6,581.1 km2) of South Korea included in Soil and Water Assessment Tool - Calibration Uncertainty Program (SWAT-CUP): Sequential Uncertainty FItting algorithm (SUFI-2), Generalized Likelihood Uncertainty Estimation (GLUE), Parameter Solution (ParaSol). As a result, there was no significant difference in the objective function values between SUFI-2 and GLUE algorithms. However, ParaSol algorithm shows the worst objective functions, and considerable divergence was also showed in 95PPU bands with each other. The p-factor and r-factor appeared from 0.02 to 0.79 and 0.03 to 0.52 differences in streamflow respectively. The p-factor and r-factor appeared from 0.07 to 0.67 and 0.15 to 2.73 differences in water quality respectively. In general, the ParaSol algorithm showed the lowest p-factor and r-factor, SUFI-2 algorithm was the highest in the p-factor and r-factor. Therefore, in the SWAT model calibration and uncertainty analysis of the automatic methods, we suggest the calibration methods considering p-factors and r-factors.

Keywords: Uncertainty analysis, SWAT-CUP, p-factor, r-factor, GLUE, SUFI-2, ParaSol, 95PPU

Field Scale Modeling to Estimate the Reduction in Phosphorus and Sediment using a Simplified GUI for SWAT

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Streams throughout the North Canadian River watershed in northwest Oklahoma, USA, have elevated levels of nutrients and sediment. SWAT (Soil and Water Assessment Tool) was used to identify areas that likely contributed to disproportionate amounts of phosphorus and sediment to Lake Overholser at the watershed outlet. These sites were then targeted by the Oklahoma Conservation Commission to implement conservation practices, such as no-till, pasture planting, and riparian exclusion and buffers on 250 fields. The objective of this project was to evaluate conservation practice effectiveness using TBET, a simplified user interface for SWAT developed for field scale application. TBET was applied at each field before and after conservation practice implementation to estimate the phosphorus and sediment load reductions. The percent reduction in sediment and phosphorus load from each field site was calculated as well as the cost for conservation practice implementation per kg of phosphorus and sediment reduction. TBET will also be used to illustrate its potential to develop pollutant load reduction based cost-share rates for water quality programs.

Effect of Best Management Practices on Water Quality in a Lowland Catchment

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The pollution of rivers and streams has become one of the most crucial environmental problems in many countries. The assessment of spatial and temporal variations of water quality influenced by point and diffuse source pollution is necessary to manage the environment sustainably at watershed scale. The objective of this study was to evaluate the temporal and spatial variations of water quality in a lowland catchment before and after implementation of best management practices (BMPs) using SWAT.

The study area Kielstau catchment (50 km²) is located in Northern Germany and represents a rural environment. The water quality of the catchment is not only influenced by diffuse sources from agricultural areas but also by point sources from municipal wastewater treatment plants. Diffuse as well as punctual entries are implemented in the model set-up. Calibration and validation of the model were carried out in a daily time step for flow and nutrients (N, P). The model results revealed that the SWAT model performed satisfactorily in simulating daily flow and nutrient load. The spatial distribution of nutrient load showed the subbasins with the highest concentrations and was used to identify the crucial pollution areas. This knowledge was used to implement BMPs into the model simulating distinct management practices to improve water quality effectively. These implementations cover on the one hand reduction in waste water loads and on the other hand specific measures concerning agriculture, both derived by the critical pollution areas. The results indicated that the implementation of BMPs in the Kielstau watershed would result in a significant reduction of nutrient load. Therefore, it can help decision makers to find appropriate measures aiming at improving water quality in the watershed.

Simulated Mitigation Measurements to Reduced Nitrate in Surface Water using SWAT Hydrological Modelling in an Agricultural Watershed, Southwest France

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Agriculture is known to have a great impact of nutrient enrichment on continental water resources. In South-West of France, water resources are essentially surface water and shallow aquifer. Nitrogen dynamic in river is complex and highly variable throughout season and year, depending on hydrology, land use, removal in stream. In this context, agricultural impacts on nitrogen concentration are a matter of concern for agricultural decision-maker.

In order to introduce sustainable land use concepts in this hilly, clayey and agricultural shallow soil context, the hydrological simulation model SWAT2005 has been tested as a valuable tool to evaluate the consequences of such land use changes on water and nutrient balance components. The model is able to simulate the impact of each agricultural land use at the outlet of the Gers river catchment (500 km²).

Nitrogen losses have been measured during 10 years (1996-2005) at the outlet by the French Water Agency Adour-Garonne and are used to validate the model calibration. Agricultural data at communal scale coupled with Spot image analyses have been used to evaluate agricultural distribution and pressure in SWAT. The aim of this modelling exercise is to simulate nitrogen load in surface water depending on plant growth, culture rotation and management practices. The ability of SWAT to reproduce nitrogen transfer and transformation at this scale and in this agricultural context will be evaluated by a discussion of importance of each nitrogen cycle process in nitrogen losses in surface water. Finally, SWAT was used to test 53 scenarios based on new agricultural management practices to decrease the nitrogen concentration in river. The best scenario shows a reduction of 30% of nitrate concentration in river water.

Application of BMPs Design for Inshore Alluvial Plain River System in North Jiangsu, China

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Best management practices (BMPs) are routinely used to reduce nonpoint-source pollution resulting from agricultural activities and improve water quality. Models are useful tools to investigate effects of such management practice alternatives on the watershed level. 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 BMPs 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 ($0.62<R^2<0.99$, $0.34<NS<0.96$). 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 phosphorus load is positive correlation to the fertilizer rates in three different land use types. Soluble P is the most sensitive nutrient in the three forms of P nutrients. In three land use, paddy field presented great P reduction response. Arid land and orchard were moderate response.

Keywords: SWAT, manually designed watersheds, spatial distribution, BMPs

The Impact of Land Management on Drinking Water Quality: A Water Industry Application, East of England

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In 2007, following the development of improved techniques for detecting low levels of trace substances in water, the concern for pesticides in drinking water across England increased. Metaldehyde and clopyralid are currently of highest concern as they have been detected in drinking water across the region, at levels exceeding the European drinking water standard of 0.1 µg/l. As these are difficult and costly to treat, Anglian Water Services is assessing the effectiveness of using catchment management measures as an alternative to treatment options. Such measures could bring significant long-term benefits in the form of improved raw water quality and corresponding reduction in capital and operational expenditure, carbon emissions and improved biodiversity.

The Soil and Water Assessment Tool (SWAT) is being applied to surface water catchments to assess changes in water quality in a raw water storage reservoir under various land use scenarios. The chosen study area is located in the East of England, in an area dominated by agricultural activities. Approximately half of the reservoir water derives from natural streams, while the remaining half is pumped from an adjacent catchment. Both catchments are dominated by clay soils with a high shrink-swell potential. Thus, bypass flow to the underlying tile drainage system is likely to be an important pathway for pesticides found in the reservoir.

The models were successfully calibrated for hydrology and pesticide concentrations in the river and streams feeding into the reservoir. For the reservoir itself, however, the model slightly underestimated metaldehyde concentrations and was not able to replicate the peaks. This is a result of the way reservoirs and streams are modelled in the SWAT model, where a single well-mixed water body is assumed.

Keywords: SWAT, catchment management, river basin management, pesticide, diffuse pollution, drinking water quality, land use

How to Integrate Wetland Processes in River Basin Modeling? A West African Case Study

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Wetlands are oftentimes not adequately considered or integrated in river basin management - neither in an institutional nor in a technical way. This study is concerned with the latter aspect and provides a technical solution to integrate wetland inundation and release processes in the eco-hydrological model SWIM.
The case study area, the Inner Niger Delta, is situated in an arid region in West Africa within the Upper Niger Basin. The wetland is characterized by a strong seasonality of the flow regime. Large parts of the floodplains are inundated during the rainy season, covering an area between 10,000 and 30,000 km2. Increased infiltration and evaporation from the additional water surface cause losses of approximately 40% of the inflowing water volume.

The developed inundation module accounts for these processes in the wetland. The water volume exceeding the carrying capacity of the channel is diverted to subbasin inundation storages and water traps (ponds). Water is allowed to be released from inundation storages back to the channel, but not from ponds. Hydrological response units, affected by inundation, switch between land and lake status with consequences for the calculation of evapotranspiration, infiltration, and vegetation processes. The implementation of these processes is inevitable and a necessary prerequisite to perform impact studies on climate change and water resources management.

Development and Application of a Hydroclimatological Stream Temperature Model within SWAT

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We develop a stream temperature model within the Soil and Water Assessment Tool (SWAT) that reflects the combined influence of meteorological (air temperature) and hydrological conditions (streamflow, snowmelt, groundwater, surface runoff, and lateral soil flow) on water temperature within a watershed. SWAT currently uses a linear air-stream temperature relationship to determine stream temperature, without consideration of watershed hydrology. As SWAT uses stream temperature to model various in-stream biological and water quality processes, an improvement of the stream temperature model will result in improved accuracy in modeling these processes. The new stream temperature model is tested on 7 coastal and mountainous streams throughout the Western United States for which high quality flow and water temperature data were available. The new routine does not require input data beyond that already supplied to the model, can be calibrated with a limited number of calibration parameters and achieves improved representation of observed daily stream temperature. For the watersheds modeled, the Nash Sutcliffe (NS) coefficient and root mean square error (RMSE) for the new stream temperature model averaged 0.81 and 1.76 °C, respectively, for the calibration period and 0.82 and 1.73°C for the validation period. The original SWAT stream temperature model averaged a NS of -0.27 and RMSE of 3.79 °C for the calibration period and a NS of -0.26 and RMSE of 3.82 °C for the validation period.

Keywords: stream temperature, SWAT, model, aquatic ecosystems

Soil Temperature Damping Depth in Boreal Plain Forest Stands and Clear Cuts: Comparison of Measured Depths versus Predicted based upon SWAT Algorithms

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The Forest Watershed and Riparian Disturbance (FORWARD) Project operates within the Boreal Plain ecozone in Western Canada. One focus of the study has been to adapt the SWAT model for streamflow prediction in forested watersheds of the Boreal Plain and to use the model to assist forestry companies with landscape management decisions. FORWARD has collected data on soil temperature and water content since 2005. Continuous measurements have been conducted at multiple sites representing five different characteristic soil and vegetation cover types within the ecozone, and at sites harvested via clear cut operations. Each site was automated to record daily air temperature at 0 and 2 m, and soil temperature and water content at depths ranging from 0.1 to 3 m.

Soil temperature predictions within SWAT play an important role in the redistribution of water since no flow of water can occur to or from a given soil layer if the temperature of that layer is 0ºC or below. Hence soil temperature has a strong influence upon streamflow simulation. A key factor for the prediction of daily soil temperature within SWAT is the estimation of the damping depth of the soil profile. The damping depth is estimated as a function of soil bulk density, moisture content and maximum damping depth.

The results of the soil temperature and soil moisture measurements at sites representing deciduous forest, conifer forest and clear cuts are presented in this paper and analyzed to determine a range of typical damping depths. The analysis results are compared to estimates using the SWAT model predictor equations. The results indicate damping depth is significantly underestimated for conditions on the Canadian Boreal Plain. A simple modification to the maximum damping depth equation is proposed to improve the soil temperature simulation for boreal forest sites.

Keywords: soil temperature, damping depth, SWAT model, boreal forest

Challenges and Difficulties in Sediment Modeling Applied to Sedimentation Study of the Lobo Reservoir in Brazil

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The Lobo reservoir is located at the Alto Jacaré-Guaçu, a 227,7 km² wide watershed in the state of São Paulo. The main tributaries that feed the 2,21MW hydro power dam constructed in 1936 are Itaqueri River, Lobo stream and Feijão stream. A new legislation enacted by both the Brazilian Water Agency (ANA) and the Brazilian Electric Energy Agency (ANEEL) in 2010 obliges the monitoring of sedimentation inside these reservoirs. Although São Paulo is the richest state in Brazil and despite of many researches performed in this region of the state, there is lack of sedimentological data, all data available are seasonal and no continuous data series can be found. Moreover, some parameters used by SWAT simulations are not suitable for Brazilian soils conditions e.g.: SCS soil classifications and runoff factors for the SCS-CN function. The model database which contains default information of types of crops and land use cover are equally unsuitable for the region, since the agricultural management practices adopted in the region are different from those observed in temperate countries. It is observed a general lack of any kind of studies in these fields. The present study seeks to highlight and suggest further studies to advance the development of the SWAT model in Brazil.

Keywords: Tropical Agriculture, Runoff, Sediment Modeling, reservoir sedimentation.

Using Measurement Data on Water and Matter Fluxes in Small Homogeneous Mountainous Catchments for HRU-Parameterization in SWAT

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Securing water resources has become increasingly important as changing climatic conditions are anticipated to affect both water quality and quantity. This is particularly important in regions where the supply of drinking water is allocated by large reservoirs. Modeling of discharge and streamflow nutrient concentration on the catchment scale is an important tool to predict changes in water quality and quantity. However, these modeling efforts are often hindered by a lack of knowledge about the parameterization of different land-use types. Within the catchment of the drinking water reservoir Lehnmühle (Ore Mountains/Germany) a discharge dependent monitoring program has been established. This monitoring program gathers information regarding the contribution of diffuse nutrient and pollutant sources for the catchment‘s three main land-use types (cropland, forest and grassland) and for the catchment as a whole. The monitoring program includes continuous discharge measurements in three small sub-basins with homogenous land use, and weekly water samplings which are analyzed for four main quality parameters: nitrate-nitrogen (NO_3-N), ortho-phosphate-phosphorus (PO_4-P), total phosphorus (TP), and dissolved organic carbon (DOC). The measured data show clear differences in NO_3-N, PO_4-P and DOC exports with streamflow between the land-use types. The highest NO_3-N and PO_4-P inputs occur from the agriculturally used sites while high DOC concentrations seem to originate from organic-rich wet forest sites, moors, and unidentified point sources. The bio-geochemical measurement program was set up to gather important data which is needed for process-based parameterization of the SWAT-model. Hence, the model is used to analyze the input of diffuse sources into the streams under current climatic conditions and to predict the impact of future climate and land use and management change to the matter input into streams.

Keywords: water quality, forest simulation, climate change, bio-geochemical measurements, different land-use types, nutrient pollution, reservoirs

Cost-effectiveness Analysis for Controlling Water Pollution by Pesticides using SWAT and Bio-economical Modeling

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The EU Water Framework Directive requires policy to address non-point source pollution as part of an overall integrated strategy to improve the ecological and chemical status of water bodies. Farmers and tax payers would benefit from more cost-effective control measures adequately implemented within watersheds. With this objective, we propose a framework for a spatially-distributed cost-effectiveness analysis of some mitigation measures (buffer strips, longer rotations, mechanical weeding and catch crops) included in agri-environmental programmes of rural development plans. We used the SWAT model to assess the effectiveness of the applied measures and we developed an aggregated bio-economic model using GAMS to evaluate the costs of implementation identifying synergies and trade-offs. Finally, we proposed a ranking of these measures based on their cost-effectiveness ratios and, for each measure, a map of cost-effectiveness ratios by sub basin within the watershed.

This approach is applied on the upper stream part of the Gers river basin in the South Western part of France. The findings clearly demonstrated that some measures like grass strips and mechanical weeding could be considered as the most cost-effective measures allowing reduction in pesticides concentration up to 65%. Other measures, such as longer rotation sequences and catch crops, although they appeared less costly to implement, fall short in reducing pollution by pesticides with much higher cost-effective ratios.

Possibilities and problems for integrating SWAT model with bio-economic modeling with spatial and temporal scale issues are discussed along with the use of this integrated framework as communication tools in participatory river basin management.

Keywords: Cost-Effectiveness analysis, SWAT, Bio-economic modeling, Pesticides, Mitigation measures

Assessing the Pollutant Transport with SWAT Model in an Agricultural Watershed Dominated by an Alluvial Aquifer

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In Alegria watershed, an important alluvial aquifer presents a significant rule within the agricultural contamination (including nitrates and pesticides). Pollutants are transported from the soil to the river through this alluvial aquifer or directly by runoff during flood events. This study – included in the AguaFlash (http://www.aguaflash-sudoe.eu/) European project – aims to understand contaminant load dynamics and the contribution of the alluvial aquifer and runoff to river contamination.

The SWAT model (2009 version) has been applied from October 2009 to March 2011 in Alegria agricultural watershed located in Basque Country. The alluvial aquifer represents 50% of the watershed and is located in a vulnerable zone to nitrates pollution. Water quality measurements at daily time-step have been used to assess fluxes and nitrates, suspended sediments and pesticides transport. During low flow and flood events, simulated concentrations have been compared to data collected at the watershed outlet.

Keywords: Nitrates, pesticides, flood, SWAT, modeling, Alegria River, agricultural watershed, alluvial aquifer, AguaFlash.

Assessing the Impact of Increased Cultivation of Woody Biomass for Energy Generation Purposes on Water and Matter Balances in Rural Catchments

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Given the increased need for alternative energy sources, the use of woody biomass has experienced a renaissance. Woody biomass is primarily harvested from short rotation plantations, but also from open landscapes and established forests. Thus, in Central Europe both energy companies and municipalities have begun building power plants that use dendromass as an energy carrier. The timber required for these power plants typically comes from the surrounding area and therefore may change the land use composition in these regions remarkably. In Germany the joint research program AgroForNet is investigating the requirements of producers and users of dendromass, and also the risks and regulatory tools for integrated land use planning.

Our research examines how such a vast increase of dendromass in the landscape will affect water and matter balances, and uses the SWAT 2009 model to quantify these effects. Six pilot mesoscale catchments in Germany were chosen to investigate this question. The sites have different water requirements and local soil productivity. Due to higher interception rates and increased rooting of the subsoil, woody species generally result in higher water consumption in comparison to other land-use types, resulting in a net reduction in groundwater recharge. In addition, forests and woodlands are known to impact water quality, typically by improving groundwater and surface water quality. Given these interactions, the soil and water related landscape functions and ecosystem services resulting from an increase in woody biomass needs to be analyzed and assessed. The results of this study will help guide policy formation for targeted regulation with a focus on water, carbon and nutrient balances, with the intent of optimizing land use patterns between multiple competitive demands.

Use of the SWAT model for simulation of short rotation coppice plantations and linear structures (such as roadside vegetation) is recognized as an area where model improvements are needed. Therefore, our paper intends (1) to identify the current limitations of SWAT for these applications and (2) to present and discuss ideas and preliminary approaches for further SWAT model development.

Linking Edge-of-Field Results to Stream Flow and Water Quality: A Comparison Between APEX and SWAT

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Methodologies to link edge-of-field observations to stream loadings need to be developed to integrate what we know of soil and water quality at the field scale to watersheds and river basins. A field scale model that is calibrated to observed flow, soil and water quality, and production data in a field provides a means to estimate the economic and environmental impacts of management practices under varying climate scenarios. A watershed scale model could extend the evaluation of these practices to the flow and water quality of streams, rivers and reservoirs. However, field scale models allow for increased definition of spatial variability and detailed simulation of the processes compared to watershed scale models. As the size of the area grows, there is a need for lumping spatial variations and simplifying algorithms. The APEX and SWAT models are particularly well adapted to this methodology because they belong to the same family of models and have many common input parameters. This study compares calibrated parameter sets and crop production and edge of field model results for a 35-ha field when simulated with APEX on one hand, using multiple sub-areas or one sub-area, and with SWAT on the other hand, as a 1 HRU watershed or as part of the larger 72 km^2 watershed. Discussion on how critical processes are simulated in each model and what impact they have on the results will be included. The results will help identify the model effects and differentiate them from the true scale effects.

SWAT LAI Calibration with Local LAI Measurements

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The leaf area index (LAI) is defined as the area of green leafs per area of land. LAI can be used as indicator of crops conditions, but it can also be used for estimating other parameters like evapotranspiration or biomass. In fact the area of leafs determines the partition between transpiration and evaporation and at the same time determines the amount of intercepted photosynthetically active radiation (which in turn determines biomass). The SWAT model simulates the LAI values, assuming a potential LAI growth that is corrected with stress factors (water, nutrients and temperature). On the beginning stages of plant growth potential LAI depends on temperature and empirical factors of each crop. SWAT has a data base with empirical factors for many crops. LAI estimated with SWAT might not be accurate because of uncertainty of stress factors and in some cases the empirical factors (when one considers different cultivars of a crop). To evaluate the accuracy of SWAT LAI estimations for corn, local measurements were obtained using hemispherical photographs (pictures with 180 degrees of amplitude) from a camera with a fish-eye lens. 260 photographs were taken in three different corn fields in Sorraia Valley throughout the crop campaign from May 2010 to October 2010. To estimate the LAI in each picture it was used the Hemisfer Software. When calibrated with field measurements the SWAT LAI values are close to the measured values and having accurate values of LAI the impact on evapotranspiration and biomass production is positive, making them more realistic and closed with real values in the study area.

Keywords: SWAT model, Leaf Area Index, calibration, evapotranspiration, biomass

Modeling Pesticide Fluxes During Highflow Events in an Intensive Agricultural Catchment: The Save River (Southwestern France) Case Study

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The SWAT model was tested at a daily time step to assess the fate of pesticides of a wide range of solubility. SWAT was applied on an 1100km² intensive agricultural catchment (Save river, southwestern France). Simulated pesticide concentrations were compared to data collected at the catchment outlet from July 2009 to June 2010, with weekly measurements during low flow and daily or sub-daily measurements during flood events.

SWAT was able to accurately reproduce measured pesticides concentrations during base flow and flood events, especially concentrations of pesticide in the soluble phase. During the simulation period, simulated preferred pathway for pesticide transport from land area to stream network was surface runoff. Flood events were responsible for most pesticide transfer. The SWAT model hindcasted daily pesticide concentrations back to 1998 and possible water quality policy thresholds exceeding depending on climate.

Keywords: Discharge, Pesticides, Flood, SWAT, Modelling, Save river, agricultural catchment, AguaFlash

A Mass Balance Approach: Updating the SWAT pesticide Module for Application to EMCONs

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New and emerging contaminants (EMCONs) are being applied to soil and the total environmental impact need to be assessed by SWAT. The objective of this study is to re-visit the theory and mathematical structure of SWAT as to its appropriateness for this use. The growth hormone Trenbolone and some traditional pesticides such as Glyphosate, di-bromo chloro-propane, Malathion and Methyoxychlor are used as representative biological, chemical and physical properties of EMCON's in this simulation study. A representative SWAT algorithm and the Lavoisier mass balance (LVMB) model for the same surface soil pesticide module processes was developed, used and results evaluated. Chemical degradation on the soil as well as mass transport and advection to adjoining media were quantified. Significant deviations were found. After 20 days, the LVMB Glyphosate simulation for a 2 day half-life was found to deviate ~ - 1200% from SWAT. These and other deviations of residual chemical loadings on soil (kg/ha) between SWAT and LVMB were due to several factors. Primarily, SWAT does not adhere to the law of conservation of mass; its theoretical origin and documentation support this finding. SWAT's software process computations are performed in sequence rather than simultaneously. Additionally, key thermodynamic and transport process are absent or inappropriately formulated. Thus, the estimated emissions from the top 1 cm. layer to soil surface, runoff, groundwater, and the atmosphere are incorrect. To effectively model the fate of EMCONs in river basin watersheds, it is clear that SWAT needs to adhere to the LVMB and be re-tooled.

Fate and Transport Modeling of the Herbicides Metazachlor and Flufenacet using SWAT

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Fate and transport of the herbicides metazachlor (applied on rape) and flufenacet (applied on cereals) in a rural watershed in the Eastern Uplands of Schleswig-Holstein, Germany, were characterized by the ecohydrological model SWAT (Soil and Water Assessment Tool, Arnold et al. 1998, Arnold & Fohrer 2005). The hydrological processes in the lowland displayed a good relationship between the observed and predicted data (NSE and R2 > 0.78) after manual and auto-calibration. The model evaluation was based on results of field measurements of these herbicides on different scales (catchment – sub catchment – field). The emphasis of the preceding analysis (Ulrich 2010) were non-point pathways for herbicide loads in surface waters, thus, the implementation-oriented study was focused on them to develop various management options after the best management practices (BMPs) to reduce the risk for herbicide loss.

Keywords: SWAT, herbicides, metazachlor, flufenacet, non-point pathways

A Comparison of SWAT Pesticide Simulations Based on Varying Input Resolutions Using a Minimal Calibration Approach

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The Soil and Water Assessment Tool (SWAT) has proven to be an effective tool for evaluating the fate and transport of pesticides in watersheds covering a wide range of sizes and geographic locations. In recent years, there has been an increasing need to assess ecological pesticide exposure risk over broad geographical areas (national scale) for watersheds as small as 25 km2. Applying SWAT in this type of application precludes a typical site-specific calibration strategy and requires a simpler approach, incorporating regional calibration of a limited set of parameters. Another important consideration for this type of SWAT application is balancing computational efficiency and the appropriate scale and resolution of key input datasets, including subbasin delineation, land use, and soils. An approach for applying SWAT with limited calibration was developed and applied to 20 watersheds of 25 to 250 km2 across the Midwest corn belt of the United States. This minimal calibration approach was applied to models for each of the 20 watersheds developed using both medium resolutions (1:250,000 scale) STATSGO soils data and high resolution (1:25,000 scale) SSURGO soils data. In addition, the size of subbasins and the level of heterogeneity in the land use dataset were varied for the SSURGO-based models in order to assess the whether a simplified land use dataset and fewer subbasins (resulting in fewer HRUs) could result in a comparable level of model performance. The pesticide simulation performance of these various model structures was compared based on the models‘ ability to predict the daily concentration distribution function and rank the watersheds from lowest to highest risk of pesticide exposure. The model parameterization and minimal calibration strategy will be presented, followed by a comparison of the model simulations and a recommendation for the appropriate model structure for use in national scale pesticide exposure assessment using SWAT.

Hydrologic Evaluation Using Two SWAT Shallow Water Table Depth Algorithms in the South Fork Watershed

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Recently, a new shallow water table depth (*wtd*) algorithm (Modified DRAINMOD) that relates drainage volume (*vol*) to *wtd* was incorporated into the Soil and Water Assessment Tool (SWAT), a continuous-time physically-based watershed-scale hydrologic model, to improve water table depth fluctuation profile simulation. In the Modified DRAINMOD approach, *wtd* is computed as a function of *vol* and a variable water table factor (*wt_fctr*), which converts *vol* into *wtd*. In the current SWAT *wtd* simulation method in (SWAT-M), *wtd* is computed beginning with the bottom soil layer above the confining layer. When the bottom soil layer reaches field capacity, additional water is allowed to fill the profile from the bottom of the soil layer upward from which the height of the water table above the restrictive layer and hence the *wtd* from the ground surface is computed. The Modified DRAINMOD *wtd* simulation approach has been evaluated at the field scale level in fields (hydrologic response units) without tile drainage. In this study, 1) the streamflow prediction accuracy performance of SWAT using SWAT-M and Modified DRAINMOD *wtd* simulation approaches will be tested using measured streamflow data from the South Fork watershed in north-central Iowa, and 2) the differences in simulated water budget components will be determined and their implications on water quality discussed. SWAT will be calibrated and validated for streamflow using the two *wtd* methods and the streamflow prediction performance and the simulated water budget computed using the two methods will be compared. The results of this study will be presented.

Keywords: Simulation, Streamflow, SWAT, Watershed, Water budget, Water table depth

Application of SWAT Model to a Sprinkler Irrigated Watershed in the Middle Ebro River Basin (Spain)

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The Soil and Water Assessment Tool (SWAT) is a well-established and distributed hydrologic model. However, in the case of Del Reguero watershed (DRW) it is shown that the SWAT2005 version doesn‘t reproduce correctly the irrigation return flow generated under sprinkler irrigation system. The objective of this study was to adapt and assess the SWAT2005 model for correctly simulating the main hydrological processes in the study area. The main model source code modification was focused on the maximum amount of water to be applied as an irrigation event. The adjusted version of the model was named SWAT-IRRIG and was calibrated and validated for streamflow, sediments and phosphorus loads. SWAT-IRRIG was calibrated considering data from January to December 2008; while an independent 12-months period was used for the validation process (January to December 2009). A sensitivity analysis was conducted aiding in model calibration. Model source code modification increases the Nash-Suttcliffe coefficient of efficiency (ENS) for monthly flows from -0.50 to 0.90. The monthly ENS value was 0.80 for the validation process. Average monthly sediments losses were underestimated with 15% of the measured data and the corresponding monthly ENS was 0.72 for calibration and 0.52 for validation processes. SWAT-IRRIG also adequately predicted monthly trends in average total phosphorus loading during the calibration and validation periods with NSE values of 0.66 and 0.63, respectively. The results of this study indicated that SWAT-IRRIG is an efficient tool for the evaluation of best management practices effects on water quality in terms of water yield, sediments losses and total phosphorus loads.

Keywords: hydrological and water quality modeling, sediments, phosphorus, SWAT model, model modification.

Malfunctioning of Stream-gauge Stations in the Chanza and Arochete Rivers (Huelva, Spain) Detected from Hydrological Modeling with SWAT

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To carry out the hydrological modeling of the Odiel river (SW, Spain) using of the SWAT program, stream-gauge stations in the north of the basin are necessary because this zone has a hydrological behaviour that is different from the rest of the catchment, due to the outcrop of carbonate materials. At the northern neighbouring catchements of the Odiel basin there are two stream-gauge stations located on the Chanza and Arochete rivers. The aim of this study is to develop a hydrological model of these rivers using SWAT in order to transfer the parameters of these basins to the northern sub-catchments inside the Odiel basin. The models are calibrated and validated using SWAT-CUP. The statistical indexes obtained are acceptable: the Chanza river in the calibration period (1980-1993) obtained a value for the NSE (Nash and Sutcliffe Efficiency) of 0.54 for daily flows, and a diversion of the volume of runoff (DV) of 0.95. For the Arochete river which was calibrated for the period 1980-1990, the value of NSE is 0.52 for daily flows and DV is 1.13. The main problems are the obtained mass balance results. In the Chanza river, the value for the deep aquifer recharge variable (rchrg_dp) is too high, what is not supported by any hydrogeological reason. For the Arochete river, the value for this variable is also too high, in addition, we got an excessive decrease for the curve number (CN2) and an increase for soil available water capacity (sol_awc). This can be explained by the bad quality of the observed stream data for these rivers that seem to underestimate the flow values. Due to these errors, SWAT_CUP has to increase the recharge to a deep aquifer and soil availabe water capacity and decrease the curve number. This makes that these stream-gauge stations are not suitable to calibrate the model.

Keywords: Hydrological modeling, SWAT, SWAT-CUP, Chanza river, quality of stream-gauge data

Application and Validation of SWAT Model to an Alpine Catchment in the Central Spanish Pyrenees

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Modeling runoff and sediment transport at catchment scale are key tools to predict water and sediment yields with the purpose of preserving soil and water resources. This study aims to validate the SWAT model for its use in an alpine catchment as a simulator of processes related to water quantity and soil erosion in order to minimize indirect impacts such as reservoir siltation and loss of water quality.

The newest version of Soil and Water Assessment Tool (SWAT2009), coupled with a GIS interface (ArcSWAT), was applied to Barasona Reservoir catchment located in the central Spanish Pyrenees. The 1509 km2 catchment presents an altitudinal range close to 3000 meters and a precipitation variation of 1000 mm/km. The high mountainous characteristics of the catchment required specific definitions for some parameters. The snowmelt is a significant process in the hydrologic regime of the drainage area of the reservoir. The snowmelt was defined with the temperature-index plus elevation bands algorithm. The model was calibrated and validated using continuous streamflow data from a gauge stations. Calibration and validation results showed good agreement between simulated and measured data. Model performance was evaluated using several statistical parameters, such as the Nash–Sutcliffe coefficient.

The information gained with this research will be of interest to identify sediment sources and areas of high sediment yield risk, and to identify erosion and sediment transport patterns in the catchment.

Keywords: SWAT, mountainous catchment, snowmelt, streamflow, alpine catchment

Estimation of Transported Pollutant Load in Ardila Catchment using the SWAT Model

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Excess of organic matter and nutrients in the water body promotes algae blooms, which can accelerate the eutrophication process, situation often observed in the Ardila river. This river was identified as very polluted and classified as critical for Alqueva-Pedrogão System. The aim of this study was to estimate the transported nutrients load in a transboundary catchment using the SWAT (Soil and Water Assessment Tool) model and to determine the contribution of nutrients load in the entire catchment. Ardila catchment is about 3711 Km^2 and is located in the East part of Portugal (22%) and Badajoz province on Spanish soil (78%). It was discretized into 32 sub-basins using automated delineation routine, and 174 hydrologic response unit. Monthly average meteorological data (time period from 1947 to 1998) were used to generate daily values through the Weather Generator Model incorporated in SWAT. Real daily precipitation series data (1931 to 2003) were introduced. The model was calibrated and verified using: flow data (1950 to 2000) and nutrients (1981 to 1999). Model performance was evaluated using statistical parameters, such as Nach-Sutcliffe efficiency (NSE) and root mean square error (R^2). Calibration and verification flow results showed a satisfactory agreement between simulated and measured monthly date from 1962 to 1972 (NSE=0.8; $R^2 = 0.9$). The results showed that the most important diffuse pollution comes from the two main tributary of Spain. The estimated nitrogen and phosphorous load contribution per year was about 72%, 59% respectively (Spain) and 28%, 41% (Portugal). The SWAT model application reveals a useful tool for integrated water management.

Keywords: diffuse pollution, SWAT model, nutrients, integrated water management

Modeling the Pollutant Dynamic in an Intensive Irrigation Agricultural Watershed of a Semi-arid Zone: The Flumen River in Northeastern Spain

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River water pollution is of major concern in agricultural watersheds. In Europe, the introduction of the Water Framework Directive in 2000, binds obligations on member states to achieve good ecological status of surface water and groundwater by 2015.

Non-point pollution takes place in river waters after agricultural irrigation through surface runoff, lateral and groundwater flows, in relation with agricultural practices and soil, and geomorphologic and meteorological characteristics of the watershed. This work was investigated in the Flumen watershed (1,500 km², in Monegros region in Aragon, Northeastern of Spain), an agricultural watershed located in semi-arid environment, and was supported by the EU AguaFlash project (http://www.aguaflash-sudoe.eu/). In this watershed, agricultural use corresponds to an intensive irrigation for cereal, maize, rice and alfalfa production.

The SWAT model (2009 version) has been applied from October 2009 to March 2011. Daily time step was used to assess the flux and transport of nitrates, suspended sediments and pesticides. Simulated concentrations were compared to data collected at the watershed outlet with weekly measurements during low flow and daily or sub-daily measurements during flood events. Low water during summer period in the Flumen watershed is controlled by the drainage of water used in agriculture lands for irrigation. Consequently, nitrate and soluble pesticide concentrations were diluted during flood events. Annual transfer shows a low correlation with watershed annual water yields. Suspended sediments were transported during flood events with some pesticides associated to the particles.

Keywords: Nitrates, pesticides, flood, SWAT, modeling, Flumen river, agricultural watershed, irrigation, AguaFlash

Soil Erosion Modelling in an Agro-forested Catchment of NE Spain Affected by Gullying using SWAT

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Soil erosion is recognized as the major cause of land degradation in Mediterranean and semiarid environments. The present work shows the first results of the application of SWAT (ArcSWAT 2009.93.5) to model soil erosion in an agro-forested catchment (2049 ha) located in the Anoia-Penedés region (NE Spain). This area belongs to the Penedés Tertiary Depression, where unconsolidated materials (marls) outcrop. The area is severely affected by gully erosion processes. The main agricultural uses are vineyards, rainfed herbaceous crops (winter barley) and olive trees. An important part of the area is covered by natural vegetation (Pinus halepensis, Quercus ilex, Quercus faginea), that mainly occupies the steepest slopes affected by gullying. The main data sources to run SWAT were the detailed Soil Map of Catalonia, a 5 m resolution DEM and land use / vegetation maps of 2005 and 2010. The first was adapted from the Land Cover Map of Catalonia (3rd edition) and a supervised classification of a WorldView-2 multispectral image (2 m resolution) (06/July/2010). Soil losses for periods with different climatic characteristics were analysed (2005, with low precipitation, 365 mm, and 2010, above the average, 729 mm). Average annual soil losses ranged between 2.9 and 40.7 t/ha, with clear differences between HRUs depending on land use and soil characteristics. The highest values correspond to vineyards lands. Forest plays a very important role as protection cover on gully walls, avoiding major sediment production rates. Nevertheless, the increase of runoff by almost 350% in the wet year, with respect to the dry year, favours the actuation of other processes different than sheet and rill erosion on gully walls (e.g. bank erosion, mass movements), which are not estimated by MUSLE integrated in SWAT.

Keywords: soil loss, agro-forestry catchment, detailed scale, wet and dry years

Development of Algorithms for Sedimentation-Filtration Basins in SWAT

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The Soil and Water Assessment Tool (SWAT) is being used for a number of urban water quality and storm water management projects in Texas. However, current SWAT model lacks sub-hourly modeling capability that is necessary to properly simulate the complex urban landscape. In addition there is no capability in the model to route the stormwater through BMPs. Therefore, a project is carried out to develop tools for sub-hourly flow and sediment modeling and simulation of stormwater BMPs. This paper describes the model development for sedimentation-filtration basin and its validation. Sedimentation-filtration basin is an onsite stormwater treatment system that combines a sedimentation pond and a sand filter, which is a common type of BMPs being used in Austin, Texas. Physically based models for flow through the sedimentation-filtration basin and the removal efficiency of Total Suspended Solid (TSS) have been developed within SWAT. The performance of the sedimentation-filtration algorithm was tested on a small urban drainage area in downtown Austin, TX by calibrating through-flow rate and TSS removal efficiency for short- and long-term periods. The model development, its linkage to SWAT and the test results on a highly urban watershed will be presented.

Mapping Sugar Cane Yield for Bioethanol Production in Veracruz, México

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Bioethanol from sugar cane is accepted as the most cost, energy and greenhouse gas mitigation efficient biofuel to substitute fossil gasoline. Bioethanol yield may be increased if residues (tops, leaves and bagasse) are used for cellulosic bioethanol production. However, to efficiently achieve maximum biomass yield and avoid competition with food production, highly and marginally productive areas most be identified. The objective was to map sugar cane yield in Veracruz, to assist decision makers in planning rural development and bioethanol refineries establishment. The SWAT (Soil and Water Assessment Tool) model was used to simulate total sugar cane biomass yield throughout the 7.18 million hectare of Veracruz. To define the Hydrological Response Units, base digital elevation model, soils and land use maps scale 1:250,000 and 90x90m pixel size, acquired from INEGI were used. Weather data was taken from 160 uniformly distributed weather stations with at least 20 years of records between years 1960-2000. The sugar cane management was designed for highest yield attainment. Most sensitive crop parameters such as LAI, RUE, Tb, HU, biomass partition and rooting depth were taken from previously local research and peer review literature. Total theoretical bioethanol (sugar ethanol + cellulose + hemicellulose ethanol) was calculated and mapped. Results are presented and discussed in terms of ten productivity class maps of sugar cane biomass and total (Sugar + Cellulose + hemicellulose) theoretical bioethanol yield and amount and spatial distribution of highly and marginally productive areas.

Keywords: Biofuel, Geographical Information Systems, ArcSwat, Simulation Models, Rural Development

Improving the Simulation of Biofuel Crop Sustainability Assessment using SWAT Model

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Cellulosic perennial energy crops, such as, switchgrass and Miscanthus are expected to play a significant role in meeting biofuel production goals. It will become increasingly important to evaluate the impacts of transition into and production of these emerging feedstock varieties. For this reason, there is need to evaluate adequacy of existing crop growth models and the data that drives modeled growth. Fortunately, Purdue University has collected relevant field data from emerging and established plots of switchgrass (Shawnee) and Miscanthus in northwestern Indiana. This includes relevant biomass, leaf area, crop nutrient uptake, crop height, root distribution, and climate data. In this study, we conducted a sensitivity analysis to establish key crop growth parameters in SWAT, and used measured data to improve parameter values, associated curves, and model representation. Improved crop growth representation is validated at the field scale and used to evaluate various likely energy crop scenarios in Wildcat Creek watershed in Indiana. We will discuss the results of the model applications to quantify biofuel crop production sustainability as field and watershed scales. We will also discuss further model improvements that are needed to answer emerging questions related to land use changes, biofuel production and ecosystem health.

Mapping King-grass (*Pennisetum purpureum*) Biomass Yield for Cellulosic Bioethanol Production in Veracruz, México

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Cellulosic Bioethanol from grass biomass is considered as the most promissory alternative to liquid fossil biofuels, in part, due to higher biomass production, net energy ratio and greenhouse mitigation potential, as compared with other plant species. To efficiently achieve maximum biomass yield and avoid competition with food production, highly and marginally grass productive areas most be identified. The objective of this work was to simulate and map the biomass yield of king-grass in Veracruz, in order to assist decision makers in planning rural development and bioethanol refineries establishment. The SWAT model was used to simulate total biomass yield throughout the 7.18 million hectare of Veracruz. To define the Hydrological Response Units, base digital elevation model, soils and land use maps scale 1:250,000 and 90x90m pixel size, acquired from INEGI were used. Weather data was taken from 66 uniformly distributed weather stations with at least 20 years of records between years 1960-2000. The king grass management was designed for high yield attainment. Most sensitive crop parameters such as LAI, RUE, Tb, HU, biomass partition and rooting depth, were taken from previously local research and related peer review literature. Total theoretical cellulosic bioethanol was calculated and mapped. Results are presented and discussed in terms of nine productivity class maps of king grass dry biomass and total theoretical cellulosic bioethanol yield, identification of compact areas for bio-industrial development (development poles) and projected cellulosic bioethanol refinery capacity for each of the development poles identified.

Keywords: Biofuel, Geographical Information Systems, ArcSwat, Simulation Models, Rural Development

Climate Change Impacts on Water Availability in Three Mediterranean Basins of Catalonia (NE Spain)

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The Mediterranean region might become one of the most vulnerable areas in Europe regarding climate change. There is a social concern related to climate change impacts on water resources. In this context, the IPCC Fourth Assessment Report (2007) points out a significant decrease in runoff in Mediterranean regions at the end of the Century.

This work assesses the main climate change impacts in three medium-sized catchments in Catalonia (NE Spain) with different environmental conditions: Fluvià, Tordera and Siurana. The main aim is to develop adaptive measures to cope with the expected climatic and social changes.

The Soil and Water Assessment Tool (SWAT) was used to simulate the hydrologic response to climate changes. Downscaled projections of ECHAM5 GCM under two IPCC emission scenarios (A2, B1) were used. In comparison with baseline conditions (1984-2008), climate projections predicted a 12% (B1) to 28% (A2) reduction in precipitation, and a 2.2ºC (B1) to 3.6ºC (A2) increment of mean annual temperature at the end of the XXI Century (2076-2100).

SWAT simulations predicted a 22% to 48%-reduction of stream flow and a 14% to 25%-reduction of real evapotranspiration for 2076-2100 respectively under the above mentioned scenarios. Autumn and summer were the most affected seasons. These results highlight the strong impact of climate change in regional water resources and reflect the importance of incorporating theses analysis into adaptive management in the Mediterranean region.

This work is part of the ACCUA project (www.creaf.uab.cat/accua) that aims at evaluating the territorial vulnerability of the Mediterranean coast to the main effects of global change in relation to water availability.

Keywords: climate change, water availability, SWAT, Mediterranean

Application of SWAT Model to Evaluate the Impacts on Water Resources of Some Climatic Scenarios in a Catchment of the Basque Country

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Changes in climate and variations in the use of the land cover in a catchment could have some consequences in its hydrological response, and therefore in water resources. To study the effects of climatic variations, the Soil and Water Assessment Tool (SWAT, 2009 version) model was implemented to simulate the hydrologic regime on Goi-Nerbioi (Basque Country, Spain) catchment. The study of this basin is included in K-Egokitzen, a project created by the Basque Government to carry out research into the Climatic Change. The model was fed with registered daily inflows during 13 hydrological years (1996/1997-2008/2009) and different climatic variables from IPCC (A2 and B2 scenarios) were introduced on the model to estimate the impact of climate change on water resources. Expecting better results, the predicted climate scenario showed that spring and winter flows suffered a decrease in mean and maximum discharge values, whereas in autumn and spring the decrease it is not significant.

Keywords: SWAT, modelling, climatic change, Goi-Nerbioi catchment, A2 and B2 scenarios.

Impact of Climate Change on the Water and Nutrient Cycles in the Po River Basin (Italy)

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Various studies have been developed and applied to assess the impact of climate change on crop production. Under a changing climate, agriculture will also impact water resources in terms of quantity and quality, and adaptation and mitigation strategies have to be developed and tested. In this context the SWAT hydrological model was applied to the Po river basin, a large agricultural watershed in Italy, to assess the impact of adaptation strategies under climate change.

The model was calibrated for the period from 2000 to 2006 for the water and nitrogen balance. The calibrated model was then run using climate change (CC) scenario for the period 2001–2100. The CC scenario is based on a one way-nested Climate Change Simulation, driven by ECHSAM5 data with the regional climate model REMO, under the A1B emission scenario. Under the climate change scenario (A1B), the increase of temperature and the reduction of precipitation causes a overall decrease in annual water flow by 1.8% in the period 2025-2050, 14% in the period 2050-2075 and 8% in the period 2075-2100, however with large seasonal variation (flow increases from January to March and decreases in July-August and October-November). It was also observed a decrease in runoff (-4% in 2000-2050 and -17% in the 2050-2100). Nutrient and sediment river loads are generally lower, but there is an increase in nitrogen leaching, more evident in the intensive agricultural areas. It is predicted that irrigation practices can limit crop yield loss, however leading to a large depletion of groundwater while increasing nitrogen leaching.

Keywords: SWAT, nutrients, Climate Change, environmental impact assessment

Estimating Water Pollution Abatement Cost Functions using the Soil and Water Assessment Tool (SWAT)

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Coastal ecosystems are increasingly affected by water pollution from anthropogenic sources in coastal catchments, even though these ecosystems are important from an environmental, social and economic perspective. Sustainable development of coastal regions requires Integrated Catchment and Coastal Zone Management (ICCZM) that specifically acknowledges the inherent relationship between coastal catchment land use, water pollution, ecosystem state and associated environmental values. In particular, to warrant sustainable economic development of coastal regions we need to balance the marginal costs from coastal catchment water pollution abatement and the associated marginal benefits from coastal resource appreciation. Diffuse source water pollution abatement costs across agricultural sectors are, however, not easily determined given the spatial heterogeneity in bio-physical and agro-ecological conditions as well as the available range of best agricultural practices for water quality improvement. We demonstrate how the Soil and Water Assessment Tool (SWAT) can be used to estimate diffuse source water pollution abatement cost functions across agricultural sectors – based on a stepwise adoption of identified best agricultural practices for water quality improvement and, corresponding, estimates for water pollution deliveries and agricultural incomes. A case study is presented for Dissolved Inorganic Nitrogen (DIN) water pollution by the key agricultural sectors in the Vouga catchment, Portugal. Results indicate that DIN water quality improvements of up to about 15% can provide a private gain to the agricultural sectors, while water quality improvements of up to 30% can be obtained at no additional cost to the agricultural sectors. DIN water quality improvements beyond these levels lead, however, to significant costs for the involved agricultural sectors.

Keywords: Diffuse source pollution; Abatement costs; Best agricultural practices

Quantifying Trade-offs Between Bioenergy Production, Food Production, Water Quality and Water Quantity Aspects in a German Case Study

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Worldwide increasing bioenergy production is on the political agenda. It is well known that bioenergy production comes at a cost – several trade-offs with food production, water quality and quantity issues, biodiversity and ecosystem services are known but a quantification f these trade-offs is missing. Hence, we will show in our presentation an analysis of trade-offs between bioenergy production, food production, water quality and water quantity aspects in the Parthe catchment, close to Leipzig, Central Germany. The analysis is based on using SWAT and a multi-objective genetic algorithm (NSGA II). The genetic algorithm is used to find Pareto-optimal configurations of crop rotation schemes. The Pareto-optimility describes solutions in which an objective cannot be improved without decreasing other objectives. This allows us to quantify the costs at which several levels of increase in bioenergy production come and to derive recommendations for policy makers.

Simulations of Water Balances in Different European Climates – Potentials and Limitations of Integrated Forest and Land-Use Impact Modelling

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The presentation is based on our investigations of the role of forests in watershed management analysis within a European East-West gradient spanning from subtropical Portugal to temperate Ukraine. In the Águeda Basin (Central Portugal), about 50 % of the surface is cultivated with eucalyptus (Eucalyptus globules) as short rotation coppice. A successful calibration of the SWAT model has been achieved, but analyses concerning forest fire effects reveal limitations of mimicking fire effects in SWAT. This is based primarily on the conceptuality of tree growth in SWAT, representing LAI developments rather for temperate deciduous trees than for evergreen trees in the subtropics or coniferous trees. Furthermore the LAI development is rigid and biomass simulations do not account for tree growth from seedling to a mature stand. Thus, we will focus on the presentation of limitations of biomass and LAI simulation for forest and suggest potential for enhancement.

Another study area is the Western Bug watershed (North West Ukraine), where short rotation coppices are seen as a potential land-use management-related measure to improve the river water quality. Forest covers currently around 37 % of this watershed. Beside the presentation of different case studies of our project, ideas for improved forest simulation in SWAT will be discussed.

Analysis of the Future Climate Change Impact on Vegetation Canopy and Growth Period

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About 50 % of the total water resources in South Korea are consumed for agricultural use, and it is a key part of water resources management in the future. This study describes the future climate change impact on vegetation canopy and growth period and suggests irrigation scheduling design using the soil water assessment tool (SWAT) model. The forest dominant Chungjudam watershed (6,585.1 km2) located in the north-eastern part of South Korea was selected for the future assessment. For the future climate change scenario, the MIROC3.2 hires A1B and B1 data were downscaled using the 30 years (1971-2000) of observed meteorological data at 6 locations, and the future daily data of 2021 - 2100 (2021-2060: 2040s; 2061-2100: 2080s) were generated at each meteorological station using the long ashton research station–weather generator (LARS-WG). The future 2080s A1B temperature changes were +4.3℃ in winter, +3.7℃ in autumn, +3.5℃ in summer and +1.7℃ in spring. The future 2080s B1 precipitation changes were +28.3% (24.3 mm) in winter, +44.0% (112.2 mm) in autumn, 16.3% (121.1 mm) in summer and +55.1% (111.7 mm) in spring. The future vegetation canopy scenario was prepared from the nonlinear regression between monthly Leaf Area Index (LAI) of Moderate Resolution Imaging Spectroradiometer (MODIS) and monthly mean temperature for seven years (2000-2006) data. The watershed average LAI of the 2040s A1B and B1 scenarios increased 0.13 and 0.15 respectively compared to the LAI of 1990-2009. However the LAI of the 2080s A1B and B1 scenarios decreased 0.15 and 0.13 respectively. This is because the growth was limited by the stress from high temperature continuation. In the 2080s scenarios, the growth began one month forward and the maximum LAIs decreased 0.29.

Keywords: Climate change, LARS-WG, Vegetation canopy, LAI, SWAT

Projections of Hydrological Extremes under Climate Change in Germany by Combining Different RCMs with SWIM

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More frequent and intense extreme events are expected as a consequence of climate change in many regions. In Germany, a general increase in precipitation in winter and a decrease in summer have been observed. There have been more frequent floods in Germany during the last two decades, some of which have been among the most destructive ones ever recorded. During the same period, some extreme drought events (like the 2003 drought) occurred endangering crop yield and water supply. Hence, the potential climate-driven changes in both extreme events are now at the focus of interest.

A study was performed for Germany with the aim to project the future flood and low flow conditions accounting for various river regimes and under different emission scenarios: A2, B1 and A1B. All large river basins in Germany: Rhine, upper Danube, Elbe, Weser and Ems were included. The ecohydrological model SWIM was intensively calibrated and validated in terms of flood and low flow conditions respectively for the five basins. At most of the gauges, the seasonal discharge, annual maximum discharge as well as the low flow frequency curves of the simulated discharge using SWIM with observed climate data (1961 – 2000) had a good agreement with the observed ones for the control period. Climate scenarios from two dynamical regional climate models (REMO and CCLM) and one statistical-empirical model (Wettreg) were used as input data for SWIM to simulate future river discharges.

The Generalized Extreme Value distributions were fitted to the annual maximum flow and annual minimum 7-day mean flow series for the control and scenario periods. The 50-year flood/low flow values estimated for two scenario periods (2021 – 2060 and 2061 – 2100) were compared to the ones derived from the control period using the same climate models (no bias correction). Regarding the flood conditions, the results driven by two dynamic RCMs give various change directions depending on river basin, emission scenario and time period, whereas the results driven by Wettreg mostly show a declining trend in flood level. More specifically, the results driven by two dynamic RCMs suggest an increase of about 10 – 20% in the 50-year flood level in the rivers Weser, Rhine, Main, Saale and Elbe; whereas there is a likelihood of 20% decrease in the flood level for the Neckar. In contrast, the model Wettreg projects a downward trend for the northern basins Ems and Weser (10%), and Saale (20%), and no distinct trend could be found for the Main, Danube, and Neckar. The low flow condition is likely to be more severe agreed by most of the RCMs realizations in western, southern and central Germany especially during the second scenario period.

The uncertainty in estimating floods remains high, while more robust signals can be found in the low flow projections. The uncertainty sources included in this study are the differences in regional climate models, emission scenarios and multi-realizations generated by RCMs. Nevertheless, possible adaptation strategies should account for a high probability of future increase in flood intensity and extreme low flow occurrence in many rivers in Germany.

Modeling Hydro-climatic Extremes and Flood Damages Under Climate Change Conditions

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According to NASA GISS and NOAA analyses, the year 2010 tied with 2005 as the globally warmest year in the instrumental record extending back to 1880. The year 2010 was also the year with the largest global number of major floods since 1980 (Munich Re, 2011). Whenever a major hydro-meteorological event occurs, it triggers a discussion about the possible impact of climate change. Detection of trends in extremes is of crucial interest for those exposed to hazard and also for decision makers, responsible for building an adequate preparedness system.

The study presents the results of a joint project with the German Insurance Association and discusses possible trends in flood generation and related damages under climate change conditions in Germany. The study makes use of global climate scenarios regionalized for the main German river basins. The hydrological model SWIM was applied to transform the regional climate scenarios into river runoff for more than 5000 river reaches. Previously, the model has been calibrated and validated for the main gauges within the German river basins. Extreme Value Distributions have been fitted to the hydrographs of the river reaches to derive the basic flood statistics. The simulated runoff for each river reach has been linked to related damage functions as provided by the German Insurance Association. The results show that under scenario conditions a strong and significant increase in flood damages can be expected throughout Germany.
However, the results are associated with high uncertainty, and additional studies are recommended to improve the understanding of the underlying processes and possible trends.

Keywords: Climate change, flood, flood damage, hydrological trend, hydrological extremes

Quantifying SWAT Runoff using Gridded Observations and Reanalysis Data for Dakbla River Basin, Vietnam

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Many research studies that focus on basin hydrology have used the SWAT model to simulate runoff. One common practice in calibrating the SWAT model is the application of station data rainfall to simulate runoff. But in regions lacking robust station data, there is a problem of applying the model to study the hydrological responses. To overcome this limitation, this research study uses available gridded high resolution precipitation datasets to simulate runoff. Four popular gridded observation precipitation datasets- APHRODITE, TRMM, PERSIANN and GPCP and one reanalysis dataset (NCEP/NCAR) are used to simulate runoff over the Dakbla river (a small tributary of the Mekong River) of the Sesan river basin in Vietnam. Wherever possible, available station data are also used for comparison. Bilinear interpolation of these gridded datasets is used to input the precipitation data at the closest grid points to the station locations. Sensitivity Analysis and Auto-calibration are performed for the SWAT model. The Nash-Sutcliffe Efficiency (NSE) and Coefficient of Determination R2 indices are used to benchmark the model performance. This entails a good understanding of the response of the hydrological model to different datasets and the uncertainties in these datasets are quantified. Such a methodology is also useful for planning on Rainfall-runoff and even reservoir/river management both at rural and urban scales.

Keywords: SWAT, gridded observations, Rainfall-runoff, uncertainties

Effect of Climate Change on Environmental Flow Indicators in the Narew Basin, Poland

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This paper discusses the effect of climate change on environmental flows in the semi-natural lowland rivers in north-eastern Poland. The analysed rivers belong to the Narew basin occupying ca. 28.000 km2. This region is known for its valuable river and wetland ecosystems, many of them in pristine or largely un-impacted conditions. Although many factors have influence on the state of these types of ecosystems, it has recently been widely accepted that flow regime is a key driver. This has led to the development of the environmental flows concept. The objective of this study was to assess changes in environmental flow regime of the Narew river system, caused by climate change, as simulated by hydrological models with different modelling scale: (1) Soil & Water Assessment Tool (SWAT), a river basin scale model; (2) WaterGAP, a global model of water availability and use. The main feature differentiating these models is the level of spatial aggregation of hydrological processes. Both models were run using consistent climate change forcing, in terms of monthly precipitation and temperature changes projected from two General Circulation Models (GCMs) coupled with the A2 emission scenario: (1) IPSL-CM4 from the Institute Pierre Simon Laplace, France; (2) MIROC 3.2 from the Center for Climate System Research, University of Tokyo, Japan. To assess the impact of climate change on environmental flows, we used a method based conceptually on the Range of Variability Approach (RVA) using Indicators of Hydrological Alteration (IHA), a desk-top technique for assessing if environmental flow requirements are met. Preliminary results indicate that environmental flow regime in the Narew basin is subject to climate change risk, whose magnitude varies with climate model and hydrological modelling scale.

Keywords: environmental flows, SWAT, WaterGAP, climate change

Coupling SWAT with In-stream Models for an Integrated Assessment of Sediment Transport

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In the study catchment Kielstau, located in the Northern German lowlands, erosion from fields, sediment input from artificial tile drains and in-stream erosion are the main sediment sources. For depicting these three pathways, SWAT is used on the catchment scale to simulate sediment input to the streams with the Modified Universal Soil Loss Equation (MUSLE). Impact of artificial tile drainages on the sediment load is assessed with a GIS-based tool (SEPAL). The estimated tile drain sediment load is linked to the modeled SWAT tile flow and added to the MUSLE soil loss to gain total subbasin sediment input to the river. A GIS interface was programmed to couple SWAT hydrographs and total sediment loads with the HEC-RAS model. This 1D-hydraulic model is used to depict in-stream erosion and deposition processes. The 2D-hydraulic model ADH, for which an ArcGIS interface was created, is applied on a 300m river section to gain refined spatial information on sedimentation and erosion.

Results show that modeled to measured sediment loads as well as the temporal dynamics are consistent. Catchment sediment input from agricultural fields and drainages are a minor contributor to total sediment fluxes at the catchment outlet while major sediment sources are the rivers bed and banks. In-stream movable sediment consists mostly of fine sand which causes siltation of lakes and downstream reaches. Findings from the two dimensional hydraulic simulation include detailed spatial distributions of substrate changes caused by certain flow stages and according sediment loads.

Impact of Historically Changed Land Use on the Water Quality of the Rivers Reka and Dragonja, Slovenia

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The aim of the research was to examine the susceptibility of the flysch soil, in the rivers Reka and Dragonja in Slovenia, to the historical changes in land use. Further, how is this reflected on the quantity and quality of surface waters through soil erosion and transfer of nitrogen and phosphorus in to the watercourses. Historical land use scenarios of catchment development were tested with the SWAT model. The quality of the results in the calibration process was significantly impacted by data on water-physical properties of the soils. Varying hydraulic conductivity and water-retention properties of the soils had a significant impact on the proper modelling of flow and transfer of sediment, nitrogen and phosphorus. Modelling scenarios of the historical agricultural land use (1780, 1830, 1940 and 1984) showed that their preservation or realization in present climatic conditions is likely to lead to increased levels of sediment, nitrate and total phosphorus in the rivers exceeding current average measured concentrations and by the legislation recommended guide levels (25 mg l^{-1}). Changes would also affect water quality, however their influence on the flow would be insignificant.

Application of SWAT to a data scarce catchment in the Three Gorges Region, China: The impact of land use change on sediment and phosphorus transport

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Changes in land use can have a considerable impact not only on the water balance, but also on the sediment and phosphorus transport in river basins. In order to safeguard the usability of water resources and to protect aquatic ecosystems it is important to quantify the effects of land use change on water quantity and quality. This applies especially to very dynamic and fast changing areas like the Three Gorges Region in China. Here, a large scale land use change was triggered by the construction of the Three Gorges Dam. Numerous people had to be resettled, new infrastructure was built and agricultural areas had to be shifted from the valley bottoms to steep, formerly wooded slopes. This land use change is expected to continue in the future.

The impact of past as well as possible future land use change is assessed by applying SWAT2009 to the 3099 km^2 large Xiangxi Catchment in Hubei Province. Discharge was calibrated against a daily time series measured at Gauge Xingshan in the center of the catchment, resulting in a satisfactory agreement of measured and simulated data. As there are no adequate records of sediment and only monthly data on phosphorus available, calibration of those variables poses a much greater challenge than discharge calibration.

Results of water balance simulations are presented alongside preliminary results of sediment and phosphorus calibration, taking account of the effects of past and present land use patterns as well as possible future land use scenarios. Difficulties encountered when modeling data scarce catchments and possible strategies to deal with these are discussed.

Sub-hourly Modeling of Sheet Erosion and Sediment Transport using the SWAT Model

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The assessment of gully erosion poses a great challenge because of the complexity and connectivity of the geomorphic processes involved (i.e. mass movements, sheet erosion, channel incision). The study site is a gullied sandy catchment of 1.29 ha (*Barranca de los Pinos*) located at the northern piedmont of the Guadarrama Mountains in the Central System of the Iberian Peninsula. Sheet erosion seems to play a fundamental role in this particular type of gullies in terms of explaining a major fraction of the total sediment yield. In this respect, sheet erosion and sediment transport was modeled by using a sub-hourly routine within the SWAT model. The model was calibrated with flow and sediment data measured since June 2009 at the outlet of the catchment. To this purpose, a Parshall flume is being used to measure water discharge, whereas a siphon and Reid slot samplers are being used to estimate suspended and bedload sediment, respectively. Additionally, annual gross sheet erosion was averaged based on the implementation of a dendrogeomorphic approach, whereas sediment yield was obtained from the estimation of the sediment delivery ratio corresponding to the catchment studied. This dendrogeomorphic approach was used to demonstrate that sheet erosion is predominant in the catchment studied.

Development and Testing of Improved Physically Based Streambank Erosion and Sediment Routing Routines in SWAT

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Overland erosion, streambank erosion and routing of eroded sediment through the stream channel is an important component of SWAT model. In SWAT 2009, four physically based streambank erosion and sediment routing models have been added. They are 1) Simplified Bagnold Equation 2) Kodatie model 3) Molinas and Wu model and 4) Yang sand and gravel model. 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 was permittted to occur at a one time. In the current version, deposition can occur simultaneously with erosion. 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 can now 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. The model is tested with streambank erosion rates previously monitored with erosion pins, submerged jet testing and water level recorders at 12 sites in North-Central Texas for a period of one year. Cumulative annual erosion based on erosion pins ranged from 30-572 mm in the clay channels and from 27-150 mm in the sandy channels. The simulations from the improved routines compared well with the erosion pin and submerged jet data and illustrate the models capability to give resonable estimates of channel erosion.

Preliminary Results of the Hydrological Modeling of the Bouregreg Watershed (Morocco) using SWAT

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SWAT model was tested and calibrated in different worldwide sites but it has never applied in large-scale basins of Morocco. Thus, the aim of this study is to test the application of SWAT model in Bouregreg watershed located at the north-central of Morocco.

The big problem to implement such model in theses areas is the unavailability or scarcity of data especially for the daily step time. It was then question to prepare and gather all the data necessary to run the model taking into account the very large size of the study area (9600 km²) and the combination of data coming from various sources and scales (data collected from local organizations, data delivered by international agencies and data generated from satellite images or by using GIS). The parameters of the model were calibrated from 1996 to 2000 and validated from 2001 to 2005 using ArcSWAT tool and autocalibration method.

The preliminary results obtained for both calibration and validation showed a good correlation for the monthly average discharge ($R^2 > 0.8$ and NSE > 0.8) and low concordance for the daily discharge ($R^2 < 0.4$ and NSE < 0.3). These first results prove that this model can represent the hydrological functioning of semi-arid areas such the Bouregreg watershed especially if we take into account the different approximations made in the context of this work due to the unavailability of more accurate and more spatial data.

Keywords: hydrological modeling, large-scale basin, Bouregreg Watershed, Morocco, SWAT

Using MODIS Imagery to Validate the Spatial Representation of Snow Cover Extent Obtained from SWAT in a Data-scarce Chilean Andean Watershed

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Andean watersheds present important snow coverage during the winter season depending on the relative altitude and ambient temperature. Snowpack stores significant amount of precipitation water which is released to surface runoff and groundwater when solar radiation increases, mainly during the spring and summer season, controlling the shape of the annual hydrograph and affecting the water balance at monthly and shorter scales. Thus, the effect of snowmelt on the water balance is critical for agriculture, hydropower generation and wildlife habitat quality. However, in the case of the Chilean Andes (as in many places around the world) there is a lack of both meteorological input and hydrological validation data, which complicates the analysis of those hydrological processes that take place in this important part of many of the country‘s river basins. The objective of this study is to use remotely-sensed snow cover information obtained from MODIS imagery in order to validate the spatial snow cover extent and thus the representation of stream hydrology calculated with SWAT. Obtained results showed satisfactory to good general model performance for representation of long-term and annual mean discharge at the basin outlet, as well as a reasonably good description of snow cover extent under a number of circumstances.

Keywords: Snow hydrology, MODIS, SWAT

Assessment of SWAT Potential Evapotranspiration Options and Data-dependence for Estimating Actual Evapotranspiration and Streamflow

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Evapotranspiration is a major component of the water balance at the watershed scale. However, its measurement has always been difficult especially at the watershed spatial scale. The Swat model offers the possibility of using several methods for computing the potential evapotranspiration methods including: (i) Penman-Montheith (PM), (ii) Hargreaves (H) and (iii) Priestly-Taylor (PT). The main objective of this study is to compare the subset of potential evapotranspiration (PET) models provided by SWAT and to assess their impact on actual evapotranspiration and on streamflow for a 418km² watershed located in a sub humid context. In the first part, we focus on the PM model that requires five climatic parameters: temperature, solar radiation, wind speed and vapour pressure. The SWAT weather generator was used to estimate different climatic parameters for computing PET and the results are compared with the complete data from the Beja meteorological weather station. For each run the results are compared based on two statistical parameters: the Nash-Sutcliffe efficiency and correlation coefficient. Our results show that the SWAT weather generator was relevant to predict missing data using a nearby meteorological station. A good performance of PM method was observed with generated data. In the second part, the model was executed using the different PET models. The results showed that the different PET computation methods did not affect considerably streamflow but it did affect the predicted actual evapotranspiration AET. The Priestly-Taylor method underestimated predicted AET; the Penman-Monteith method overestimated it compared to Hargreaves method.

Keywords: potential evapotranspiration, weather generator, Penman-Monteith, Hargreaves, Priestly Taylor, SWAT model, subhumid Tunisia

The Effects of Floodwater Spreading on Soil Infiltration Rate in Kowsar Aquifer Management Station

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Desertification control through floodwater spreading for artificial recharge of aquifers is a logic improve action that not only improve groundwater reserves but also degradated lands due to suspended load in the flood artificial recharging of groundwater through floodwater in Gareh Baygan plain caused to improve environmental condition and provided a good situation for animal and plant societies geological of Iran watershed cause to produce runoff with a lot of turbidity and high suspended loud. Clay and fine particles in flood decrease infiltrability of sedimentation basin most of artificial recharging ponds that constructed with a great cost faced with decreasing in infiltrability. Infiltration decreasing in floodwater spreading systems happens less than other recharging ponds because of wide sedimentation and areas nevertheless after several years infiltration rate decreasing is certain make a hard layers and clays and particles fine size especially Pallygorsgite shorten the life of artificial recharging systems. Root channels that form by Eucalyptus increase infiltration rate in sedimentation basin and recharge ponds, despite thick crust layer, infiltrability of soil finally decrease. In this case study we investigated infiltration rate in floodwater spreading system in Kowsar research training and extension station by double ring method application. Results showed that infiltration rate in first plot of Bisheh Zard 1 decreased from 10.33 cm/h to 2.13 and in second and 3rd. plot in this system decreased to 2.49 and 7.47 cm/h respectively. Infiltration decreasing happen mainly in first to 3rd plot. Floodwater spreading system in Gareh Baygon Plain after 25 years old is active and useful.

Keywords: Infiltration, floodwater spreading, Gareh Baygan plain, Fasa.

Integrated Surface-Groundwater Analysis on Groundwater Dam Effect in Ssangcheon Watershed in South Korea

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Groundwater dams are structures that intercept or obstruct the natural flow of groundwater and provide storage for water underground. Their use is in areas where flows of groundwater vary considerably during the course of the year, from very high flows following rain to negligible flows during the dry season. The basic principle of the groundwater dam is that instead of storing the water in surface reservoirs, water is stored underground. The reservoir is recharged during the monsoon period and the stored water can be used during the dry season (Centre for Science and Environment, 2011). In this study, the fully integrated SWAT-MODFLOW (Kim et al., 2008) is applied to Ssangcheon watershed in Korea to evaluate the effect of groundwater dam construction. After construction the groundwater level has raised in upstream area of groundwater dam while lowered in downstream area. Also, it is shown that the exchange rate of river-aquifer interactions has increased in the upper area of the dam. Since the storage in the aquifer has largely increased in the upper area of the dam, the exploitable groundwater could be greater as much. These examples demonstrated that groundwater dams may be very useful instrument to substantially increase the available storage in the aquifers. It is also demonstrated that the analysis using SWAT-MODFLOW are useful for the planning and operation of the groundwater dams.

A New "Floodland" Module in the SWAT Codes for the Simulation of Periodically Wet Areas

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The Soil and Water Assessment Tool is widely applied for describing the hydrological and water quality processes in catchments with a strong focus to the agricultural management. Less attention may be given to landscape elements such as wetlands and paddy field, even though they strongly influence the hydrology and chemical cycling in river basins. In many parts of the world, fields have pounding water during different stages of the cropping season as it is the case for paddy field. In natural circumstances, water impoundment may occur in wetlands that are periodically or constantly flooded or impoundment of dry land may occur during flooding events. In all cases, flooded areas have a fundamental different behavior: water is stored in the landscape instead of going to the river, the underlaying soils can become saturated which may reach up to the groundwater and a free water surface gives exposure to evaporation. The water flow velocities drop to zero and may force the suspended sediments and other solids to settle down. The wet soils may quickly convert to anoxic conditions favorising denitrification processes. A proper representation of periodically wet areas is important for Land Cover/Land Use changes studies. A land use change can have strong effects on hydrological and chemical mass balances especially when areas go from dry land to wet land or the other way around.

Within SWAT, different modules exist for wet conditions ranging from land units, or the so-called Hydrological Response Units (HRU's) (potholes, paddy fields and floodplains), water elements that are located in the landscape (ponds or wetlands) and that are located on the rivers (reservoirs). All these elements have their own hydrological and chemical process formulations. In this study, we propose to use a single modeling approach, for the wet areas called _floodland', which contains the formulations for the areas that have pounding water. The _floodlands' are HRU's or parts of HRU's that are temporally or constantly flooded. Each type has its own routines for the impoundments (flooding and releasing). This approach does not only allow for a more efficient and better structured coding, but also resulted in important improvements and corrections with regard to the hydrological mass balance components.

Development of a Fully Integrated System for SWAT and REMM Model

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Various Best Management Practices (BMPs) are applied to manage non-point source pollution (NPS) in watershed, riparian buffer system (RBS) has been known as one of effective BMPs. Therefore, the plant species and width of the RBS should be designed first before installation along the rivers to meet expected water quality improvement with the RBS. In recent years, many efforts were made to evaluate the RBS at watershed with loosely-coupled SWAT-REMM models. Although many improvements were made in the SWAT-REMM system, model users have to run the SWAT first, REMM for riparian modeling, and then SWAT routing, which is time-consuming for a bigger watershed. Thus, fully integrated SWAT-REMM system is being developed in this study with modifications in SWAT source codes and GIS interface. With these efforts, the SWAT-REMM auto-calibration module could be developed for practical application of SWAT-REMM for various studies regarding riparian buffers at a watershed.

Keywords: auto-calibration, BMPs, REMM, riparian buffer system, SWAT

Evapotranspiration Forecast Using SWAT Model and Weather Forecast Model

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SWAT calculates reference evapotranspiration (ETo) using three different methods: i) Priestley-Taylor ii) Hargreaves and iii) Penman-Monteith (P-M). All the methods use meteorological measurements for this calculation. However the P-M method is the most intensive in terms of meteorological measurements but is also considered the most accurate one.

SWAT uses ETo to estimate actual evapotranspiration (AET). For that it takes in consideration water availability in the soil, as well as the development stage of the plant. Water availability depends on soil properties and irrigation practices while plant development depends on agriculture practices and meteorology. This variables accuracy is very much dependent on input.

Traditionally farmers estimate a crop evapotranspiration (ETc) which is calculated by multiplying the reference evapotranspiration ETo, by a crop coefficient (Kc). The calculation of these variables has been standardized by FAO using a set of tables with successive corrections to Kc to obtain AET. These corrections have a correspondence to the SWAT plant stresses and Kc has correspondence to SWAT plant module.

An accurate estimation of AET is very important for farmers, because it allows them to better estimate the amount of water that is being removed from the soil. With this they can better estimate how much water they must use in irrigation.

In this perspective SWAT model is running in forecast mode using meteorological data from the previous week and forecasts for the next week. The weather data is from the closest station of each field (precipitation, temperature, relative humidity, wind speed and solar radiation). The weather forecasts come from a weather forecast model that is running for Portugal. This service is running for Sorraia Valley which is located in Portugal and is a typical irrigated agricultural area, mainly corn crops.

The SWAT model results were sent by mobile phone messages to the corn producers in the Valley Sorraia every week during the irrigation season of 2010 (May-September). Farmers received the temperature, precipitation and actual evapotranspiration data measured last week and the forecast for next week.

This study was developed in AquaPath-Soil project and supported by the European Space Agency (ESA).

This presentation will show the implemented service but will also show the accuracy of AET estimations using meteorology from weather forecast model.

Keywords: SWAT model, evapotranspiration, Penman-Monteith, Irrigation

Adaption to the Sub-Surface Processes in the Soil and Water Assessment Tool

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The European Water Framework Directive aims for obtaining a good status in all water bodies. The guidelines for the directive make a clear distinction between the surface and the groundwater. The groundwater has however a dual role: at one hand, it is a _water body', while at the other hand, a groundwater can also be seen as a source of pollution towards the surface water and may hence threaten the aquatic ecology. The latter role is however often underestimated or overlooked both by managers as by scientists. To tackle this issue, the EU funded project _AQUAREHAB' aims at testing and promoting novel remediation technologies with the dual goal to improve the status of the groundwater bodies, as well as to protect the surface water bodies from toxic pollution.

The Soil and Water Assessment Tool is a widely used tool that has a comprehensive representation of a large number of river basin processes that is developed with the aim to support river basin management. One of the weaker parts of the module is the groundwater component. The aim of this study is to identifify the weaknessess and to propose adaptations to the groundwater module.

The following limitations have been identified:

(1) The groundwater is stored in shallow groundwater elements below the Hydrological Response Units. Since these elements do not have a position in the landschape, it is not possible to implement a real groundwater model where flow is steered by the difference in groundwater heads.

(2) There is a limited interaction between the soil profile and the shallow aquifer. When the aquifer level rises, it is not moving into the soil profile,

(3) The deep groundwater body is _black hole' in the model. All water that is sent to the deep aquifer becomes unavailable the model (except for irrigation). However, it reality, deep aquifer volumes may still be able to recharge to the river in downstream areas.

The following modifications are implemented:

(1) The variable source concept has been implemented into the SWAT codes by linking the shallow water table to the soil profile. In such a way, the soil profile may get saturated by water from down upwards when the shallow groundwater rises.

(2) A deep aquifer storage element has been created at sub-basin scale. This reservoir may move downstream sub-basins (following the routing configuration) whereby part of the water feeds the downstream deep aquifer, while another fraction may discharge into the shallow aquifer of the downstream sub-basin.

The adapted model has been tested on the Odense river basin in Denmark.

The Use and Results of the Soil and Water Assessment Tool in Brazil: A Review of 1999 until 2010

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The Soil and Water Assessment Tool (SWAT) is becoming a familiar tool for some Brazilian students, professors and professionals. The model has been applied for several hydrological studies and evaluations under Brazilian conditions. This research was carried out with the objective of identifying the SWAT model applications in Brazilian watersheds, its strengths, and its weaknesses. Over 70 publications such as theses, dissertations and articles about the use of the model in Brazilian watersheds were analyzed. From these, 60 are referred to in this paper. Despite the significant variability of climates and hydrological behaviors of the modeled watersheds, the results provided by the papers demonstrate that the model had good performance in several Brazilian regions. Based on the papers‘ results, it is also possible to identify that the SWAT performance in Brazilian watersheds permits its use as a support decision tool for municipalities, state companies, federal institutions, basin committees, and environmental organizations. However, there are very few reports about using the SWAT as a practical assessment tool in Brazil. Furthermore, there is some evidence that the hindrance to use SWAT in Brazil is not whether the model can be used here or not, but how to obtain enough quantity and quality data to simulate a basin.

Keywords: SWAT, Brazil, review, application.

Application of SWAT Model in Land-Use Change in the Nile River Basin: A Review

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Land-use change has become a worldwide concern, and it is one of the major topics in current global change studies. It is caused by a number of natural and human driving forces. Whereas natural effects such as climate change are felt only over a long period of time, the effects of human activities are immediate and often radical (Woldeamlak, 2002). In any watershed, land-use change has an impact on hydrological processes, such as infiltration, base flow, runoff and groundwater recharge. The Nile River is the longest river in the world with a length of 6,650 km with a total catchment area of nearly 3 million km2, which covers about 10% of the area of Africa, spread over ten countries. During the last decades strong changes in land-use occurred causing a significant effect on river stream flow and erosion. The Soil and Water Assessment Tool (SWAT) is one of the tools that has been most intensively used to investigate the hydrologic cycle of the Nile. This paper provides a review of studies performed with SWAT on the impact of land-use changes on the hydrology and erosion in Nile River Basin. In general, SWAT model adequately simulates river flows in the study catchments with proper global spatial data or accessible limited data in catchments within the Nile countries.

Keywords: SWAT, Nile Basin, land-use change

Current Application Trends and Data Challenges Regarding the Use of the Soil and Water Assessment Tool (SWAT) in Africa

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The African Continent can be characterized as both a region of vast potential as well as a region facing vast challenges. Severe climatic and environmental stresses are occurring in several African subregions, underscoring the need for advanced analyses that provide critical insights needed for enhanced management of resources. This in turn places increased demand on robust analytical tools that can be used to assess water utilization and protection as well as assessment of other critical resources. The Soil and Water Assessment Tool (SWAT) model has emerged worldwide as a key water quantity and quality model, and is beginning to be embraced more widely in Africa for impact assessments of changes in climate, land use, and other conditions on water resources, and for other types of analyses. A brief review is initially presented in this study regarding the historical use of SWAT in Africa, starting with the first reported applications that occurred in southern and northern Africa, and then expanding to applications that have been performed in countries located in the Nilotic region of Africa as well as other major subregion applications including the entire African continent. The core of the study then focuses on reviewing current application trends with the model, especially for: (1) the Nilotic region countries of Ethiopia, Kenya, and Tanzania, which currently represent the highest concentration of SWAT-related studies in the peer-reviewed literature; and (2) a cutting-edge blue water/green water analysis performed for the entire African continent. Additional discussion is provided regarding data limitations and accessibility facing SWAT users in Africa. Data development needs such as parameters for crops and land use/cover at large not currently included in the SWAT database is critical. Besides, the use of higher resolution of the spatial data is recommended (such as climate) and to better represent the landscape features such as wetlands and ponds. The issue of model accessibility could potentially be addressed by using the recently developed software support tools for SWAT applications such as the public domain Map Windows SWAT (MWSWAT) interface.

The Worldwide Use of the SWAT Model: Technological Drivers, Networking Impacts, Simulation Trends, and Potential Future Constraints

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The Soil and Water Assessment Tool (SWAT) is one of the most widely used watershed-scale water quality models in the world. Over 700 peer-reviewed SWAT-related journal articles have been published and hundreds more have been published in conference proceedings and other formats. The SWAT model has proven to be a very flexible tool for investigating a range of hydrologic and water quality problems at different watershed scales, as well as very adaptable for applications requiring improved hydrologic and other enhanced simulation needs. We investigate here the various technological, networking, and other factors that have supported expanded use of SWAT, and also highlight current worldwide simulation trends and possible impediments to future increased usage of the model. Examples of technological advances include easy access to web-based documentation, user-support groups, and SWAT literature, a variety of Geographic Information System (GIS) interface tools, pre- and post-processing calibration, statistical evaluation, and other software, and an open source code which has proven to be a model development catalyst for multiple user groups. Extensive networking regarding the use of SWAT has also developed, via internet-based user support groups, model training workshops, regional working groups, regional and international conferences, and targeted development workshops. The use of SWAT has expanded dramatically, not only in developed regions such as North America and Europe but also in developing nations such as China, India, and Iran. Several important trends have also emerged regarding improved hydrologic, best management practice (BMP), and pollutant transport methods, which will be further highlighted.

Calibration of a Sub-Daily SWAT Model and Validation using Different Land Use Data To Examine the Impacts of Land Use Changes

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The City of Austin Watershed Protection Department examined the validity of developing and calibrating a sub-daily SWAT model based on one land use dataset, then applying different land use datasets to examine the impacts of different development scenarios. A sub-daily SWAT model was developed for the 145.8 km2 Walnut Creek watershed encompassing portions of northern and eastern Austin, Texas based on an existing daily SWAT model. The sub-daily model used 15-minute precipitation data and land use patterns based on 2003 data. Most calibration parameters were left at their default values but the routing method was changed to Muskingum and the gamma function unit hydrograph method was used. Alpha baseflow was also changed substantially for the sub-daily model. The model was calibrated at a 15-minunte time-step resulting in an NSE = 0.74 for 15-minute data and NSE = 0.86 for aggregated daily results. The model was then run using land use estimates from 1964 based on aerial photography and rainfall from that time period, however only hourly rain was available for this period so the hourly totals were divided by four to approximate 15-minute rainfall. The resulting NSE was 0.572, which was considered acceptable given the data limitations. Other measures of the hydrologic regime were also considered during calibration and validation. The third model was created using a land use dataset approximating full build-out of the watershed. All three models were run using weather inputs from 1990-2007 to producing 15-minute flows at various locations in the watershed under different scenarios.

Keywords: SWAT, sub-daily, modeling, urban, land use

Applying the Sub-Daily SWAT Model to Assess Erosion Potential under Different Development Scenarios in the Austin, Texas Area

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The sub-daily version of SWAT was applied to the 145.8 km2 Walnut Creel watershed encompassing portions of northern and eastern Austin, Texas using land use patterns from 2003. The model was calibrated at a 15-minunte time-step with an NSE = 0.74 for 15-minute data and NSE = 0.86 for aggregated daily results. The model was then run using land use from 1964 and estimated build-out land use using the same calibration parameters and weather inputs. Changes in flooding and erosion potential due to increased urbanization were evaluated at four locations on Walnut Creek. Flooding was evaluated based on the changes in the frequency and duration of bank-full flow rates. Erosion was evaluated based on the changes in annual average cumulative excess shear. The frequency of bank-full flows increased with increasing urbanization while the average duration for these flows decreased indication flashier storm flows. Erosion potential increased with increasing development. The City of Austin Watershed Protection Department plans to use these data along with further enhancements in SWAT for urban applications to create plans and locate hydrologic and water quality controls to help mitigate the impacts of urbanization.

Keywords: SWAT, modeling, urban, land use, erosion, flooding

Use of SWAT by International Engineering Firms

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International engineering consulting firms are involved in major water resources management projects around the world, working with international funding agencies like World Bank, regional development banks, national and local governments, and the private sector. SWAT can be a useful tool for these firms. SWAT's international reputation and widespread use make it an analytical tool of choice for planning of watershed management/protection, agricultural/irrigation development, flood and erosion/sedimentation control, water supply, wastewater treatment, water quality protection, environmental sustainability, water conservation, and climate change projects. Engineering consulting firms can provide experienced SWAT users and developers, including both students and researchers, with opportunities for both project cooperation and employment. This paper presents ideas and examples for the application of SWAT by international engineering firms, and the international SWAT community is encouraged to develop collaborative projects involving such firms.

Applying the Sub-Daily SWAT Model to Assess Aquatic Life Potential under Different Development Scenarios in the Austin, Texas

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The use of modeled SWAT flow for an Austin, Texas watershed in conjunction with a statistical model of aquatic health based on hydrologic metrics is demonstrated as a tool to allow evaluation of impacts to biological community structure under different development scenarios and in response to watershed management measures. One measure of the effect of urbanization on streams in the City of Austin is the health of its biological communities. The difficulty in identifying direct relationships between aquatic biology and measurable stream data limits planning and design efforts for improving the aquatic environment. In Austin, Texas, hydrologic alteration from development is an important stressor in biological community degradation (Scoggins 2000). A statistical analysis of the correlation of individual measures and composited indices of biological communities with daily and sub-daily hydraulic metrics was conducted, expanding the work of Glick et al. (2009). Critical hydrologic metrics are identified and compared with those from a calibrated sub-daily version of SWAT applied to the 145.8 km2 Walnut Creek watershed encompassing portions of northern and eastern Austin, Texas with land use patterns from 2003. In addition, flows output from a historic model using land use from 1964, as well as a future model using estimated build-out conditions, were used to compute the critical hydrologic parameters for subbasins with benthic monitoring sites. These metrics were used to estimate the impacts on aquatic communities under the three different development scenarios. The identification of critical flow characteristics and ability to use SWAT models to predict relative improvements to the hydrologic regime, and subsequently receiving water biological communities, may lead the City to changes in management strategies.

Keywords: SWAT, modeling, urban, land use, aquatic life, benthic community

Evaluating the Effects of Conservation Practices on Water Quality in the Ohio-Tennessee River Basin using a Regional Scale Modeling System

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Increased use of conservation practices in agriculture in the United States has reduced the field losses of sediment, nutrients and pesticides and pollution to the rivers/streams and other water bodies. A number of studies exist that provide the effects of conservation practices on soil and water quality at field scale and watershed scale. However, there is a limitation of a comprehensive effort to quantify the effects of the conservation practices/programs at regional scale/national scale. Hence, an analytical approach involving modeling strategy and farmers survey 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. This paper describes the modeling approach used for evaluating the effects of conservation practices on water quality in major river basins in the United States. Ohio-Tennessee River Basin is focused in this study.

The modeling approach 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. GIS databases consists of databases uniquely developed for national assessment on land use, soils, land use management, topography, weather, point sources and atmospheric depositions that are used to derive model inputs. APEX is used to simulate conservation practices on cultivated cropland and Conservation Reserve Program land based on a subset of farmer surveys. Output from APEX is input into the SWAT in the HUMUS (Hydrologic Unit Modeling for the United States) system. 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.

SWAT/HUMUS system is calibrated at 8-digit watersheds and at selected gauging stations for flow, sediment, nutrients and pesticides. Calibrated model is used to simulate various conservation scenarios. Loadings generated by APEX for cultivated cropland with conservation practices currently in use (Current conditions) and without practices (No practices) and various conservation treatment need (Alternative) scenarios are input into HUMUS/SWAT watershed modeling system. Effects of various scenarios on water quality are determined by comparing source loads and in-stream loads at 4-digit watersheds and major locations in the river basin. Effects are reported as reductions in sediment, nitrogen, phosphorus and pesticides. Modeling tools has capability to provide science based information for implementation of practices, conservation of resources and program development.

Keywords: CEAP, National Assessment, Soil and Water Assessment Tool, Agricultural Environmental Productivity Extender, Conservation Practices, Water Quality Benefits.

Rapid National Model Assessments to Support US Conservation Policy Planning

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Decision makers are often faced with the need to develop conservation policy without adequate information about the resulting environmental impacts. Models such as SWAT and APEX can provide those answers, but national scale models are very complex, and time-consuming to develop. Decision makers debating potential policies require quick answers, forcing modelers to speed up the modeling process. We have developed a framework for the rapid assessment of US National policies. This framework consists of a pre-calibrated SWAT model of the US running in a custom software/hardware platform.

Assessing Impacts of Rangeland Conservation Practices prior to Implementation: A Simulation Case Study using APEX

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Information on grazing land conservation practices and their effectiveness in controlling nonpoint source pollution and watershed health at the watershed/landscape scale is necessary for future planning and resource allocation. Utilizing computer simulation allows land managers the ability to leverage empirically derived data at smaller scales to evaluate potential impacts of conservation measures at larger scales. The objectives of the current study were to test the Agricultural Policy/Environmental eXtender (APEX) model and utilize it to test possible conservation practices within a rangeland watershed. The model was calibrated and validated for flow and sediment yield for the Cowhouse Creek watershed (1178 km2) in north-central Texas. The Nash–Sutcliffe efficiencies (NSE) ranged from 0.67 to 0.81 for monthly stream flow. Monthly sediment yields were compared well for both the calibration and validation periods. Scenario analyses identified substantial reductions in overland sediment losses for conversion of range brush to range grass on Evant soil areas, with an average reduction of 58.8% from treated areas, followed by brush conversion on Eckrant soil area (an average reduction of 53.8% for conversing brush on both soils). Combining brush conversion on these soils to brush grass and reducing stocking rate from 10 ha/herd to 15 ha/herd on all grazing lands would result in an average overland sediment loss reduction of 30% from treated areas and watershed sediment yield reduction of 18%. The study shows that the APEX model is a useful tool for simulating rangeland managements.

Keywords: APEX, Conservation Practices, Sediment, Watershed modeling.

Calibration of SWAT Model for Large-scale Application

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There is an ongoing national assessment study called Conservation Effects Assessment Project (CEAP) aimed to address the environmental benefits obtained from United States Department of Agriculture (USDA) conservation programs implemented in cultivated cropland. The modeling framework is a revised HUMUS (Hydrologic Unit Modeling for the United States) set up, comprising of SWAT (Soil and Water Assessment Tool) with updated databases and APEX (Agricultural Policy/Environmental Extender). APEX, a farm scale model is used to simulate cultivated land with conservation practices. Monthly output from APEX are arranged at the sub-watershed level and input to SWAT. SWAT is used to simulate uncultivated land and route the flow, sediment, and pollutants from point sources, cultivated and uncultivated land to the outlet of each river basin. The entire simulation period is from 1960-2006 at annual time step.

Calibration is carried out separately for APEX and SWAT because they model cultivated and uncultivated land separately. However, there is a lot of back and forth effort in making the overall results acceptable with respect to observations. APEX uses four parameters for flow calibration and SWAT uses an automated procedure with nine parameters to match predicted annual average flow with that of observations for each sub-watershed. Sediment, nutrient and pesticide calibration uses a semi-automated procedure. Flow and water quality results were calibrated/validated at selected gauging stations covering the entire river basin. Where available, the uncertainty limits in observations and data on different constituents of nutrients (NO_3, NH_3 and TKN, Ortho Phosphate etc) were used to evaluate model results. Upstream gauging stations were calibrated before attempting the downstream stations. Statistics on predictions and observations and model performance evaluation measures suggest that the calibrated model results are adequate to make scenario trials. The predicted water quality results were mostly within the uncertainty limits. Selected results from a few gauging stations will be presented.

Keywords: calibration, SWAT, CEAP, large scale, flow, sediment, nitrogen, phosphorus, atrazine.

Utilizing SWAT for Water Supply Planning in Texas

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The Trinity River Basin is the most populated river basin in Texas and includes the Dallas-Fort Worth Metroplex. It supplies water to approximately one-fourth of Texas‘ population. The anticipated rapid growth of North Central Texas over the next 20 to 50 years has increased concerns that sediment and nutrient loads received by drinking water reservoirs are and will continue to seriously reduce reservoir volumes and water quality. The objectives of this project were to use the Soil and Water Assessment Tool (SWAT) model to (1) assess current rates and sources of sediment and nutrient loading of twelve major water supply reservoirs in ten watersheds of the Upper Trinity River Basin, (2) to predict the effects of anticipated future urbanization and (3) to consider possible conservation practices that could decrease sediment and nutrient loading of these reservoirs. This presentation will discuss the results of the project as well as compare SWAT predictions to real world loading rates which have been observed in specific water quality sampling programs in the area.

Cost Effective Multiple BMPs to Reduce the Total Phosphorus Level in a Reservoir

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Eagle Mountain Watershed, located northeast of Dallas-Fort Worth Metropolitan, TX, USA, is one of the five reservoirs that Tarrant Regional Water District (TRWD) manages for water supply to 1.6 million people across 11 counties in the north-central Texas. Recent study indicated that the water quality in the reservoir has been a concern of increasing Chlorophyll-a concentration 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. An intensive sediment study in both channels and reservoir and a long-term water quality data from monitoring stations was used for model calibration. The calibration and validation for hydrology, sediment, and nutrient loading for 36 years using Soil and Water Assessment Tool (SWAT) was conducted and used as a baseline for BMPs scenarios. The impacts of Best Management Practices (BMPs) were assessed with various practices scenario at 100% adoption rate as a sensitivity analyses. Then, the cost of each BMP was estimated at dollar amounts per reducing a kg of total phosphorous. Research groups and stake holder had set the water quality goal as 30% reduction in total phosphorous loading into the reservoir. Based on the goal and the cost analyses, a set of BMPs will be established and implemented in the model to reach the 30% reduction with the minimum cost.

A Decision Support Tool for a Cost-effective Mitigation of Non-point Source Pollution

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Agricultural Best Management Practices (BMPs) are gaining ground as a means to mitigate diffuse nutrient pollution of surface waters in agricultural catchments. However, their efficiency and hence, the ratio between cost and effectiveness in reducing pollution at the catchment scale highly depends on the location-specific characteristics of the land in which they are applied. In order to rapidly identify the most favorable catchment management solutions with respect to environmental and economic objectives, an efficient decision support tool (DST) was developed in MATLAB and integrates the river basin SWAT model into an optimization framework consisting of a multi-objective genetic algorithm. The algorithm is able to search for optimal selection and placement of BMPs across the landscape to satisfy the conflicting objectives, however; for the evaluation of a huge number of BMP combinations in the catchment, a BMP Database, automatically developed in the form of a look-up table, substitutes the time-demanding SWAT model and accelerates drastically the optimization process. The tool has been already implemented in a Greek catchment evaluating the cost-effectiveness of nutrient application, crop, soil and livestock management measures and their combinations in reducing total annual diffuse losses of phosphorus (P) and nitrate-nitrogen (NO3-N) from land to surface waters. A solution identified on the optimal two-dimensional trade-off curves of cost-TP and cost-NO3-N, lead to significant reductions of nutrients in the river demonstrating a spatial management pattern of affordable cost of implementation that would be impossible to plan otherwise. The purpose of the paper is to demonstrate the methodology and tool, which promise a rapid evaluation of management schemes across large agricultural landscapes aiding a cost-effective implementation of the environmental legislation.

Keywords: cost-effectiveness, diffuse pollution, multi-objective optimization, SWAT, trade-off

SWAT-APEX Modeling of the SRI BMP Scenario Effect in an Agricultural Reservoir Watershed of South Korea

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Environmental models are used to evaluate various best management practices (BMPs) at watershed level or field level with a limited number of BMP scenarios individually. The SWAPP (SWAT-APEX Program), the coupling of SWAT (Soil and Water Assessment Tool) watershed model and APEX (Agricultural Policy/Environmental eXtender) field model, is capable of evaluating the BMP scenarios from the watershed to the field application successively. This study tries to evaluate the SRI (System of Rice Intensification) BMP scenario for a typical agricultural watershed (465.1 km2) of South Korea using SWAPP. The watershed includes a reservoir, Yedang and the reservoir irrigates rice paddies of the downstream. As a feasible SRI BMP scenario, the control of irrigation amount, that is, the reduction of ponding depth was applied. The SWAPP was calibrated with 2 years (2000-2001) of daily streamflow and monthly water quality (T-N and T-P) data, and validated for another 4 years (2002-2005) data. The average Nash–Sutcliffe model efficiency of streamflow during validation was 0.65, and the coefficient of determination (R2) of T-N and T-P were 0.74, 0.76 respectively. The application of SRI scenario by control of ponding depth from present to 25%, 50% and 75% reduction in the paddy showed that the T-N and T-P (25% scenario) decreased 26.6% and 28.2% by saving the total irrigation water of 26.98 ton/ha/day during 25% scenario.

Keywords: SWAPP (SWAT-APEX Program), Nonpoint source pollution, SRI scenario

Analysis of Effects on Validation of Spatiotemporal Changes in Cropping at Agriculture-dominant Watershed

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Numerous researches have been performed over the years to reduce the speed of water quality degradation. In addition, Best Management Practices (BMPs) have been suggested for these ends. Various monitoring and modeling approaches have been utilized for selection of site-specific BMPs. In recent years, the modeling approaches have often been used because it can be used for various BMP scenario analysis at a watershed scale. Prior of application of the model to real-world problem, the model should be calibrated and validated properly. In most modeling approaches, the validation process is done by assuming no significant changes occurring at the study watershed between calibration and validation periods, which is not proper assumption for agricultural dominant watersheds. If simulated results obtained with calibrated parameters match observed data with higher accuracy for validation period, this does not imply the simulated result represents rainfall-runoff, pollutant generation and transport mechanism for validation period because temporal and spatial changes in land use/crop rotation are not simulated properly. Therefore, the Soil and Water Assessment Tool (SWAT) was applied to Mandae study watershed in Korea to evaluate effects of spatiotemporal changes in landuses on estimated values using 2009 and 2010 crop data for each field at the watershed. The NSE values for calibration and validation with either 2009 or 2010 crop map will be evaluated and the NSE value for calibration with 2009 map and calibration with 2010 crop map will be compared. The results to be obtained in this study will provide the insight in evaluating model performance with calibration/validation process without considering temporal changes in land use/crop/managements.

Keywords: SWAT, BMPS, Calibration, Verification, Validation

Calibration and Sensitivity Analysis of SWAT for a Small Forested Catchment, North-Central Portugal

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The Soil and Water Assessment Tool (SWAT) was applied to a small forested watershed covered predominantly by commercial eucalypt plantations (*Eucalyptus globulus* Ait.) in North-Central Portugal. The initial model parameterization was carried out a data set composed of widely available data. A manual calibration was performed for the monthly discharges of the period from January to December 2009, resulting in a Nash - Sutcliffe model efficiency (E_{NS}) of 0.82. Subsequent manual calibration for daily discharges produced worse results but the obtained E_{NS} of 0.49, is still widely regarded as acceptable. A sensitivity analysis for the daily calibration was conducted using 20 of SWAT's parameters to identify the most sensitive of these parameters. The six most influential parameters were, in order of decreasing importance, the following: curve number (CN2); soil depth (Sol_Z); hydraulic conductivity (Sol_K); soil evaporation compensation factor (ESCO); threshold water depth in the shallow aquifer for evaporation to occur (REVAPMN); and threshold water depth in the shallow aquifer required for return flow to occur (GWQMIN). Ongoing work will contrast the results of the manual calibration with those obtained by auto-calibration.

Keywords: forest catchment, sensitivity analysis, autocalibration

Comparing Different Model Calibration Strategies for Improved Representation of Landscape Conditions in SWAT at the Example of a Large Heterogeneous Catchment

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An accurately spatially calibrated model provides a basis for developing sound land use and management scenarios that can help to improve water availability and quality in a catchment. Hence, in a large complex watershed with high spatial variability it is important to delineate the calibration sites (subbasins) in such a way that the heterogeneity of the catchment is represented well by the model structure. Typical problems that can arise here are a limited number of gauges, the nested characteristics of the sites or just time constraints to set up the model due to the increasing complexity of the calibration process with high number of potential calibration sites.

Hence, it is important to know the most suitable calibration strategy that is able to represent landscape heterogeneity. Therefore, the Mulde river catchment (6100km²) in Central Germany was calibrated and validated for streamflow, sediment and nutrients by using and comparing four different calibration strategies: (1) single-site calibration using only the basin outlet of the watershed, (2) multi-site calibration using hydrologically connected sites, (3) multi-site calibration using mutually independent gauges, (4) splitting the catchment and setting up separate models for each individual calibration site. Model calibration and estimation of parameter and predictive uncertainty were performed by using the Sequential Uncertainty Fitting (SUFI-2) routine, which is linked to SWAT under the platform of SWAT-CUP2.

The different parameter sensitivities, calibration results and the variability ranges of the calibrated parameters subject to the chosen strategy will be presented. Recommendations will be given on how to set up a model subject to the variety of landscapes in a catchment and provide an estimation of parameter uncertainties using the different approaches. The recommendations derived from the study results can help to improve the representation of landscape conditions in SWAT, which also supports the significance of simulated land use and land management scenarios developed for specific landscape types.

Multi-objective Calibration on Flow and Sediment on a Small Danish Catchment

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Multi-objective calibration procedures are capable of exploiting all the useful information and important characteristics about the physical system contained in the catchment. Previous works focus the multi-objective calibration on a single model. In this study, the model efficiency among different model set-ups is accessed. The SWAT models for a small agricultural Danish lowland catchment are built with different set-ups: SWAT2009 with simplified sediment routing Bagnold equation (EQN-0), SWAT2009 with improved simplified Bagnold equation (EQN-1) and SWAT2005 EQN-0. These models are calibrated using NSGAX on runoff and sediment. The Pareto fronts from the 3 models show that SWAT2009 EQN-0 is the best for the catchment. All three models are equally good in flow but SS results from SWAT2009 EQN-1 are the poorest. SWAT2009 EQN-0 with the parameter set selected from the Pareto front generates good daily flow during both calibration and validation period. The model can capture the dynamics on low concentrations on weekly SS results but not the peaks.

Keywords: Multi objective, calibration, NSGA-II, SWAT, sediment, flow

Runoff and Soil Loss Prediction in a Vineyard Area at Very Detailed Scale using SWAT Model: Comparison Between Dry and Wet Years

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The present work shows an application of SWAT (ArcSWAT 2009.93.5) to map soil erosion at watershed scale in the Penedés (NE Spain), in which important erosion problems are recorded. The main crop is vineyards, alternating with cereals and olive trees. The main data sources were the detailed Soil Map of Catalonia, a 5 m resolution DEM and a crop / land use map derived from 2010 orthophotos. In addition, a 0.5 m multispectral image of a reference vineyard was acquired at the end of July 2010 by means of a multispectral camera (SpecTerra Services, Au) to compute the Normalised Difference Vegetation Index (NDVI). Runoff and soil losses for years with different climatic characteristics were analysed (two dry years with 447.8mm and 365 mm respectively and two wet years with 75.5mm and 729.4 mm with different distribution throughout the year). For the analysed basin (46 ha), differences in annual runoff rates were observed between years, which ranged between 10% and 23% of annual rainfall for dry and wet years, respectively. Soil losses ranged between 1.5 and 25.5 Mg/ha, with clear differences between watersheds depending on soil characteristics and slope degree. This means N losses ranging between 4.4 and 48 kg N-Org/ha and P losses between 1.3 and 7.4 kg P-Org/ha, mainly associated to sediment losses. The results also highlight a relation between soil losses and crop development measured by the NDVI at grape veraison, which is particularly significant in the hydrological response units (HRU) in which gullies are developed within the vineyard field.

Keywords: runoff and soil loss, NDVI, nutrient losses, vineyards, wet and dry years

Modelling Nitrogen in Streamflow from Boreal Forest Watersheds in Alberta, Canada using SWAT

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The present study, which is part of a long-term project (FORWARD: Forest Watershed and Riparian Disturbance) intended to integrate data from watershed ecosystem studies to landscape management, explores the feasibility of using the Soil and Water Assessment Tool (SWAT) as a nitrogen export modelling tool in a forest dominated watershed on the Canadian Boreal Plain. SWAT (in its distributed form as well as a version to better represent nitrogen cycling in forested ecosystems) was used to model nitrate (NO3-) and ammonium (NH4+) concentrations in the Willow Creek watershed (~ 15.1 km2) in the Swan Hills region of Alberta, Canada. Water quality and streamflow data collected during 2002- 2004 were used to calibrate the model. Preliminary results for NO3- and NH4+ concentrations and monthly loads suggest that the model can predict reasonably well only for some periods while showing substantial deviations from the observed values for the rest. Both original and modified nitrogen conversion and pathway routines did not yield satisfactory results, probably indicating the limitations of the algorithms used in SWAT to represent the biogeochemical processes in forested ecosystems. Moreover, the distinct characteristics of the study area such as cold climate, relatively low precipitation (average annual ~ 480 mm) and episodic events (snow melt etc.) along with growth season and evapotranspiration may also have an effect on the temporal variation in NO3- and NH4+ export from the watershed.

Integration of a Landscape Sediment Deposition Routine into Soil and Water Assessment Tool Model

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Sediment delivery from hillslopes to the rivers is spatially variable; this may cause long-term delays between initial erosion and the related sediment yield at the watershed outlet. The concept of sediment transport capacity of overland flow is often applied to the modeling of watershed erosion. The Soil and Water Assessment Tool (SWAT) model already models landscape process using slope classes while dividing the HRU‘s, however, it does not account the deposition process across the landscape. In an attempt to simulate a landscape unit routing of sediment SWAT model version 2009 was modified. A sediment transport capacity of overland flow was calculated using a landscape delineation routine. The new routine was tested on the Arroio Lino watershed, located in Brazil. Simulation results indicated that approximately 60% of the mobilized soil is being deposited before it reaches the river channels. Hence, sediment delivery from hillslopes to river channels is rather limited with an average value of 19.70 t ha-1 year-1. The modified model provided reasonable simulations of sediment transport across the landscape positions. Despite the promissing results of the new SWAT sediment routine simulation, the calibration of the transport capacity parameters (ktc) in the new sediment routine has yet to be adequately solved, so further research is needed to address the uncertainties involved. This new sediment routine needs to be applied and evaluated using others input datasets, especially in areas where reliable spatial sediment transport patterns and spatially distributed depositional data is available.

Keywords: landscape positions; soil erosion, sediment delivery modeling

Use of SWAT to Scale Sediment Delivery from Field to Watershed in an Agricultural Landscape with Topographic Depressions

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For two watersheds in the northern Midwest USA, we have shown that landscape depressions have a significant impact on watershed hydrology and sediment yields, and that the Soil and Water Assessment Tool (SWAT) has appropriate tools to simulate these depressions. We used SWAT to model the watersheds of the Willow River in Wisconsin and the Sunrise River in Minnesota. In each model we implemented SWAT Ponds and Wetlands to capture runoff from about 40% of the area in each watershed. These depressions trapped considerable sediment, yet further reductions in sediment yield were required and achieved by reducing the Universal Soil Loss Equation (USLE) P factor to 0.40-0.45. We have suggested a framework for discussing yields at different spatial scales and shown how SWAT output can be partitioned to extract data at each of these scales. Plot-scale or gross sediment yields are those calculated with the USLE or revised USLE (RUSLE) formulas. Field-scale or modified gross sediment yields are those calculated with the modified USLE (MUSLE), with adjustment parameters such as the USLE P factor set to one. Upland-scale yields are also those calculated with the MUSLE, but with USLE P reduced as necessary to match measured yields reaching lowland depressions and channels. Pre-riverine-scale yields are those reaching the channelized network after runoff has been processed by lowland depressions. Watershed-scale yields are those based on sediment load at the watershed outlet, after pre-riverine loads have been modified by additions from near-channel erosion processes and by losses to sediment deposition on floodplains and in reservoirs.

Water Quality Modeling in Luxembourgish Watersheds for the Identification and Quantification of Sources for River Water Pollution

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The watersheds in Luxembourg are dominated by intensive human activities like agricultural production as well as urban areas with housing, traffic and industrial production. Therefore the river water quality in these catchments is affected by two major sources: (I) diffuse pollution through the use of organic and inorganic fertilizer and pesticides in the agricultural production process mainly in the headwater area of the watershed and (II) continuous discharges of sewage treatment plants connected to urban areas.

We use the Soil and Water Assessment Tool to investigate the impacts of the various pollutant sources on the water quality and to identify river sections and subbasins with possible critical water pollution. The model will be applied to the Wark and to the Mamer catchments. Both watersheds have an area of around 85km2 and a comparable share of arable land on the watershed area with 19% and 21% respectively but differ in the proportion of urban areas. Aim of the study is to generate first information of spatially distributed river water quality to enhance and support decision making for an adapted monitoring strategy. Therefore the model results at the subbasin and HRU scale are used to identify the dominating source of pollutants and to quantify their impacts on river water quality in both watersheds and as well as their temporal behavior.

Modeling Watershed Dynamics in Agricultural/Silvopastoral System of a Semi-arid Zone: Enxoé River in Southeast Portugal

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Enxoé watershed is located in the south-east of Portugal and this watershed is ended by a reservoir. Enxoe River is a semi-arid system of the southern Europe. Enxoé reservoir was built in year 2000 serving water for human consumption and in the first year high flow season (a dry year in the area) introduced excess nutrients in the reservoir boosting cyanobacteria blooms (up to 300 μg/l) that are toxic algae and jeopardize water quality for water production.

The watershed land use is composed of i) olive trees and ii) oak silvopastoral systems. In Enxoé watershed floods rise fast (rising levels to peak occur up to couple of hours) showing runoff contribution that may drag sediment and organic material deposited during dry periods in upland and river. The understanding of watershed soluble and particulated fluxes and their quantification may help in the design and testing of implemented management actions to reduce Enxoé reservoir trophic state.

Enxoé reservoir algal blooms diminished their intensity but still remain high concentrations up to the present and the goal of the study was: i) to quantify the watershed input loads to the reservoir and ii) understand watershed dynamic to support management responses.
This study was supported by the EU AguaFlash project (http://www.aguaflash-sudoe.eu/).

Enxoé is an ungauged river system and validation was done using reservoir water balance and field data collected in the current duration of the project.

Keywords: watershed modelling, SWAT, erosion, Enxoé, Aguaflash

Choosing a Potential Evapotranspiration Method in the Absence of Essential Climatic Input Data

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The three potential evapotranspiration (PET) methods included in SWAT, requires to varying degree of climatic inputs including air temperature, solar radiation, relative humidity and wind speed. In some watershed, there is a need to use the SWAT model for hydrological modeling , despite the unavailability of all or some these inputs. A comparison on the performance of the three PET methods was carried out in the Mara river basin, Kenya, a watershed with varying agroclimatic zones and land cover, ranging from savanna grassland to montane forest, and with precipitation as the only weather input into the SWAT model. The performance was assessed using Nash-Sutcliffe efficiency, and a comparison of the water balances of the observed and simulated data. Although the NSE for daily time series for all the three methods was 0.60, the water balances were completely different between Penman-Monteith and Hargeaves on one hand and the Preistly-Taylor Method on the hand. The Priestly-Taylor method predicted the highest water yield with no surface runoff and grossly underestimated PET. It also predicted the lowest Evapotranspiration/Precipitation (ET/Pcp) ratio , and the highest precipitation/Potential evapotranspitation (Pcp/PET) ratio. Both Penman-Monteith and Hargeaves methods predicted surface runoff accounting for 30% of the water yield, and consistent with observed flows. All the three methods under-predicted the water yield from observed flow by almost a quarter. Compared to literature values of PE (open water) 1400-1800mm, ET/Pcp 0.62, and pcp/PET 0.7, the Penman-Monteith and Hargeaves methods simulate the flow better than the Preistly-Taylor Method.

Keywords: PET methods, water yield, water balance, Nash-Sutcliffe, climatic inputs

Analysis of SWAT Simulated Soil Moisture with the MODIS Land Surface Temperature and Vegetation Index for Soyanggang Dam Watershed of South Korea

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The purpose of this study is to identify how much the MODIS (Moderate Resolution Imaging Spectroradiometer) vegetation index and land surface temperature can explain the soil moisture simulated from SWAT (Soil and Water Assessment Tool) model. For Soyanggang Dam watershed (2,694.4 km2) in South Korea, the SWAT model was calibrated using daily streamflow data for five years (2000-2004) and was validated for five years (2005-2009) at three locations of the watershed with the average Nash-Sutcliffe model efficiencies of 0.71 (A), 0.72 (B) and 0.71 (C), and soil moisture data at three locations with the average coefficients of determination (R2) of 0.63 (a), 0.56 (b) and 0.60 (c), respectively. To derive relationship between the SWAT simulated soil moisture versus MODIS NDVI (Normalized Difference Vegetation Index) and LST (Land Surface Temperature), the spatial and temporal correlation and multiple regression analysis were conducted and compared with SWAT spatial soil moisture during the forest leaf growing and falling periods respectively.

Flood Routing for Continuous Simulation Models

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Recent advances in computer capabilities make continuous flood routing of short time interval hydrographs feasible. Continuous simulation models like the Agricultural Policy/Environmental eXtender (APEX) and the Soil Water Assessment Tool (SWAT) operate on a daily time step and offer options for simulating some processes on shorter time steps (1 h or less). However, they are not adequate for applications like designing flood control structures or estimating flood damages. The flood routing methods must be computationally efficient and robust—convergence problems that cause crashes are not acceptable for continuous simulation. Three flood routing methods (Muskingum-Cunge, Variable Storage Coefficient, and Storage with Variable Slope) were selected for testing for accuracy, efficiency and reliability. Results from these methods are compared with results from the HEC-RAS unsteady flow equations as a test of accuracy. These routing methods were tested in various hydraulic conditions including short/long reach lengths, channel flow only/floodplain flow, and mild/steep slopes. Results show that the Storage with Variable Slope method gave the best overall hydrographs fits. The Muskingum-Cunge method conserved mass balance well, but showed early flow responses in long reaches which was also significant where floodplain flow occurred. The Variable Storage Coefficient and Storage with Variable Slope methods required iterative solutions because they are sensitive to dynamic water surface slopes. The routing methods will be installed in the SWAT and APEX models for extensive testing in a variety of watersheds.

Keywords: Flood Routing, Muskingum-Cunge, Variable Storage Coefficient, Storage with Variable Slope

Impacts of Precipitation Interpolation on Hydrologic Modeling in Data Scarce Regions

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Accurate precipitation data are of prime importance as input to hydrologic models. Monsoon regions often exhibit large spatial and temporal variability of precipitation. Also, the available measurements are scarce in these regions, often show data gaps, and require careful analysis of the data quality. Our study aims at analyzing different precipitation interpolation methods and their effect upon runoff model results calculated with the Soil and Water Assessment Tool (SWAT). The study was carried out in the meso-scale catchment of the Mula and the Mutha Rivers (2036 km²) upstream of the city of Pune, India. Measured precipitation data were tested for homogeneity and consistency using double mass curves and were corrected for wind effects. Data gaps were filled. The corrected precipitation was spatially interpolated using three different methods: i. Thiessen polygons, ii. a geostatistical pooled kriging approach, and iii. a combined regression - inverse distance weighting method. The quality of the different interpolation methods was analyzed a) with respect to their capability to reproduce measured data and b) with regards to their effects upon SWAT model results, particularly runoff. We found that the more complex methods (ii, iii) reproduce the measured precipitation data better. Differences in the catchment‘s modeled water balance are small. However, runoff at the sub-catchment level shows more pronounced differences for the different interpolation schemes. Hence, addressing spatial heterogeneities, the chosen interpolation method is very important particularly in data scarce regions to reproduce runoff accurately.

Keywords: SWAT, Precipitation interpolation, Pooled kriging, Data scarce environment, India

Studying the Viability of a Limno-reservoir using SWAT: The Ompolveda River Basin (Guadalajara, Spain) as a Case Study

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The construction of small dams on the edge of large reservoirs, creating a body of water with a constant level (which we have termed limno-reservoirs), is an innovative idea designed to counteract some of the negative impacts caused by the construction and use of reservoirs.

Pareja Limno-reservoir, located in the left margin of Entrepeñas Reservoir (Guadalajara province) is among the first limno-reservoirs in Spain. Earlier reservoirs such as this one were constructed to create a habitat for birds, but the Pareja Limno-reservoir is the first to promote socio-economic development. However, its construction raises some questions about hydrologic viability, siltation risk and possible eutrophication problems.

Pareja Limno-reservoir is just placed at the outlet of the Ompólveda River Basin, where was installed a streamflow gauging station, operative until 2004. This fact makes it an extraordinary place to apply most of the possibilities that the SWAT model offers. SWAT model has been calibrated and validated in order to analyse the hydrologic response of the basin and, overall, the model had a good performance reproducing the observed streamflows. It will allow predicting the river discharges into the reservoir after 2004 and will dispel some of the doubts about the Limno-reservoir viability.

SWAT also can predict the sediment yield at the basin outlet and, consequently, the the sediment load into the Pareja Limno-reservoir. Although this component could not be calibrated and validated, results suggest that most of the sediments produced in the basin would not reach the Pareja Limno-reservoir. Further results will be compared with the in-situ studies that are on-going in the Ompólveda River Basin.

Keywords: Ompólveda River Basin, runoff, sediment, SWAT.

Using SWAT and GETM to Model Integrated Water Cycle within the BASHYT Environment

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Scientific portals are key components of many large-scale Earth Science projects. Such web environments provide a strong support in accessing to quality information and centric gateways to applications based on workflow and dataflow services. The EnviroGRIDS (http://www.envirogrids.net), NUVOLA and MOMAR (http://www.mo-mar.net/) projects address these needs integrating, tools and expertise with the objective to organize and make available an operational service easy to customize and use for decision makers and technicians. The tool targets the needs of watershed and coastal water resource management, where enlarged and interdisciplinary working groups need to collaborate.

This paper will detail the realizable benefits from moving the traditional desktop approach to a web based paradigm. In particular we will be focusing on the development of a interactive and innovative application based on the SWAT hydrological model and the finite difference General Estuarine Transport Model (GETM). GETM is optimized to be applied in the shelf seas with relatively large tides, where the vertical mixing is intensive. The combined use of these two models proves to be rather useful in estuaries when studying the mixing between fresh water for the river and sea waters.

The portal will expose applications of the above models on the Black Sea region and the Orosei Gulf in Italy to evaluate significant variable states of watershed and marine coastal waters.

Assessing the Application Potentials of Treadle Pump Irrigation Technology in Sub-Saharan Africa

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Sub-Sahara Africa is the least developed region in the world. With the rapid growth of population, the Sub-Saharan countries are faced with great challenges in maintaining food security and poverty reduction. Past experiences have shown that under many circumstances, the smallholder irrigation provides a solution to help secure the food supply and improve the income of farmers. In this paper, we present a comprehensive study to assess the application potentials of the treadle pump irrigation, one of most promising smallholder irrigation technologies, in Sub-Saharan countries. This study is featured by the application of the Soil and Water Assessment Tool (SWAT) and several other modeling/analysis tools. The SWAT applications for major Sub-Saharan African river basins were developed to estimate the amount of water available for irrigation, the yield increases of corps cultivated under irrigation, and the intensities of the irrigated water use. The information produced in the SWAT modeling was integrated with the outcomes of the GIS-based ex-ante suitability analysis and the supply-demand analysis tool into an optimization framework to identify the profitable adoption schemes of treadle pump irrigation in each Sub-Saharan African country. Based on the simulation and optimization results, it was concluded that the application potentials of the treadle pump technology is substantial from the biophysical perspective, but the actual adoption rates are heavily constrained by the market conditions.

Grid Based Hydrological Model Calibration and Execution by SWAT Application

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The presentation concerns with key concepts and architectures supporting calibration and execution of SWAT (Soil Water Assessment Tool) models over Grid infrastructures. The Grid capabilities are required due to the large number of runs required in both calibration and execution processes.

The assessment of the sustainability and vulnerability in the Black Sea Catchment is one of the goals of the FP7-funded enviroGRIDS project (April 2009 – March 2013). By developing a Spatial Data Infrastructure for this catchment region, different scenarios based on environmental changes and water quality models will be simulated.

One of the water quality models that will be used is SWAT (Soil Water Assessment Tool). SWAT is a model designed to estimate impacts of land management practices on water quantity and quality in complex watersheds. The SWAT model requires specific information about weather, soil properties, topography, vegetation, and land management practices of the watershed. The information is collected from stations distributed all over the water basin. The density of these stations is closely related with SWAT input data correctness.

The SWAT application will be integrated as a module in the enviroGRIDS portal. This application will allow the calibration of the SWAT models and the execution of different scenarios based on a calibrated SWAT model. The calibration process will use the SUFI2 uncertainty analysis routine. The flow for calibrating a model is the following: randomly generate uncertainty model parameters, run the SWAT model in several iterations until the objective function is meet and extract the required outputs that correspond to the observed data from the model output files. Different scenarios could be developed by hydrologic experts for executing on a calibrated model and the results of executions could be displayed in different outputs and formats depending on the user‘s requirements.

Both the calibration and the execution require a great number of input and output data files. All the SWAT model files are stored on the Storage Element inside the Grid infrastructure. The input files are uploaded on Storage Element by the hydrologic model developers. The calibration output is used for defining scenarios and for running these scenarios. The visualization and report generation modules use the output data files of the scenario execution.

In order to run the SWAT calibration on the Grid, a parallel approach at the data level should be used. The Grid based approach will speed-up the entire calibration flow of the model. This means that the process could be split in multiple sub-processes that could run simultaneously on Grid nodes. In conclusion, this solution could significantly reduce the total execution time compared to the same process that runs on a single machine that in some cases could take hours or even days. The execution over the Grid infrastructure is done by using Ganga and Diane gLite‘s software packages. Those packages are used as an upper layer above the gLite middleware and provide useful functionalities in managing and monitoring the jobs submitted on the Grid. The large user community of SWAT inside the enviroGRIDS consortium may greatly benefit from a gridified version of the software.

Representation of Modeling Errors by AR(1) Process and Uncertainty Analysis of SWAT Model under Bayesian Approach

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SWAT model is calibrated for simulating streamflow of the Ruscom River watershed, Southwestern Ontario, Canada. The differences between observed and simulated streamflow are described as the modeling errors. The errors may arise from the uncertainties in model input, parameters, structure and output. In the study, the first order autoregressive [AR(1)] process is used to represent the modeling errors via the likelihood function. This likelihood function is used for parameter inferences in the Bayesian approach based calibration process. The uncertainty in model parameters is estimated by the posterior probability distribution. The posterior probability distribution is analyzed by the Shuffle Complex Evolution Metropolis algorithm (SCEM-UA), a Markov chain Monte Carlo (MCMC) sampler and optimization tool. The efficiency of streamflow simulation at the optimum parameter values is quantified by the Nash-Sutcliffe efficiency criterion. The study reveals that the percentages of observed streamflow data covered by model parameter uncertainty are 11.2% and 6.1% during model calibration and validation, respectively. The narrow prediction uncertainty due to model parameters indicates that structural uncertainty is dominating over model parameter uncertainty in simulating streamflow. The adequacy of the statistical error model is verified by some posterior diagnostics. The inclusion of AR(1) model in the calibration process has removed the non-randomness of model residuals. But the residuals are observed to be heteroscedastic. Therefore, for more realistic assessment of parameter uncertainty, the heteroscedasticity needs to be considered in the calibration process.

Soil Erosion Hazard Prediction using SWAT Model and Fuzzy Logic in a large Watershed

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Soil erosion is a major environmental threat to sustainability and agricultural productivity. It can adversely affect the quality of surface and groundwater by adding transported sediments, nutrients, and pesticides, and also by increased turbidity. This study, aimed to identify and prioritize the critical sub-basins in a highly mountainous watershed with imprecise and uncertain data (Bazoft watershed, southwestern Iran). The Soil and Water Assessment Tool (SWAT) was used to develop a hydrologic model for the study area. In combination with the SWAT, a Sequential Uncertainty Fitting Program (SUFI-2) was used to calibrate and validate the model using the daily river discharge and daily sediment load. Uncertainty analysis was also performed for model reliability. A fuzzy logic approach was also developed to assess the soil erosion hazard in the area and further compared with the SWAT model predictions. For this, three important landscape features related to soil erosion hazard, including vegetation cover, slope, and soil erodibility factor was used. The calibration and validation results of the SWAT model showed that most of the predicted discharge and sediment yields agreed well with the observed data. However, the predicted discharge values were more satisfactory than those of the sediment values. The sub-basins S5, S6, S4, and S31 were accounted for about 76% of the total soil loss from the watershed, while they only covered about 11% of total area of the watershed. Furthermore, a large part of the watershed (24 sub-basins) was predicted to be endangered of a high or very high erosion risk using the Fuzzy logic model and only 4 sub-basins fell under very low erosion hazard class.

Keywords: Soil erosion hazard, SWAT, Fuzzy logic, Watershed management

Understanding Water-Human Interaction Through an Intelligent Digital Watershed: Initial Development and Implementation

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Understanding how human activities influence water resources system and how the system responses to those influence is important in developing any sustainable system. This coupled human-water system is quite dynamics in nature and considerable research has been performed to develop an understanding of the impact of local land use decisions on field and catchment scale water related processes. How well we understand and predict those dynamic impacts to do trade-off among profitability and environmental sustainability, aids hugely in formulating long term policies for our sustainable development.

On this context, we propose to develop an Intelligent Digital Watershed (IDW) which fuses emerging concepts of Digital Watershed (DW). DW is a comprehensive characterization of the eco hydrologic systems based on the best available digital data generated by measurements and simulations models. Prototype IDW in the form of a cyber infrastructure based engineered system will facilitate novel insights into human/environment interactions through multi-disciplinary research focused on watershed-related processes at multiple spatio-temporal scales. In ongoing effort, the prototype IDW is applied to Clear Creek watershed, an agricultural dominating catchment in Iowa, to understand water-human processes relevant to management decisions by farmers regarding agro ecosystems. This paper focuses on some of our initial developments and implementations on it.

Keywords: Human-water dynamics, Intelligent Digital Watershed (IDW)

Geospatial Framework for Water Resources Assessment & Planning

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Water resources projects are inherited with overlapping and at times conflicting objectives. These projects are often of varied sizes ranging from major projects with command areas of millions of hectares to very small projects implemented at the local level. Thus, in all these projects there is seldom proper coordination which is essential for ensuring collective sustainability.

Integrated water resources development and management is the accepted answer but in turn requires a comprehensive framework that can enable planning process involving all the stakeholders at different levels and scales. Such a unified hydrological framework is essential to evaluate the cause and effect of all the proposed actions within the drainage basins.

The present paper describes a hydrological framework developed in the form of a Hydrologic Information System (HIS) which is intended to meet the specific information needs of the various line departments of a typical State connected with water related aspects. The HIS consist of a hydrologic information database coupled with tools for collating primary and secondary data and tools for analyzing and visualizing the data and information. The HIS also incorporates hydrological model base (SWAT model output) for indirect assessment of various entities of water balance in space and time. The framework showcases the mechanism to maintain and update the most accurate data and information required for planning and management. This framework provides a common information base to all the line departments and can serve as the first step towards true integrated approach.

The paper presents the implementation of Web-based GIS (ArcGIS Server) and is available at http://gisserver.civil.iitd.ac.in. The aggregation of information is done by placing a database server and by adapting the Hydro data model. Implementation has been designed to ensure that internal GIS capabilities are shared with users in the line departments, while a Web-based platform is maintained for dissemination to external users.

Keywords: Hydro Data model, Hydrological information system, Water Resource management, SWAT model

SWAT2009_LUC: A Tool to Activate Land Use Change Module in SWAT 2009

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Soil and Water Assessment Tool (SWAT) 2009 algorithm has a land use change (LUC) module which results in watershed responses that are also a function of changing land usage. To activate this module, the algorithm requires the area of all hydrological response units (HRUs) to reflect changing land use distribution. However, calculating area of numerous HRUs could easily become a time consuming process for large watersheds and for setting up a long term study. In this project, we report development of a stand-alone, graphical user interface (GUI) driven, SWAT2009_LUC, to automate the processing of land use information at the HRU scale and produce necessary input files to activate the LUC module. The tool has user-friendly sequentially-enabled elements that allow a modeler to upload multiple land use layers. Subsequently the tool connects with the SWAT project, post-processes the HRU layer (if thresholds are used), re-distributes the changing land-uses, and outputs the updated fractional area of the HRUs. The presentation will focus on the conceptual background and test results using SWAT2009_LUC tool.

SWATCUBE: An OLAP Approach for Managing SWAT Model Results

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Nowadays Data Warehouse and On-line Analytical Processing (OLAP) are well known technology in financial services, retail and other market oriented applications. But its application in Water Resources management is comparatively new. In the present study OLAP cube has been used for analysis and visualization of large data sets of SWAT Model generated results to support high performance querying.

Analyzing simulation SWAT model output presents a special challenge because large data volumes are generated much faster than is supported by the available data analysis and summarization technologies. OLAP server facilitates the rapid and flexible exploration and complex analysis of SWAT model results stored in the data warehouse which is typically modelled *multidimensionally*.

OLAP provides functionalities such as summarization, consolidation, and aggregation as well as the ability to view SWAT model result from different aspects. This system shall provide the ability to discern new or unanticipated relationships between variables, the ability to identify the parameters necessary to handle large amounts of data, to create an unlimited number of dimensions, and to specify cross-dimensional conditions and expressions.

OLAP has been implemented on a case study and usefulness of OLAP strategy has been demonstrated to process and manage SWAT output efficiently. The SQL Server Analysis Services (SSAS), ASP.NET application accesses the SSAS using ADOMD.NET Client dynamic-link library have been used in the implementation.

Keywords: Data Warehouse, On-line Analytical Processing (OLAP), Swat hydrological model

A Web Interface to Write the txtinout file for Scenarios Development

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BASHYT is a java based software to expose complex, data driven web applications, optimized to enable temporal and GIS oriented spatial analysis for the SWAT model. It aims at supporting and encouraging scientists to develop their own web applications from scratch and maintain and further develop new services. The software exposes (Wiki like) a fast, flexible, and easy to use processing system based on XML templates. This mechanism enables to combine SQL statements, Java Velocity instructions and JavaScript to program high interactive applications. The platform is based on a distributed DBMS paradigm, a compromise between the traditional RDBMS‘s and a file based distributed data store architecture. Such design has been driven by application workload, data accessibility, scalability and preexisting data configuration. In addition, SPRITE and SWATSL ETL procedures enables users deploy new SWAT projects on the servers. The current version of the software is optimized to expose SWAT results on the web.

In the present work, we explore a web based procedure, its pros and cons, to produce the TXTINOUT files to run new scenarios directly within the BASHYT web framework. In this way, our web based SWAT interface is expected to improve usability, enabling users to develop new scenarios and run the model directly within its framework.

Evaluation of Climate Change Impacts on the Blue Nile Flows using SWAT

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This contribution aims at the quantitative assessment of the impacts of climate change on the water resources and hydrological flow pattern of the Blue Nile River basin using hydrological modeling technique. The Blue Nile River contributes around 60% of the total mean annual flow of the Nile, and most of this flow is generated during the flooding season (July – October) by high precipitation received in the Upper Blue Nile catchment. Large irrigation schemes in Sudan and Egypt are mainly dependent on the flooding in the Blue Nile, which get water from several reservoirs built along the system. However, recent observations show that the climate has changed at an unprecedented rate during the last decade, with an evident increase in extreme precipitation events and temperature in eastern parts of Africa. This increases the vulnerability of downstream located countries for probable effects on their widespread agricultural based economic activities.

This research analyzed the climate change impacts on the Blue Nile River basin by the year 2025, through use of the hydrological model SWAT, with spatial maps and synthetic weather data input. The model was calibrated at a monthly time scale against observed discharge series of four gauging stations of the Blue Nile. The climate change scenarios were constructed using outcomes of two General Circulation Models (MIROC and INMCM) for emission scenarios A2 and A1B, by adjusting the baseline climatic variables that represents the current precipitation and temperature patterns. The constructed climate scenarios were applied to the calibrated and validated hydrological model, to generate runoff and investigate climate change impacts on water yield and hydrological flow patterns.

The results show that the climate is likely to become wetter and warmer in 2025 (2010-2039) in most of the Blue Nile basin; annual water yield is expected to increase at basin scale and low flows become higher, while, the outflows from the Rosieres reservoir show substantial increase in magnitude under combined pressure of climate change and loss of the reservoir storage due to sedimentation. However, uncertainties on the results are high on account of the quality of the baseline climate data, the discharge series and the accuracy of climate models. Overall, the study suggests that the water resources of the Blue Nile River basin will not be adversely affected by climate change depending on future actions. The increase in precipitation and resulting water resources may help to meet future water needs in the region.

Keywords: SWAT, climate change, hydrological model, the Blue Nile, water yield.

Assessment of Future Climate Change Impacts on Stream and Lake Water Quality using SWAT and WASP model

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This study is to evaluate the future potential impacts of climate change on stream and lake water quality for a 6,581.1 km^2 Chungju dam watershed in South Korea using SWAT (Soil and Water Assessment Tool) and WASP (Water Quality Analysis Simulation Program) model. The SWAT model was calibrated and validated using 6 years (1998-2003) daily dam inflow and monthly stream water quality (SS, T-N, and T-P) data with the average Nash-Sutcliffe efficiency of 0.63, 0.74, 0.69, and 0.70 respectively. For the lake of 2.75 billion m^3 storage capacity and 65.7 km^2 maximum water surface, the WASP model was calibrated and validated using the measured monthly lake water quality data (water temperature, DO, BOD, TN, TP, and Chl-a) by using the SWAT simulated results. For the future climate change scenario, the MIROC3.2 hires A1B and B1 data were downscaled for 2020s, 2050s and 2080s using the change factor statistical downscaling method. The 2080s A1B temperature and precipitation were + 4.8 ? and + 34.4 % based on 2000. Through the SWAT assessment, the 2080s watershed sediment load showed the tendency of increase in June and July and decrease in August and September depending on surface runoff change. In spite of the increase surface runoff and water yield, the future decrease of total sediment load could be explained by the overall decrease of peak runoff. The 2080s T-N showed an increase tendency up to 87.3 %, but the T-P load showed 19.6 % increase in 2080s A1B and 7.8 % decrease in 2080s B1 scenario. Under the above future impact on stream water quality, the lake water quality was projected using WASP model. Detailed results and discussions for the lake water quality will be suggested.

Keywords: Climate change, GCMs, MIROC3.2 hires, Hydrological components, Water quality modeling, SWAT, WASP

Comparison of Temperature-Index Snowmelt Models of Varying Complexity in SWAT for Predicting Water Yield in a Cold Region

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The accurate prediction of snowmelt runoff is important in cold regions where snowfall constitutes a significant portion of the annual precipitation. Temperature-index models, which assume an empirical relationship between air temperature and melting, are commonly used in operational hydrological models to predict snowmelt runoff. The popularity of temperature-index models is due to their simplicity, computational efficiency and low data requirements. Moreover, temperature-index models have consistently proven to be just as accurate as more complex energy balance models. A review of the literature reveals that a plethora of temperature-index models of varying complexity have been developed in the past few decades. The objective of this study was to determine how snowmelt models of varying complexity would affect the performance of SWATBF for predicting runoff from two cold regions watersheds. Temperature-index models utilised by several operational hydrological models were incorporated into SWATBF. The number of parameters required by the snowmelt models considered in this study ranged from 2 to 11. Model performance was tested on two watersheds on the Canadian Boreal Plain that are subjected to long, cold winters. Despite variations in model complexity, it was found there was little difference in the performances of the models for predicting runoff from both watersheds. The results of this study demonstrate that simpler temperature-index models can perform just as well as more complex temperature-index models in SWATBF.

Keywords: SWAT, snowmelt, temperature-index model, cold regions hydrology

Economic Valuation and Hydrologic Analysis in View of Sustainable Watershed Management: The Case of Sigi Catchment in Tanzania

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Watershed management options are increasingly faced with conflicting goals between development and conservation. In Tanzania, forest and water resources management authorities and the local communities have not joined in one platform to lay down joint strategies to address the conservation and development matters. As a result, the increased use of the resources for the production and consumption of goods to improve household welfare is the priority under the development goal. However, continued use of these resources in production and consumptions increases pressure and results to watershed degradation. On the other hand, the conservation goal centers on restricting the direct use of the watershed resources as a means to ensure watershed sustainability. This situation has put watershed conservation and human development policy options in great conflicts, thus jeopardizing the sustainability of many watersheds in the country. This paper presents the methodology and results from the developed model to bridge this policy gap. The study used an integrated economic valuation and hydrologic analysis to identify the hotspot areas for conservation and crop production in the Sigi catchment in Tanzania. The hydrologic analysis, through the Soil and Water Assessment Tool (SWAT), established the homogeneous zones or hydrological response units (HRUs) and the crop yield in the study area. An economic analysis established the crop revenue of the HRUs. The study found an average maize yield to be 1.72 ton/ha. HRUs in the ―forest" land use category were found to have higher crop yield and revenue than HRUs in the land use category ―intensive cultivation", ―shrub land" and ―scattered cropland". The implication is that high yield differentials would cause households currently cultivating in low yield areas to encroach forested areas for crop cultivation. Investments on awareness creation and on the use of improved farming methods, necessary to boost crop productivity, are needed in the study area. The novelty of this paper is that crop yield estimation by the SWAT model fits well as a link variable between the biophysical and the socioeconomic attributes of the sections of the watershed. As such, the methodology allows for the cost-effective identification of areas suited for both the conservation goals and for the economic development at the catchment scale.

Keywords: SWAT, economic valuation, hydrologic valuation, integrated valuation, watershed conservation, household welfare

Assessing Hydrologic Impact of Anthropogenic Activities Located at the Upper Part of Jequetepeque River Basin, Peru

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This study develops the distributed watershed simulation model Soil and Water Assessment Tool (SWAT) to model run-off and sediments transport, applied to the Peruvian Jequetepeque watershed (4372.5 km2) with an important anthropogenic activity: the presence of open pit mines with different location, importance and temporality in the upper-middle part of the watershed. On the other side, Páramo ecosystems are also found in the upper part of the watershed. They may notably influence the hydrologic regime of the basin, being highly vulnerable to climate changes and anthropogenic activities. The purpose focuses on the evaluation of the contributions from wetlands, lakes, future mine sites and other anthropogenic activities, and identify and evaluate the critical source areas at watershed scale. Then, different scenarios according to future mine projects allocated at the recharge sites of the watershed are performed. First, specific developed mine soil is evaluated. Model is calibrated with data from 1999 to 2005 and validated with data from 2006 to 2009. Parameter identification and specification are performed with the LH-OAT method and the SCE-UA method respectively, included in ArcSWAT2005. Results show very good values with the Nash-Sutcliffe Efficiency coefficient of 0.87, the Percent Bias of 9.4 % and the Observations Standard Deviation Ratio of 0.37. Therefore different scenarios of future mine projects are made and the impact on hydrological contributions is assessed due to these land use changes (from wetlands and pastures to pine forestation or open pit mine). Identifying and quantifying these influenced factors in the basin is crucial in addressing the water scarcity conflicts.

Keywords: impact assessment, land use changes, wetlands, mining

Application of SWAT to Model Rangeland Production Dominated by Sagebrush (*Artemisia sieberi)* in Hable-Rud Basin, Iran

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The rangeland areas in arid and semi-arid regions of Iran account for 85% of the national total rangeland area. Despite suffering from high grazing pressure and periodic droughts, they make an important contribution to country‘s economy as well as playing an important role in environmental protection and food security. To determine how to better manage this important resource, we developed a rangeland-livestock model using the Soil and Water Assessment Tool (SWAT). The model was tested in the Hablerud River basin in Tehran and Semnan Provinces, Iran. Sagebrush species of Artemisia sieberi L. and Artemisia aucheri L., (covering more than 50% of the total rangeland areas in Hablerud) were chosen and their phonological characteristics were used to add the necessary plant growth parameters to SWAT land use database. In combination with the SWAT model, the Sequential Uncertainty Fitting Program (SUFI-2) was used to calibrate and validate a hydrologic model of the watershed based on river discharges and biomass production of Sagebrush species, taking into consideration historic grazing management in the region. This study can be extended to predict the rangeland production under climate change impact in drought prone areas. This provides the basis to assess feasibility of alleviating drought induced livestock losses through forward looking forage planning. The analytical framework in this study can be used for the assessment of forage production and livestock management toward environmental protection and sustainable food production in arid and semi-arid environments.

Keywords: Arid environments, food security, proper stocking rate, rangeland-livestock model, SUFI-2, yield calibration.

Modelling the Nitrate Dynamics and the Role of Buffer Zones in a Major European Catchment, the Garonne River, in Southwest France

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Nitrogen dynamic in surface water is complex and highly variable in space and time, depending on hydrology, landuse, and removal in stream and buffer zones. The main sources of nitrogen in lowland catchments are fertilizer from agriculture and domestic and industrial effluents. The main source in upland forested areas is from atmospheric deposition. It is believed that the major sources of denitrification in watershed include in-stream processes, riparian zones and wetlands.

In southwest France, water resources are essentially surface water and shallow aquifer. The Garonne (63 000 km²) is the principal catchment in southwest France and the country‘s third longest river. Agriculture occupies approximately 60% of the total catchment area (mainly maize and a minority of wheat, oilseed, vineyards and fruit trees).

To understand the factors and processes influence flow and nitrate dynamics in surface water (under different climate zones and geological characteristics); and to assess the relative inputs, the spatial and temporal dynamics of nitrate concentrations in the river network of the Garonne (52 000 km²) are modelled by the SWAT model.

Keywords: Nitrates, Garonne River, buffer zones, SWAT model, European catchment

Community Based Watershed Modeling in Nigeria

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A major challenge for small to medium-sized watershed modeling in Sub-Saharan Africa is the lack of data for model development and calibration. Fortunately, many datasets have become available for SWAT including ASTER digital elevation models for basin delineation and slope, Landsat data for a land use/cover, and European digital archives of soil maps. Meteorological datasets are available through the National Oceanic and Atmospheric Administration (NOAA), however, these datasets are often incomplete. To address data scarcity for model development, a community based SWAT modeling project is underway in Osun and Ondo States, Nigeria where secondary school teachers are collaborating with faculty and graduate students at the Federal University of Technology at Akure and Bowen University in Nigeria and Brooklyn College, North Lake College, and University of Nebraska-Lincoln in USA. Two automated data loggers have been installed at Ataoja Secondary Science School and Bowen University in June 2009 to increase the spatial and temporal resolution of meteorological data. During teacher trainer workshops in Osun State, land use/cover validation data were collected to assess the accuracy of the land cover map created from Landsat data and soil samples were analyzed to improve the soil classifications used in SWAT. Now that the model has been developed, the next major challenge is to determine ways to calibrate the model. After refining this pilot project in southwestern Nigeria, the community based approach will be applied to other Nigerian states to the north to allow an extensive study of water resources along a climatic gradient of wet climates in the south to arid regions in the north, and to project how climate change will affect these resources at the small to medium watershed scale.

Evaluation of Snowmelt Contribution to Streamflow in a Heavy Snowfall Watershed of South Korea using SWAT Model

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This study is to evaluate the snowmelt impact on streamflow of Youngsangang watershed (3,455 km^2), one of the heavy snowfall regions in South Korea. The SWAT (Soil Water Assessment Tool) model was adopted and the snowmelt parameters (elevation bands, precipitation and temperature lapse rates, rain/snow threshold, melt coefficient, snowpack temperature melt threshold, and areal snow coverage threshold) were estimated. The areal snow coverage was from MODIS (Moderate Resolution Imaging Spectroradiometer) products at 500 m resolution, and the snow depth was spatially interpolated using snowfall data of ground meteorological stations. The elevation effect was considered by applying the lapse rates. The SWAT model was calibrated and validated using 9 years (2000-2008) streamflow data and the average Nash-Sutcliffe model efficiency was 0.62. The streamflow especially for the snowmelt period and the runoff contribution among the annual runoff will be will be discussed.

Keywords: SWAT, snowmelt, MODIS, snow coverage area, lapse rate

Runoff Simulation in a Glacier Dominated Watershed of Rhone River using Semi Distributed Hydrological Model

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The semi-distributed hydrological model soil water assessment tool (SWAT) has been applied successfully in agricultural watershed all over the world but very little in mountainous glacier dominated catchments. To address this application gap, a pilot study was undertaken to apply SWAT in a glacier-dominated watershed located in the Rhone River catchment in Switzerland. This work is a part of the 7th Framework European project entitled ACQWA (Assessing climate change impact on quantity and quality of water). The catchment area covers 40 km2, where most of the land cover is dominated by glacier that covers 48 percent of the watershed. Stream flow calibration was done both monthly and daily for the period of 2001-2006, and validated for 2006-2009. The ice thickness of the glacier was converted with equivalent water using an empirical equation and substitute to four elevation bands. Model performance was evaluated both visually and statistically where a good relation between observed and simulated discharge was found. NSE for monthly and daily calibration was 88 and 80 percent and between 70 and 80 percent for the validation period. Information gained from this study can be applicable for the high elevation snow and glacier dominated catchment with similar hydro-physiographic constraints.

Keywords: temperature index model; snow melt; snow fall; elevation band

Development of SWAT Hydrologic Input Parameter Guidelines for Specific Iowa Landform Regions for TMDL Analyses and Other Water Quality Assessments

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This research focused on applying the Soil and Water Assessment Tool (SWAT) model version 2009 to determine the most appropriate choices of input parameters for performing hydrologic assessments with the model in seven principal Iowa landform regions. These regions cover the majority of the state and capture most of the intensively cropped regions in the state. The appropriate input parameters for each landform region were developed using a simulation strategy that consists of: (1) calibrating SWAT on an initial watershed in a given landform region, and (2) validating SWAT on a second watershed within the same landform region using the calibrated parameters developed for the first watershed. Thus, SWAT analyses are being performed for 14 different watersheds across the seven different landform regions. The SWAT simulations were initially constructed in the ArcSWAT interface using land use, soil, topographic, climate and other data compiled by the Iowa Geologic and Water Survey. The SWAT simulations were then ported to the interactive SWAT (i_SWAT) interface developed by the Center for Agricultural and Rural Development (CARD), to perform the simulation analyses for each watershed. A key initial step in the SWAT simulation analyses was the determination of the most accurate representation of total baseflow versus surface runoff contributions for each of the landform regions, using hydrograph separation techniques and information from previous studies. These baseflow analyses were used as guidance to determine baseflow contributions for the calibration watersheds in each landform region. Accounting of subsurface tile drains were a key component of the baseflow contributions in some of the watersheds. Additional calibration of SWAT for both annual and monthly streamflows in each of the calibration watersheds was performed using standard manual calibration methods described in previous Iowa and other modeling studies. Calibration and validation results for selected landform regions will be presented, as well as insights regarding the effects of land use and geologic features unique to some of the different landform regions.

Simulation of Stream Discharge from an Agroforestry Catchment in NW Spain using SWAT model

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The Soil and Water Assessment Tool (SWAT) was applied to the Corbeira catchment, a small agroforestry area (16 km2) located in Northwest Spain under humid temperate conditions. The study area is mostly covered by forest (65%), the remainder consists of grassland (26%) and cultivated land (3.8%). The aim of this study was to determine the applicability of SWAT for modelling stream discharge using both manual calibration and autocalibration. The stream discharge data at the outlet of the catchment for the hydrologic years 2005/06-2009/10 were used for model calibration (2005/06-2007/08) and validation (2008/09-2009/10).
The results show a satisfactory agreement between the observed and simulated discharge, based on the Nash-Sutcliffe model efficiency (NSE), with the results of autocalibration being slight better than those of manual calibration during the calibration period. The model was able to capture the dynamics of the catchment response well, although with a slight overestimation of peak discharge and a slight underestimation of low flow. The results suggest that groundwater and soil characteristics are the most sensitive parameters in this catchment. Therefore, improvements regarding groundwater and soil parameterization are necessary.

Keywords: SWAT, NW Spain, agroforestry catchment.

An Assessment of Climatic and Anthropogenic Impacts on a Hydrological System

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Stream flows in the Himayat Sagar Catchment (HSC), Andhra Pradesh, India have been declining for the last two decades due to various changes such as, climate change and major anthropogenic changes including land use changes, increased in hydrological structures and groundwater extractions in the catchment. The major focus of this research is to assess the historical and future impacts of these changes by understanding the interactions and dynamic nature of hydrological pathways in the catchment. This study characterises the major anthropogenic changes in the catchment and quantify their relative impacts on stream flows of HSC. As part of the study, an ArcSWAT model (Surface water hydrological model) has been developed and calibrated for 5 years (1995-2000) and then validated for 5 years (2000-2005). Further analysis, such as separating the individual influences and quantifying their historical and future impacts are under progress.

POSTER SESSION

Development of Conceptual Model for the Integrated Surface-Groundwater Analysis in Jeju Island

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The novel conceptual framework for the integrated surface-groundwater analysis in Jeju Island is being developed by using SWAT-MODFLOW coupled model. The characteristics of groundwater flow in Jeju Island shows radial flow from the highest mountain called Mt. Halla. Most streams in higher elevation region show dried condition except some large rainfall event. The unsaturated depths below these streams are more and more reduced according to the topography. Therefore time delay parameter in SWAT should be carefully determined. In this study, PRISM(Parameter-elevation Regressions on Independent Slopes Model) is also used for the accurate estimation of precipitation. Soil characteristics in Jeju Island is newly updated with the recently investigated data by NAAS(National Academy of Agricultural Science).

Keywords: Conceptual model, SWAT-MODFLOW, Jeju Island

The Effect of DEM Resolution on Slope Estimation and Sediment Predictions

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Moderate resolution (30 m) digital elevation models (DEMs) are normally used to estimate slope for the parameterization of non-point source process-based water quality models. These models, such as the Soil and Water Assessment Tool (SWAT), utilize the Universal Soil Loss Equation (USLE) and Modified USLE (MUSLE) to estimate sediment loss. USLE relies on a slope length and steepness (LS) factor which has a very significant effect on USLE outputs. For example, a four-time increase in slope potentially results in a four to 10 times increase in the LS factor and subsequent sediment estimation, depending on the slope length. Recently, the availability of much finer resolution (~2-3 m) DEMs derived from Light Detection and Ranging (LiDAR) data have increased. With the expectation of better and perhaps more accurate model erosion estimates, water quality modelers are eager to take advantage of these finer resolution information. However, the use of these finer resolution data are not always appropriate, since slope values derived from fine spatial resolution DEMs are usually significantly higher than those estimated from coarser DEMs resulting in considerable variability in model output. This paper addresses the implications of parameterizing models using slope values calculated from DEMs with different spatial resolutions (90, 30, 10, and 3 m). Here, we see a 100% increase in slope from the 90m to 3m DEMs, which has a 78% increase in soil loss estimate from the USLE. The results of a comparison among different slope calculations and associated sediment model predictions on a well-monitored watershed are presented and discussed.

Keywords: DEM, LiDAR, SWAT, MUSLE, Watershed Models

Simulation on Runoff of Rivers in Jeju Island using SWAT Model

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In Jeju island, which is the famous island in Korea, most streams dry up due to rapid recharge of rainfall to deep aquifer through highly permeable volcanic basalt rock. For this reason, the accurate estimation of hydrologic components by using watershed model is very difficult. In this work, stream flow simulation was carried out by using SWAT. For this purpose, accurate measurement of stream flow in 4 major streams is being performed. This preliminary modeling is to check the runoff rate of those watersheds and to compare this with existing flow data which is very limited. The modeling result shows that the average runoff rate of Cheonmi watershed which is located in the eastern region of Jeju island is 22% for the applied period. It is the similar value to the existing average runoff rate. The modeling result for Oaedocheon watershed which is located in the northern region shows R2 of 0.93, RMSE of 14.92 and ME of 0.70 when comparing with the existing measured flow. The result for the Ongpocheon watershed which is located in the western region shows R2 of 0.86, RMSE of 0.62 and ME of 0.56 when comparing with the existing measured flow in 2002~2003. The result for Yeonoaecheon watershed which is located in the southern region shows R2 of 0.85, RMSE of 0.99 and ME of 0.83 when comparing with the existing measured flow in 2003. As results, the simulated stream flow by SWAT model generally shows good agreement with the existing measured flow data. When flow measurement for the major streams in Jeju island is perfomed, the model calibration and validation would be fairly enhanced.

Keywords: SWAT model, Runoff Simulation, Jeju Island

Sensitivity Analysis and Calibration of the SWAT Model: Understanding Model Behaviour in Hydrological Studies of the Daning Catchment, China

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Since the construction of the Three Gorges Dam in China, the effects of natural and human-induced changes have made the management of the Three Gorges Reservoir Region (TGRR) extremely complex. The Daning River catchment, one of the important tributary basins of the TGRR, has experienced changes in flow regime as well as enhanced sediment erosion and nutrient enrichment. The downstream part of the basin has been inundated forming a backwater zone which suffers from eutrophication. A large challenge is to understand the hydrological and water quality responses to these changes. Hydrological and water quality models are useful tools to simulate the influences of land use, soil, topography, and climate conditions on flow, sediment and nutrient yields under different temporal and spatial dimensions. Using the Soil and Water Assessment Tool (SWAT 2005), this study is to determine the appropriate level of subcatchment division that can efficiently and adequately simulate the catchment behaviour and avoid over parameterization of the model. It is also to assess the performance and applicability of the SWAT2005 model for prediction of river flow and sediment yields in the Daning catchment. The results show variation in the subcatchment area has little effects on the parameters and ranking stability for surface runoff modelling. 25 km^2 is a critical level of subcatchment scaling for sediment modelling. The performance of SWAT2005 model in hydrology and sediment modelling at Daning River catchment was proved well by calibration and validation. The predicted runoff fits well with the observed discharge with determination coefficient of higher than 0.7.

Preliminary Investigation for the Development of a Water Allocation Module in SWIM to Study the Impact of Prospective and Conflicting Irrigation and Water Resources Management Plans in the Inner Niger Delta under Climate Change Conditions

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The Inner Niger Delta is a network of tributaries, channels, swamps and lakes in the climatic sahelian zone which forms an inundation plain experiencing a drastic seasonal variation in discharge, and flood extent, from 8 to 25 thousands km^2. Consisting of the middle course of the Niger River; the third longest river in Africa with a watercourse of 4200 km and a drainage basin of 2.1 million km^2, water serves multiple and conflicting functions for more than 1 million people in the sub- region.

The current infrastructure in the Upper Niger River is composed of dams, reservoirs and diversion channels. In the coming decades this infrastructure will be reinforced allowing capacity to develop energy production and to expand fully managed irrigation system upstream. Coupled with the effects of climate change, these projects have a significant impact on the ecosystem and on the flow regime of the Inner Niger Delta which compromise the perenniality of traditional free submersion agriculture practices, essential for meeting regional food security targets.

The study aims to introduce the diversity of irrigation systems in Mali, and to explore, based on the existent data, adaptive methodologies to represent in SWIM water allocation management. Therefore, a review of the methodologies applied in various models to represent irrigation practices and the corresponding intervention in the crop and soil interface is presented. Some preliminary applications in SWIM are tested to model the impacts of irrigation on crop growth and yield and in the change of flow regime.

Investigation of Monsoon Variability and Related Impacts on Hydrological Processes in the Nile Basin under Climate Change Conditions

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The Nile River basin drains a catchment area of about 3 million km² ranging over an extremely wide band of latitude, from 4°S to 32°N. The water serves multiple functions for more than 150 million people living in the basin area. Almost the entire basin is influenced by the climate pattern of the Hadley Circulation, while the eastern part of the region is affected by monsoonal precipitation accounting for a significant amount of the system input. The discharge regime is directly coupled with the monsoon season spending high precipitation amounts from June to October. The variability of the monsoon can be high and is the reason for extreme drought and flood events in the Nile River basin. Therefore, the basin represents an illustrative study area to investigate climate change impacts on monsoon variability and related feedbacks on a global to regional scale.

The study aims at analyzing the intra-seasonal variability of the monsoon and its consequences for the Nile River under the conditions of climate change. This knowledge forms the basis to develop a sustainable and effective water use management. Strategies for adaption to climate variability and change will be investigated in model simulations and in communication with local experts.

To analyze these effects a system of models will be applied including regional climate models and the eco-hydrological model SWIM. Furthermore, existing data sets will be statistically analyzed and compared with the modeling results.

Climate Change Impacts on River Flow Regime and Discharge into the Danube Delta including Quantification of Scenario Uncertainty

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The Danube River Basin covers a vast area of 801,463 km2, making it the second largest river basin in Europe. Both discharge decreases and increases are generally considered to be detrimental for aquatic ecosystems. Future discharge changes of the Danube due to climate change are still unclear.

As Europe's largest remaining natural wetland, the Danube Delta maintains an enormous biodiversity and wildlife. Many of the species that live within the static freshwater ecosystems of the delta are unique to it, but its ecosystems are affected by changes upstream the Danube River. The prevalence of the wet zones of the Danube Delta is caused by the high quantities of water discharged by the Danube River.

To quantify possible impacts of climate change on Danube‘s discharge rates and flow regime, the eco-hydrological model SWIM (Soil and Water Integrated Model) is applied to simulate daily time series of river discharge. Climate data from various regional climate models based on different global climate models and scenarios are used as input for SWIM. The results serve for quantification of the range of scenario uncertainty.

Upgrading the Grid-based Discretization Scheme in SWAT

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For modeling purposes a watershed has to be spatially discretized. Because of the routing command language implemented in SWAT it is theoretically possible to model a watershed based on either grid cells or representative hill slopes or by partition into sub-watersheds. All current interfaces use the sub-watershed discretization, which divides the watershed into sub-basins based on topographic features and management practices. The sub-watershed discretization scheme is unable to account for spatial variability within a watershed and for large watersheds currently there is no interface available generating the SWAT input files based on grid cells. A grid-based model approach has been developed. ―SWATgrid" has successfully accomplished the first model runs using SWAT test data sets. First, a watershed configuration file is generated by processing a digital elevation model using TOPAZ (TOpograpic PArametriZation, version 3.1). Then the remaining SWAT input files are created using grid-based data. Thus, SWATgrid enables a conservation of detailed spatial information such as remote sensing data. In this paper, the functioning of SWATgrid will be demonstrated by comparing results of SWATgrid with conventional SWAT model results and the development of the grid-based discretization scheme will be presented. The paper focuses on the performance, problems and advantages of the grid-based discretization within SWAT.

Keywords: grid cell, grid-based, discretization scheme, SWATgrid, model interface

Reduction of the Peak Streamflow as a Result of Vegetation Rehabilitation in the "Yesos of Barrachina" Protected Area

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The objective of this study was to evaluate the impact of vegetation rehabilitation in the ―Yesos of Barrachina" protected area (Spain), using a modelling approach. The SWAT model was applied in the Jiloca watershed. We present the Pancrudo subbasin results, where the protected area is located. The model was calibrated for monthly streamflow using a 10-year data record obtained in three monitoring stations (NSE between 0.52 and 0.63; RSR between 0.60 and 0.69 and PBIAS between 5.27 and 22.67). The model simulated streamflow successfully in the Pancrudo River when the rainfall events were generated by active Atlantics fronts. However, high intensity convective thunderstorms were not captured by model. The calibration scenario represents conditions of the subbasin prior to the implementation of rehabilitation treatments, while the "Vegetation" scenario represents the conditions of the watershed after a simulated rehabilitation process. Mean streamflow in the "Vegetation" scenario was a 26% lower (0.022 m3 s-1) than in pre-treatment conditions. For the events generated by active Atlantics fronts, the daily stream flow was an 83% lower (5.194 m3 s-1). For the estimated high intensity convective events, daily stream flow was a 37% lower (1.433 m3 s-1). Overall, our results reflected a reduction of the peak streamflow as a result of vegetation rehabilitation

Keywords: peak streamflow, rehabilitation, storm, SWAT model

Modeling the Water Balance Processes for Understanding the Components of River Discharge in a Non-conservative Watershed

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The study was conducted at Shibetsu watershed, eastern Hokkaido, Japan, to examine the possibility of using the Soil and Water Assessment Tool (SWAT) model in a non-conservative watershed with external contribution (EXT) and to understand the components of river discharge. The EXT is hard to measure directly and also challenge to simulate by SWAT due to its subsurface circulation. In this study, the EXT was roughly estimated by water balance equation using measured data. The average daily value of EXT (1.38 mm/day) was added as point source discharge at the assumed point in SWAT. Monthly estimates of streamflow during calibration and validation phases produced satisfactory results with a Nash Sutcliffe coefficient (ENS) of 0.89 and 0.81, respectively. Evapotranspiration (ET) simulation was satisfied with seasonal patterns, compared with measured data. Those results suggest that the EXT added as assumed discharge in SWAT can well simulate the streamflow in Shibetsu watershed, although the internal hydrological processes should be more refined. The EXT then was examined by looking at the difference of observed streamflow and simulated streamflow without adding assumed point source discharge. Future work may need to improve the SWAT to simulate the EXT directly.

Keywords: SWAT; external contribution (EXT); water balance

Estimating Relationship Between Vegetation Dynamic and Precipitation in Central Iran

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We analyzed the relationships between precipitation and vegetation dynamics in a part of Yazd province of Iran. The analysis was built upon a monthly time series of Normalized Difference Vegetation Index (NDVI) derived from the Advanced Very High Resolution Radiometer (AVHRR) onboard the meteorological satellite of National Oceanic and Atmospheric Administration (NOAA) and precipitation data from meteorological stations across the study area during the period of 1996-2008. Monthly, seasonal and annual precipitation maps were produced using the co-kriging interpolation approach in combination with a digital elevation model (DEM). Inter-annual and intra-annual relationship between precipitation variations and vegetation dynamics were examined by means of statistical linear and non-linear regressions. Results showed the strength of the relationship between precipitation and NDVI is depended on species combination in the vegetation cover. High response of vegetation to precipitation was observed in the northern and eastern parts of the area where annual forbs and grasses such as Scariola orientalis, Launaea acanthodes, Stipa barbata, Euphorbia heterandena, and Echinops orientalis are considerably exist. On the other hand, the correlation is low in the south-west parts of the area that could be due to the existence of some shrubs and bushes such as Tamarix ramosissima, Cornulaca monacantha, Seidlitzia rosmarinus, Ephedra strobilacea, Haloxylon aphyllum and Calligonum comosum that are not sensitive to precipitation.

Keywords: precipitation variations, vegetation dynamic, DEM, AVHRR, NDVI, Iran

Evaluation of the APEX Model for Organic and Conventional Management under Conservation and Conventional Tillage Systems

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Research is ongoing at the Mountain Horticultural Crops Research and Extension Center in Mills River, N.C. to evaluate surface water quality from certified organic and conventionally managed farming systems. Rotated vegetable and continuous tomatoes and sweet corn in 20 plots were also under consideration since 1995 to 2010. Runoff, sediment and nutrient predictions of the Agricultural Policy Environmental Extender (APEX) model will be evaluated under organic and conventional management, and conservation and conventional tillage systems. APEX predictions on the control and four treatments: organic management in conventional tillage system, organic management in conservation tillage system, conventional management in conventional tillage system, and conventional management in conservation tillage system will be shown. APEX simulation will be tailored for each plot with runoff, and soil and nutrient losses outputs summarized for each treatment. The mean measured values of runoff, and soil and nutrient losses for each treatment from the year 2010 will be compared with the mean APEX values. Crop yield and biomass is also estimated and compared with measured data for 16 years, from 1995 to 2010. Statistical measures of good fit between predicted and measured values will be calculated. This research may extend the application of APEX for simulating organic systems and may confirm its applicability for use in the Piedmont.

Keywords: APEX model, organic production, crop yield, nitrogen, phosphorus, modeling

A Coupled Catchment-lake Model to Simulate Historical, Contemporary and Future Water Quality of a Eutrophic, Polymictic Lake

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Diffuse pollution in the form of nitrogen loads from increasingly pastoral landuse over recent decades have resulted in increased productivity and frequent cyanobacterial blooms in Lake Rotorua, New Zealand. Local government are investigating the retirement of dairying in the lake catchment with the aim of returning water quality to historic levels prior to landuse intensification. The coupled hydrodynamic-ecological model DYRESM-CAEDYM was used to simulate the lake ecosystem over six 8-year periods within 1920–2100. Meteorological input included historic measurements and forecast simulations based on IPCC climate change predictions and downscaling with the model DARLAM. Catchment nitrogen inputs were obtained using the NIWA model Rotorua Taupo Nitrogen (ROTAN) for three land-use scenarios, including ―business as usual" and two levels of dairy conversion within the catchment. Bottom sediments are a significant source of nutrients to Lake Rotorua, therefore, a further scenario of internal phosphorus load reduction by application of a capping agent in 2031 was also simulated. Sediment nutrient concentrations in CAEDYM are currently static, and therefore incapable of representing interactions between changes in external nutrient load and bottom sediments. We observed a significant relationship in historic monitoring data between nitrogen load and hypolimnetic oxygen demand, as well as sediment nitrogen concentrations. This relationship was used to adjust model parameters for sediment nutrient release and oxygen demand. The coupled models satisfactorily reproduced historic and contemporary lake trophic state, and showed that substantial catchment and in-lake restoration would be necessary to achieve the desired improvement in water quality.

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