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EAWAG
Swiss Federal Institute for Environmental Science and Technology

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Book of Abstracts

Karim Abbaspour and Raghavan Srinivasan, (ed.)

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The following persons are acknowledged for helping to put together the 3rd International SWAT workshops and conference:

Iswarya Srinivasan
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Shankar Srinivasan

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Conference Objective

Soil and Water Assessment

Natural watershed systems maintain a balance between precipitation, runoff, infiltration, and water which either evaporates from bare soil and open water surfaces or evapotranspires from vegetated surfaces, completing the natural cycle. The understanding of this hydrologic cycle at a watershed scale, and the fate and transport of nutrients, pesticides and other chemicals affecting water quality is essential for development and implementation of appropriate watershed management policies and procedures.

In recent years, application of models has become an indispensable tool for the understanding of the natural processes occurring at the watershed scale. As the natural processes are more and more modified by human activities, application of integrated modelling to account for the interaction of practices such as agricultural management, water removals from surface bodies and groundwater, release of swage into surface and sub-surface, urbanization, etc., has becomes more and more essential.

The program SWAT (Soil and Water Assessment Tool) due to its continuous time scale, distributed spatial handling of parameters and integration of multiple processes such as climate, hydrology, nutrient and pesticide, erosion, land cover, management practices, channel processes, and processes in water bodies has become an important tool for watershed-scale studies.

The third international SWAT conference to be held at EAWAG in Zurich, Switzerland will devote itself to discussions around the application of SWAT to watershed problems world wide. The 5-day program will include 2 days of hands on learning of the SWAT program at the introductory and advanced levels, followed by three days of conference covering a variety of topics related to watershed modelling such as hydrology, water quality, landuse management, erosion, and system analytic topics in calibration, optimization, and uncertainty analysis techniques.

Scientists associated with research institutes and those associated with government agencies and centers for policy making are encouraged to take part in this international conference in order to become familiar with the latest advances and developments in the area of watershed-scale modelling and applications.

Agenda

3rd International SWAT Workshops & Conference

Zürich 2005

Beginners & Advanced Workshops: July 11-12

July 11

9:00	18:00	First day of the workshop at the AKADEMIE Building, EMPA-EAWAG

July 12

9:00	18:00	Second day of the workshop at the AKADEMIE building, EMPA-EAWAG
18:30	**20:00**	**REGISTRATION AND ICE BREAKING COCKTAIL PARTY AT THE AKADEMIE**

	Session Description
A	Model application
B	Directions in watershed modeling
C	SWAT development & accessories
D	Calibration, sensitivity & uncertainty
E	Comparison of SWAT & other models
F	Management scenarios & application to decision framework

First Day of Conference: July 13

8:00	**9:00**	**REGISTRATION AT THE AKADEMIE**	
9:00	9:10	Karim Abbaspour, Welcome	
9:10	9:20	Peter Reichert, Introduction to EAWAG	
9:20	9:30	Franz Stössel, DEZA	Opening remarks
9:30	9:45	Mark Weltz	Conservation effects assessment project in U.S.A
9:45	10:00	Karim Abbaspour	Application of SWAT in global freshwater availability
10:00	10:15	Faycal Bouraoui	Application of SWAT in EU 15 countries
10:15	10:30	Fanghua Hao	Application of SWAT in China
10:30	10:45	Ashvin Gosain	Application of SWAT in India
10:45	10:55	Majid Afyuni	Application of SWAT in Iran
10:55	11:10	Clarence Richardson	Modeling and monitoring watersheds in U.S.A
11:10	**11:30**	**COFFEE BREAK**	

Session I: Moderator- Jeff Arnold

B	11:30	11:50	**Philip Gassman**, Review of peer-reviewed literature on the SWAT model
B	11:50	12:10	**Valentina Krysanova**, Prerequisites for application of ecohydrological river basin models in ungaged basins and large regions
B	12:10	12:30	**S.M. White**, Using SWAT in English catchments: experience and lessons
B	12:30	12:50	**Jürgen Schuol**, Limitations, problems and solutions in the setup of a large-scale hydrological SWAT application
B	12:50	13:10	**Adriana Bruggeman**, Use of SWAT for the assessment of water productivity in Mediterranean catchments, a case study in Syria
	13:10	**14:10**	**LUNCH BREAK**
	14:10	**15:20**	**POSTER PRESENTATION**

Session II: Moderator- Nicola Fohrer

A	15:20	15:40	**P.M. Ndomba**, The suitability of SWAT model in sediment yield modeling for ungauged catchment. A case of Simiyu River subcatchment , Tanzania
A	15:40	16:00	**Katrijn Holvoet**, Dynamic modeling of pesticide fluxes to surface waters using SWAT
A	16:00	16:20	**N. Kannan**, Predicting diffuse-source transfers of surfactants to surface waters from sewage sludge using SWAT
C	16:20	16:40	**Theresa Possley**, SDA SWAT Edition: Efficient spatial data analysis & visualization for SWAT results
	16:40	**17:00**	**COFFEE BREAK**

Session III: Moderator- Valentina Krysanova

	17:00	17:20	**Jeff Arnold & Raghavan Srinivasan**, New features of SWAT 2005
A	17:20	17:40	**V. Vandenberghe**, Use of optimal experimental design for river water quality modeling to update sampling strategies in river water year by year, considering costs and practical limitations
A	17:40	18:00	**Jennifer Jacobs**, Application of SWAT in developing countries using readily available data
A	18:00	18:20	**Bruna Grizzetti,** Performance of the SWAT model in an inter-comparison of nutrient loss quantification tools throughout Europe (EUROHARP project)
C	18:20	18:40	**P.M. Allen**, SWAT-DEG and channel stability assessment
	18:40	**21:00**	**SOCIAL GATHERING AT THE AKADEMIA POSTER AREA**

Second Day of Conference: July 14

Session IV: Moderator- Lutz Breuer

C	8:30	8:50	**F.F. Hattermann**, Integrating wetlands and riparian zones in regional hydrological modeling
C	8:50	9:10	**Ramesh Rudra**, Adapting SWAT for riparian wetlands in Ontario watershed
C	9:10	9:30	**Jim Kiniry**, Developing parameters to simulate trees with SWAT
C	9:30	9:50	**Brett M.Watson**, Improved simulation of forest growth for the Soil and Water Assessment Tool (SWAT)
C	9:50	10:10	**P. Cau**, A user friendly multi-catchments tool for the SWAT model
	10:10	10:40	**COFFEE BREAK**

Session V: Moderator-Antonio Lo Porto

C	10:40	11:00	**Martin Volk,** Towards a process-oriented HRU-concept in SWAT: catchment-related control on base flow and storage of landscape units in medium to large river basins
C	11:00	11:20	**Jing Yang**, Interfacing watershed models with systems analysis tools: implementation for SWAT
C	11:20	11:40	**Ann van Griensven**, Evaluation of models using SWAT 2005
C	11:40	12:00	**Ruth. A. McKeown**, Modifications of the Soil Water and Assessment Tool (SWAT-C) for stream flow modeling in a small, forested watershed on the Canadian Boreal Plain.
D	12:00	12:20	**Francisco Olivera**, Two-step method for SWAT calibration
	12:20	**13:20**	**LUNCH BREAK**
	13:20	**14:45**	**POSTER PRESENTATION**

Session VI: Moderator- Raghavan Srinivasan

D	14:45	15:05	**Johan Huisman**, The power of multi-objective calibration: three case studies with SWAT
D	15:05	15:25	**Bryan Tolson**, Comparison of optimization algorithms for the automatic calibration of SWAT 2000
D	15:25	15:45	**Griet Heuvelmans**, A comparison of parameter regionalization strategies for the water quantity module of the SWAT with application to the Scheldt River basin
F	15:45	16:05	**A.K. Gosain**, Vulnerability assessment of climate change impact on Indian water resources using the SWAT model
	19:00	**22:00**	**SOCIAL DINNER AT UETLIBERG**

Third Day of Conference: July 15

Session VII: Moderator-Karim Abbaspour

D	8:30	8:50	**Gerd Schmidt**, Effects of the spatial resolution of input data on SWAT simulations – a case study at the Ems River Basin (Northwestern Germany)
A	8:50	9:10	**Antonio Lo Porto**, Application of water management models to Mediterranean temporary rivers
D	9:10	9:30	**Feliciana Licciardello**, Runoff-erosion modeling by SWAT of an experimental Mediterranean watershed
E	9:30	9:50	**Do Hun Lee**, Comparison of daily runoff responses between SWAT and sequentially coupled SWAT-MODFLOW model
A	9:50	10:10	**M. P. Tripathi**, Hydrological modeling for effective management of a small agricultural watershed using SWAT
	10:10	**10:30**	**COFFEE BREAK**

Session VIII: Moderator- Raghavan Srinivasan

F	10:30	10:50	**Philip Gassman**, An Analysis of the 2004 Iowa Diffuse Pollution Needs Assessment using SWAT
F	10:50	11:10	**Claire Baffaut**, Potential accuracy of water quality estimates based on non-calibrated SWAT simulations
F	11:10	11:30	**Ilona Bärlund**, Assessing SWAT model performance in the evaluation of management actions for the implementation of the Water Framework Directive in a Finnish catchment
F	11:30	11:50	**Le Duc Trung**, Application of SWAT Model to the Decision Support Framework of the Mekong River Commission
F	11:50	12:10	**Lutz Breuer**, Effects of the new European Common Agricultural Policy on water fluxes in a low mountainous catchment of Germany
	12:10	**13:10**	**LUNCH BREAK**
	13:10	**15:30**	**POSTER PRESENTATION**

Session IX: Moderator- Martin Volk

F	15:30	15:50	**Jan Cools**, On the use of SWAT for the identification of the most cost-effective pollution abatement measures for river basins
F	15:50	16:10	**Michael W. Van Liew**, A Cursory Look at Downstream Stream flow and Sediment Response to Conservation Practice Implementation
F	16:10	16:30	**Michael F Winchell**, Development of Complex Hydrologic Response Unit (HRU) Schemes and Management Scenarios to Assess Environmental Concentrations of Agricultural Pesticides Using SWAT
	16:30	17:30	**Jeff Arnold & Raghavan Srinivasan**, Future of SWAT, ArcGIS-SWAT interface

Poster Presentations

Motalib Ahsan, Global Climate Change and Future of Water Resources in Bangladesh

Majid Afyuni, Nitrate pollution of groundwater in central Iran

Manouchehr Amini, Mapping risk of cadmium and lead contamination to human healthin soils of Central Iran

Saeed Boroomand, Crop coefficients of sugarcane (Ratoon) in Haft Tappeh of Iran

Saeed Boroomand, Floodwater effect on infiltration rate of a floodwater spreading system in Moosian

P. Cau, A Decision Support System based on the SWAT model for the Sardinian Water Authorities.

Johannes Deelstra, Scale issues hydrological pathways, and nitrogen runoff from agriculture- results from the Mellupite catchment, Latvia

Thorsten Dey, Spatially differentiated calculation of the water balance in a part of the Treene watershed (Northern Germany)

Shaaban-Ali Gholami, Distributed Watershed Modeling of a mountainous catchment

C.H. Green, SWAT model development for a large agricultural watershed in Iowa

Mohammad Hajabbasi, Depasturtation effects on soil physical and chemical properties in Isfahan and CharMahal Bakhtiari Region

Fanghua Hao, The study of the non-point source pollution in Heihe River Basin

Claudia Hiepe, Modeling soil erosion in a sub-humid tropical environment at the regional scale

Andreas L.Horn, Modeling water quality issues in the Treene catchment in northern Germany

A. Jalalian, Soil physical and chemical properties as indicators of the degree of land degradation in Kuhrang Area, Zayandehrud Watershed

Manoj Jha, An assessment of alternative conservation practice and land use strategies on the hydrology and water quality of the Upper Mississippi River Basin

S. Kondratyev, Macro-scale catchment modeling in North-West Russia

Peter Laszlo, Application of AVSWAT2000 to simulate the various management scenarios on the Lake Balaton watershed, Hungary

Roberta Maletta, Impact of precipitation data interpolation on the quality of SWAT simulations

Ivan Maximov, Modeling of hydrology and water quality in the Thur River Basin

Claire Baffaut, SWAT modeling response of soil erosion and runoff to changes in precipitation and cover

Maria Quiteria Oliveira, Hydrologic modeling semi arid region (Brazil)

Thorsten Pohlert, Evaluation of the soil nitrogen balance model in SWAT with lysimeter data

Joachim Post, Modeling soil carbon cycle for the assessment of carbon sequestration potentials at the river basin scale

A. Rahimi, Evaluation of soil infiltration in furrow irrigation and determination of Kostiakov & Kostiakov-Lewis equations coefficients

Pipat Reungsang, Assessment of agricultural management practices in the Upper Maquoketa River Watershed Northeast Iowa: using two modeling approaches

Juan G. Martínez Rodríguez, Using SWAT model to assess vegetation change effects on runoff volume in a semi arid watershed in Northern Mexico: I. model calibration and validation

Hamed Rouhani, Evaluation of SWAT stream flow components for the Grote Nete River Basin

Ramesh Rudra, Application of AVSWAT2000 to Fairchild Creek, Grand River, Ontario

Hossein Saadati, Investigation of the effect of land use change on simulating daily discharge flow using SWAT (case study: Kasilian catchment area)

Javad Sadatinejad, Water-salt balance in large catchments

C. Santhi, A modeling approach for evaluating the water quality benefits of conservation practices at the national level

Ivan Sarwar, Creation of monitoring system of the Dnipro River Basin to protect environment and public health

Gholamabbas Sayyad, Transport and uptake of Cd, Cu, Pb and Zn in Calcareous Soil of Central Iran under wheat and safflower cultivation – a column study

Sucharita Sen, Monitoring and evaluation of integrated watershed development programs in India: a case study of Dangri Watershed, Haryana

Sucharita Sen, Prioritizing watershed development programs in developing countries

Dongil Seo, Application of Meso-Scale Land Cover Information for Nonpoint Source Pollutant Modeling of Yongdam Dam Watershed Area, Korea using AVSWAT

Gene Takle, Climate change impacts on the hydrology and water quality of the upper Mississippi River Basin

Antje Ullrich, The sensitivity of SWAT to the variation of management parameters

A. Vassiljev, Model for nitrogen leaching from a watershed using field scale models

Gabriel G. Vazquez, Use of SWAT to compute groundwater table depth and stream flow in Muscatatuck River Watershed

Gabriel G. Vazquez, Calibration and validation of the swat model to predict atrazine in streams in northeast Indiana

T. L. Veith, Method for analyzing parameter uncertainty in SWAT 2003

S.M. White, The TERRACE project: SWAT application for diffuse chemical pollution modeling

S.M. White, Catchment scale modeling of pesticide losses with imperfect data – a case study from the UK

J. Whitehead, Ensuring appropriate hydrological response for past and future nutrient load modeling in the Norfolk Broads

Eyilachew Yitayew, Groundwater resource management in the urban environment

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Scientific Committee

Oral Presentation Abstracts

Review of peer-reviewed literature on the SWAT model

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The SWAT model (Soil and Water Assessment Tool) is a continuation of over 30 years of modeling efforts. SWAT combines features of several United States Agricultural Research Service (ARS) models and is a direct descendant of the SWRRB model (Simulator for Water Resources in Rural Basins) (1). In 1989, major changes were made to the SWRRB model developed by Williams and Arnold. Ultimately, they decided that the changes were great enough that SWRBB's name had to change. Williams then conceived the 'SWAT' acronym. Since then SWAT has been gaining international acceptance as a robust *interdisciplinary* watershed modeling tool. Two international SWAT conferences have been held in Europe, national SWAT related conferences had been held in the USA, and SWAT papers have been presented in several meetings sponsored by scientific societies in the USA, Europe, Asia, and Australia. Furthermore, SWAT is part of the US Environmental Protection Agency's BASINS' model, and is being supported by several federal and state agencies/institutions in the USA. At present, over 130 peer-reviewed articles have been published that report SWAT applications, reviews of SWAT components, or other research that somehow involves using SWAT. These and other key publications need to be summarized to know what has been done on SWAT, and what needs to be done to improve it. Thus the objective of this paper is to: (1) group SWAT peer-reviewed articles and other relevant articles into several categories such as hydrologic applications, pollutant applications, development of SWAT components, comparisons with other models, sensitivity analyses and calibration techniques, interfaces with economic and other models, climate change impacts on hydrology and other categories; (2) summarize findings in the articles; and (3) highlight emerging applications and recommend research directions for SWAT.

(1) Arnold and Fohrer 2004. *Hydrol. Process.* 18,(0-0, in press). Published online in Wiley InterScience.

Prerequisites for application of ecohydrological river basin models in ungaged basins and large regions

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The need for assessment of water resources availability and quality in large river basins, in ungaged basins and large regions has often been pointed out. It is becoming increasingly important for water resources evaluation in countries with poor data availability, and for climate and land use change impact assessment at the regional scale. The main objective of the presentation is to discuss prerequisites and conditions for such applications using ecohydrological river basin models like SWIM and SWAT. SWIM was developed based on SWAT-1993 for climate and land use change impact studies. SWIM has several improved/modified subroutines and several new modules in comparison with SWAT-2000, e.g. the crop generator to distribute crop rotations; the riparian zone module as an interface between upland areas, groundwater and river network; the forest growth module; the module for CO_2 adjustment of plant growth; and the carbon cycle module.
The following problems related to regional applications will be discussed: (a) general data needs and options to reduce data requirements, (b) choice of strategy for model validation, and (c) analysis of uncertainty related to model parametrization and input data. Based on our modelling experience, an outline of the minimum data requirements will be given, and most critical input data that need careful estimation in advance will be discussed. Another purpose is to discuss the multi-site, multi-scale and multi-criteria validation method of a regional-scale ecohydrological model based on uncertainty analysis performed in advance. This method was successfully applied for modelling with SWIM in the Elbe River basin in Germany (drainage area of about 100.000 km^2). The basin is representative for semi-humid landscapes in Europe, where water availability during the summer season is the limiting factor for plant growth and crop yield. Whereas the primary idea of distributed hydrological modelling is to reproduce water fluxes in subbasins and hydrotopes along with river discharge, the models are usually validated using only observed river discharge at the basin outlet, and multi-scale and multi-criteria validation is rather exceptional. However, this is especially important for large basins combining areas with different environmental conditions. Though river discharge is an integral attribute of hydrological processes in the basin, its correct representation by the model does not guarantee adequacy in spatial and temporal dynamics of all water components in the basin. Our validation method enables to check the reproduction of local hydrological processes like water table dynamics in subbasins, nutrient fluxes and vegetation growth dynamics in hydrotopes. Analysis of parameter sensitivity and analysis of uncertainty related to model parametrization and input data should be done before the validation in order to optimize the validation strategy.

Using SWAT in English catchments: experience and lessons

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SWAT has been applied to a range of river basins across the UK, ranging in size from 141.5 ha to 1264 km^2. The basins represent a range of environmental conditions from the far north-east (the Tees) where land use is largely un-managed moorland, through the intensive agriculture of the East Anglia region (Colworth, Wensum, Ant and Bure), to the dairy cattle dominated south-west of the country (Exe and Axe). Due to the range of land use, soil, climate and resultant hydrological response SWAT has faced some major challenges.

In addition the objectives of the studies have been very different. We have looked at the complexity of sub-catchment/HRU definition, the modelling of nutrients, pesticides and other chemicals, the impacts of climate and land use change, and the modelling of sediment yield.

The studies have enabled us to draw conclusions about the way that we need to define and parameterize inputs, and to make recommendations for model calibration and validation. The outputs are being built into a SWAT modelling strategy for the UK to enable others to use the model in a comparable way so that a body of experience and model applications can be developed. We have also been able to better define data needs to support modelling in the UK context.

Limitations, problems and solutions in the setup of a large-scale hydrological SWAT application

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Although SWAT models are applied to many basins all over the world, little research has been undertaken on their applicability in large-scale (millions of sqkm) watersheds. Our study has the goal to quantify the amount of the global country-based available freshwater starting with a (sub-)continental appraisal. Especial emphasis is given to the quantification of the spatial and temporal distribution of the total available water as well as the soil water considering its importance for rain-fed agriculture.

The approach to setup the SWAT model for whole continents using the ArcView-interface is not possible as the interface is incapable to calculate the geomorphic subbasin-parameters for such a large area with more than 1500 subbasins. Therefore we model in a first step a four-million-km^2 area in West-Africa, including the basins of the river Niger, Volta and Senegal. During this setup we faced some further AVSWAT-specific problems mainly due to the limited manual influence on stream definition and subbasin delineation. The DEM had to be manipulated in order to avoid a misrouting of the streams. Many of the necessary SWAT soil and land use parameters don't exist on a global/continental scale making it necessary to use pedotransfer functions and assumptions based on similar classes in order to assign reasonable values. The weather station density and thus the climatic data availability are in most areas of the world not sufficient and often of humble quality. This is also shown by the calculated climatic station statistics which can often not be trusted without an in-depth analysis at each station. As this analysis is not practicable at many hundred stations it didn't seem to be appropriate to use the WXGEN weather generator model included in SWAT. Instead we use gridded monthly climate data from which we calculate the average for each subbasin and based on this we generate daily values. This can be done in an automated procedure, which is very important in respect to the large scale and the huge data amount.

Once we managed to overcome the initial SWAT and data shortcomings, first simulations show promising results in respect of our freshwater quantification goal, even though detailed and quite challenging calibration efforts are still necessary.

Use of SWAT for the assessment of water productivity in Mediterranean catchments, a case study in Syria

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In large parts of West Asia and North Africa, rainfall is not sufficient for crop production. Water harvesting, the collection and storage of surface runoff provides a critical water supplement for crop production in these areas. However, the collection of water in the upstream areas affects the downstream users of the resource. SWAT2000 was applied to evaluate the long-term water productivity on a watershed basis in a small (28 km^2) catchment in northern Syria. The area has a Mediterranean climate, with a long-term average winter rainfall (October–May) of 210 mm. A small reservoir has been constructed at the outlet of the catchment. Farming families populate the valley's three villages. The main agricultural activities are rainfed barley and small ruminant production. In wet years the barley is harvested and the residue grazed by the sheep, in dry years the complete crop is grazed. Recently, farmers have started to establish olive orchards, both on the stony slopes and on the flatter, well-drained valley soils. Some farmers prepare micro-catchments in their orchards to harvest runoff water for the trees. Sheep graze the degraded natural vegetation on the stony limestone hill-slopes that border the valley. The hill-slopes are dissected by gullies, which carry runoff water down the steep, stony slopes. The runoff often disperses in the flat, deep soils of the cropland before it reaches the main *wadi*-system. This paper presents some modifications made to SWAT2000 and suggestions for the use of the model to simulate resource management processes in dry Mediterranean catchments. The modifications include the grazing of crop residues, dormancy times, and the management of olive orchards. The option "irrigation from reach" was used to re-apply runoff water to the runoff-receiving areas below the stony slopes. With these modifications ArcView SWAT was found a useful tool for the long-term simulation and visualization of the hydrological system in these dry environments. Water balance components of long-term simulations are presented.

The suitability of SWAT model in sediment yield modeling for ungauged catchment. a case of Simiyu River subcatchment, Tanzania

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In Tanzania context, different approaches of erosion control measures and modeling techniques have been applied in the past that includes government campaigns or enforcement, experimentation (runoff plots) and mathematical models. In order to cope with soil erosion problem in the Uluguru Mountains, Morogoro region, the then government of Tanganyika territory, introduced series of conservation measures. These involved compulsory bench terracing on all fields of medium slopes, with re-forestation in steeper slopes, grass barriers and firebreaks around all fields. The assumption behind was that sheet wash and flush runoff were the major problems and that large terraces were the most effective method of controlling soil erosion. The new techniques imposed to indigenous farmers did not succeed. It is no doubt; the methods that require experimentation are demanding, in terms of resources and its transferability. Models that require large calibration data from runoff plots have not been found to be a reliable tool in the region. Nevertheless, some researchers tried to use renowned empirical models such as USLE, to estimate sediment yield whereas the results of the model were validated with reservoir sedimentation surveys. However, in the previous studies it was difficult to model inter-annual erosion rates, sediment deposition, gully erosion and, riverbank erosion and to simulate individual erosion processes in the catchment. Besides, the lack of calibration data prohibited them to ascertain their findings. As a result researchers in Tanzania and elsewhere in the tropics could not have a common tool for assessing the erosion rates in the catchment. The results of Sediment yield modeling using SWAT model in Simiyu basin suggests that the model can be applied in ungauged catchment (i.e. poor data regions). For instance, daily flow data, which was used to calibrate the water balance equation in the model, was found to be almost adequate to get the simulated and scanty observed sediment loads equal. The long-time annual flows between observed and simulated were comparable with means of 12.93m^3/s and 12.67m^3/s respectively. Simulation of inter-annual flows, between 1970 and 1971, gave a modeling efficiency according to the Nash and Suttcliffe of 58%. The long-term specific yield of 0.523t/ha/year was simulated. It was also found that the use of free available Internet Geo-Spatial data for SWAT model development highlighted an opportunity for the applicability of complex models such as SWAT in the ungauged catchment. Besides a set of factors that cause erosion in the catchment could be determined. Therefore, this paper calls for sediment yield modeling community from the tropic region to customize the SWAT model in their local area for improved watershed management. Nevertheless, this paper proposes for an improved SWAT model structure in the form of coupling the model with hydraulic channel network models such that flood routing could be handled and thus sediment loads be routed.

Dynamic modeling of pesticide fluxes to surface waters using SWAT

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Pesticides are well known for their ecotoxicity, their potential bio-accumulating properties and their hormone disrupting effects. As a consequence, management practices, i.e. pesticide application will influence water quality and thus form an interesting issue in view of the European Water FrameWork Directive.

To get a better insight in the dynamic occurrence of pesticides in surface water, the release of pesticides to surface water has to be determined accurately. In this study, use is made of SWAT (Soil and Water Assessment Tool), a physically based, continuous model. It was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large, complex catchments with different soil, land use and management conditions over long periods of time. The first step is the development of a reliable hydrodynamic model within SWAT. The hydrodynamic behaviour of a river catchment will determine in great extent the transport of solutes, suspended sediments and other particles in the water system. By adding pesticide characteristics and management to the SWAT-model, the movement of the chemical in the watershed can be studied.

As an example, a small subcatchment of the Dijle river (Belgium) that was studied in detail in terms of pesticide applications by interviewing local farmers and monitoring pesticide concentrations in surface waters, is modelled. Both the dynamic hydrological regime and the associated diffuse pesticide loads are calculated at subcatchment scale. The pesticide release both dissolved and bound to soil particles depends to a large extent on hydrology. Predictions of diffuse release of pesticides are compared with measured pesticide concentrations in the studied surface water. The importance of point sources (i.e. due to the clean up of pesticide spraying equipment, leakages, etc…), versus diffuse sources is discussed.

Predicting diffuse-source transfers of surfactants to surface waters from sewage sludge using SWAT

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Chemicals present in domestic wastewater can adsorb to solid phase materials during sewage treatment. If sewage sludge (or biosolids) is applied to land, these chemicals can be transferred to soil. Under some circumstances they can also be transferred to surface waters during storm events either in solution or attached to sediment. In this work we applied SWAT 2000 (Soil and Water Assessment Tool) model to estimate diffuse-source surface water exposure to Linear Alkylbenzene Sulphonate (LAS), an anionic surfactant commonly used in household detergents. The model was applied hypothetically to a small catchment (Colworth) in Bedfordshire, UK. Biosolids were represented in SWAT as two components one with nutritional value and the other representing sludge-associated chemical. LAS transfers were estimated for two scenarios: (1) Realistic and (2) Worst case, based on assumptions about sludge application rates and the concentration of LAS in sludge. In addition, the sensitivity of the model output to the proportion of the catchment to which sludge is applied was established. Although all the scenarios examined were hypothetical, the model has been successfully applied to predict measured flows and pesticide concentrations in the Colworth catchment. This lends credibility to the predictions for LAS.

SDA SWAT Edition: Efficient Spatial Data Analysis & Visualization for SWAT Results

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SDA SWAT Edition is a customized version of Spatial Data Analyzer (SDA), a GIS-based data visualization and analysis tool, developed specifically for SWAT model output. SDA animates time series and spatial data over GIS maps with rapid display speed, even for very large model output file sizes. It can manipulate commonly used GIS data layers, all SWAT model results and any additional data (such as input and observed datasets) in ASCII format. All spatial and temporal data can be interpreted graphically as vectors, contours, color-mappings or hill-shadings. SDA generates sub-maps, which can be used for multi-angle map views, profile plots, and time series plots, which may be animated simultaneously. This includes the capability to view model results from more than one model run simultaneously, enabling quick comparison of different model scenarios. The data can be explored and edited in four-dimensional space (three dimensions in space plus time) with fully-functioned GIS navigation tools. Several functions are available for data analysis, such as creating new variables using mathematical expressions, calculating dataset statistics and calibration measures. Movies may be recorded in various formats, and high-resolution maps of model results can be generated for use in reports or public presentations. SDA has been applied for modeling and survey studies in the fields of hydrology, hydraulics, hydrodynamics, sediment transport, water quality, oceanography, meteorology, biology, and others. It has been used to animate 1D/2D/3D hydrodynamic models, hydrologic models, wave models, sediment transport models, meteorological models, particle tracking models, and animal and fish tracking models. SDA is an efficient tool for SWAT model development, calibration, verification and results analysis.

Use of optimal experimental design for river water quality modeling to update sampling strategies in river water year by year, considering costs and practical limitations

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Optimal experimental design (OED) techniques are a useful tool to construct experiments that contain information needed for building the model of the system under consideration. There exist applications of OED in many disciplines like environmental sciences (e.g. modelling waste water treatment plants), hydrology, food technology, chemistry; … A common aspect in all those researches is the fact that the experimental conditions are 'controllable': temperature, time, pH, measurement frequency, initial concentration,… For a natural river system, things become more complicated as a combination of different factors like temperature, flow, concentration, etc…is not occurring on the desired moments and as such, a method has to be found which maximises the content of information of experiments, without knowing the exact situations under which those measurements will occur. Further, external conditions like weather, discharges in the river or diffuse pollution to the river can change year after year, so measurements that are likely to be optimal for a particular year can appear to be sub-optimal the next year. All those reasons make that a normal straightforward optimal experimental design cannot be used for river water quality modelling and extensions of those designs are needed to find a good measurement set-up.
In this research it is the aim to find a good set-up for measurements in view of the calibration of a river water quality model, based on previous measurements and a model calibrated with those measurements. It is assumed that the calibrated model gives good results but that the uncertainty bounds related to the model outcomes are too wide to draw reliable conclusions for management decisions.
The results show that the strength of the method is that quite different sampling strategies can have almost the same information content and can be evaluated in terms of other criteria such as costs or practical considerations like available time, persons and instruments. Also, bad sampling layouts were observed and more in depth analysis of those layouts gives information about sampling strategies that are not giving any useful information for the calibration of a river water quality model for a certain river.

Application of SWAT in developing countries using readily available data

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The USAID Sustainable Agriculture and Natural Resource Management Collaborative Research and Support Program (SANREM CRSP) funded a research project at Texas A&M University (TAMU) to examine effects of reforestation policies on impacts to the environment and economy in the in the upper reaches of the Tana River below Mt. Kenya. The SWAT model was used to identify environmental impacts as well as to provide inputs into the economic analysis. The major limiting factor in the success of SWAT simulations for the study area was the lack of available high quality input data. This includes climate, elevation, soils, land use, and streamflow data. For this study, researchers at the Spatial Sciences Laboratory (SSL) and the Center for Natural Resource Information Technologies (CNRIT) at TAMU used various means to obtain and modify the available input data to improve the results of the model simulations and thereby the results of the analysis. Reliable climate data was not available from one source for the entire study area. Therefore, rainfall and temperature data were collected for two World Meteorological Organization (WMO) stations within the study area, and additional rainfall data was obtained for local stations from the Mpala Research Center in the Laikipia region of Kenya and satellite derived data was obtained from the Collaborative Historical African Rainfall Model (CHARM). Elevation data was derived from the USGS 1 km Digital Elevation Model (DEM) which was resampled to a 100 m resolution using the Shuttle Radar Topography Mission (SRTM) DEM. Soils were obtained from the Kenya 1:1 million scale Soil and Terrain (KENSOTER) database developed by the Kenya Soil Survey along with the International Soils Reference and Information Center (ISRIC). Additional data was derived from the EPIC crop model and the Soil Water Characteristics calculator for those soils with missing attributes. A land use grid was generated from point data provided by the Kenya Department of Resource Surveys and Remote Sensing (DRSRS) land use surveys and course scale forest boundaries provided by the Japan International Co-operation Agency (JICA). Streamflow data, which was used for calibration of the model, was obtained from the Ministry of Water Resources Management and Development headquarters in Nairobi. Modification of this input data allowed for a more accurate baseline simulation that was then used to evaluate various reforestation scenarios. These scenarios provided a 30 to 55% increase in forested areas in the upper reaches of the catchment; showed a reduction in sediment load in the river and thereby siltation of the reservoir; and produced a more predictable streamflow regime. More importantly, the simulations highlighted the fact that one of the three tributaries contributing flow and sediment to the reservoir was most responsible for the siltation problems. The Thiba River subsystem accounts for only 2.8% of the catchment area, but 40 % of the flow and 44% of the sediment load into the reservoir comes from that same subsystem. The findings of this research will help to provide a means of developing guidelines for policy implementation by the Kenyan government that will yield the best environmental result with the least negative environmental and economic impacts.

Performance of the SWAT model in an inter-comparison of nutrient loss quantification tools throughout Europe (EUROHARP project)

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The accurate quantification of the diffuse nutrient losses from agricultural activities is a major challenge facing the research community involved in national and European policy support. The Euroharp project aims at providing a scientific evaluation of different methodologies for quantifying diffuse nitrogen and phosphorus losses. The project includes 9 different methodologies and a total of 17 study catchments across Europe. The SWAT model is one of the 9 methodologies evaluated.
This paper presents the results of the inter-comparison of the 9 quantification tools in three core catchments and then analyses the performance of the SWAT model considering two specific cases, often encountered by water managers: the limited availability of data (the Guadiamar catchment in Spain) and the need for the scenarios analysis (the Zelivka catchment in Czech Republic).

SWAT-DEG and channel stability assessment

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The Soil Water Assessment Tool (SWAT) is designed to simulate watershed processes and the impact of land and water management on water quality. Recently, the channel sediment routing model (DEG) has been modified to simulate downcutting and widening. An erodibility coefficient from submerged jet testing, is multiplied by tractive force to compute downcutting and the channel slope is adjusted accordingly. Widening of the channel is accomplished through local width-depth ratios derived from measurements of streams in the Texas Blackland Prairie. Modeled results indicate the temporal change in down cutting and channel adjustment, useful in project planning and channel assessment. The bed material gradation combined with the channel forming discharge is used to estimate the equilibrium or "ultimate" stable channel slope. Discharge, site stratigraphy, and bed material information is also used to evaluate future channel width and depth by comparison to regionally derived regression equations. This information, when analyzed with bank stability considerations and pool riffle morphology, allows assessment of stable channel design dimensions for pool and riffle areas over the design reach. The results of the SWAT-DEG model and the Watson Harvey channel evolution model are used to evaluate the current state of the channel in relation to the forecast equilibrium channel. The SWAT-DEG model allows evaluation of the time it will take for the present channel to reach the forecast equilibrium state given assumptions concerning watershed climate and land use. The Watson Harvey model details where each reach of the channel is in terms of Schumm and Simon's channel evolutionary sequence. The equilibrium or design slope, derived from the slope equations, will typically be lower than the existing channel slope due to increased discharge as a result of urbanization of the basin. Because of the confined nature of many urban streams (transportation crossings, houses, commercial structures, alleys), there is typically little room to decrease the channel slope by increasing channel length through meander enlargement. Therefore, most urban channels require the addition of drop structures in order meet derived equilibrium channel slopes. Placement of the structures is based on the amount of predicted degradation, the predicted time rate of degradation, channel sinuosity, and local structural considerations such as utility crossings, storm sewers, and bridge and culvert locations and configurations. Based on the stable side slope conditions, setbacks to existing or future structures can be assessed. Setbacks = Side slope (Degradation + Bankfull Depth) + .5 Bankfull Width. SWAT-DEG allows the engineer to choose the design depth based on the rate of degradation and types of structures. Finally, the combination of equilibrium slope, new channel dimensions, drop structure locations and sizes, bridge alterations, and modifications to channel roughness are modeled to assess the impacts of the modifications on local flood levels and velocities for various design storms. Adjustments are made to make sure that regulatory flood levels within the reach are not increased and threshold velocities not exceeded for the area. A case study will be presented which illustrates the use of SWAT-DEG in the channel stability evaluation and design process.

Integrating wetlands and riparian zones in regional hydrological modeling

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Wetlands, and in particular riparian wetlands, are at the interface between well drained land and the aquatic environment, where they control the exchange of water and related chemical fluxes from catchment areas to surface waters like lakes and streams. They intercept surface and subsurface runoff with soluble nutrients and sediments from the upland areas, and therefore function as buffers for the river network. Due to their connection to groundwater and supply of nutrients from upland areas, riparian wetlands have excellent conditions for vegetation development during the whole growth season. As a result, riparian wetlands are highly effective in the reduction of diffuse source pollution and sediment loads to rivers and streams. Therefore integrating wetlands and riparian zones in eco-hydrological river basin modelling is very challenging. The model should be able to reproduce specific features and conditions of eco-hydrological processes in wetlands, like inflow of water and nutrients from upland areas, connection to groundwater dynamics, plant water and nutrient uptake, mineralisation of organic matter, denitrification, and outflow of water and nutrients to river network. Moreover, a riparian zone module should be integrated as an interface between model representation of river system and surrounding catchment area. But the correct representation of all these processes in the modelling framework with their different characteristic spatial and temporal scales is not a trivial task. Additional problems are the identification of riparian zones based on regionally available data, and verification of the results. The model used in this study is the eco-hydrological model SWIM (Soil and Water Integrated Model), in which a riparian zone and wetland module was incorporated. SWIM was chosen because it already integrates hydrological processes, vegetation growth, erosion and nutrient dynamics at the watershed scale, and has moderate data requirements. The impact of riparian zones and wetlands on the water and nutrient balance of the German Elbe river basin was investigated in our study. The presentation will show simulation results for the water and nutrient balances in soils, wetlands and the river system. The extended model allows to evaluate the impact of wetlands and riparian zones on the water and nutrient balances of the basin under different scenarios relevant for example for the implementation of the European Water Framework Directive.

Keywords: Riparian zones; wetlands; water quality; groundwater dynamics; nutrient retention

Adapting SWAT for riparian wetlands in Ontario watershed

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SWAT is widely used for simulation of watershed hydrology and non-point source pollution from agricultural watersheds. Still its applicability for watersheds with wetlands is limited. Grand River basin in Ontario, Canada, has natural wetlands, mostly riparian type, along the streams and tributaries. These wetlands are palustrine type and filter the water coming from agricultural fields before entering into streams. Attempts are being made to adapt SWAT to simulate change in the watershed hydrology and nutrient loading in streams by interfacing SWAT with wetland model. Three different approaches used in REMM, WETLANDS and WATFLOOD models for simulating wetland hydrology are being considered for interfacing with SWAT. The subbasins containing wetlands is marked and linked to the wetland model. The simulation procedure considers subbasin draining into the wetland and wetland ultimately filtering the nutrients and draining to stream through surface and subsurface flows. Output of the subbasin provides input to the wetland model at each time step.

Developing parameters to simulate trees with SWAT

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Recent work with woody species is being extended to simulate competition among woody species and competing vegetation with the goal of eventually simulating forests with SWAT. This presentation will describe published and ongoing work to develop parameters to effectively simulate the growth of mature forests both with one species of tree and with trees competing with other plant species. Efforts are especially aimed at simulating white spruce, black spruce, lodgepole pine, and trembling aspen and how they compete with shrubs, grasses and herbaceous vegetation in young stands after forest disturbance, such as harvest and fire. The goal will be to evaluate the potential of SWAT as a tool for foresters to estimate the impact of forestry practices on watershed hydrology and water quality.

Improved simulation of forest growth for the Soil and Water Assessment Tool (SWAT)

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Mass clearing of native vegetation is largely responsible for the widespread occurrence of dryland salinity across southwest Victoria, Australia, which is severely degrading large areas of land utilized for agriculture. Large scale afforestation has been proposed as a remedial measure to prevent any further degradation of land and water resources. However numerous scientists and catchment managers have questioned the adoption of this course of action because it has the potential to significantly reduce the water yield of catchments. Subsequently agricultural productivity will be reduced and waterway health will be affected enormously. There is an urgent need to determine the impacts of afforestation at a regional scale across southwest Victoria otherwise if such changes are allowed to proceed unchecked the consequences could be devastating. SWAT has been identified as a promising model to adopt for predicting land use change impacts in catchments across southwest Victoria. However one of the main limitations of SWAT is that it is unable to correctly simulate the growth of evergreen trees such as eucalyptus and pine trees. The source of this problem is attributed to two features of the plant growth module utilised by SWAT. Firstly phenological development is based on daily accumulated heat units which is a concept not used by most established forest growth models to simulate the development of evergreen trees. Secondly trees are forced to lose all their leaves and go dormant for several months in winter, which is not applicable in the case of evergreen trees. These features adversely affect the simulation of Leaf Area Index (LAI) for eucalyptus and pine trees. The LAI of these species fluctuates unrealistically over the duration of a year and this has significant impacts upon the prediction of evapotranspiration. It has been shown with SWAT that the evapotranspiration rate of forests can be less than that of pastures and crops (1), which contradicts an extensive body of research. If SWAT was to be used in its current state for determining the impacts of afforestation in southwest Victoria, erroneous results would be achieved and this would lead to seriously flawed management practices being implemented. To overcome the above problems the forest growth model 3PG (Predicting Physiological Principles for Growth) has been integrated into SWAT to simulate the growth of eucalyptus and pine trees. 3PG is a dynamic, process-based forest growth model that is based on established biophysical relationships and constants. SWAT-3PG was applied to the Woady Yaloak River catchment located in southwest Victoria to predict the long term water balance. The improved simulation of LAI for the eucalyptus and pine trees resulted in evapotranspiration from forests being greater than evapotranspiration from pasture, an outcome more consistent with the literature. Values of LAI predicted by 3PG were within the range of LAI values derived from a Landsat 7 ETM image of Normalised Difference Vegetation Index (NDVI) for native eucalyptus forests and pine plantations. This paper shows that LAI of eucalyptus and pine trees is simulated more accurately by the incorporation of 3PG into SWAT and this leads to significant improvements in the estimation of evapotranspiration from forests comprised of evergreen tree species.

(1) Watson, B. M., S. Selvalingam, and M. Ghafouri. 2003. Evaluation of SWAT for modelling the water balance of the Woady Yaloak River catchment. In: *Proc. MODSIM 2003*, 873-878

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A user friendly multi-catchments tool for the SWAT model

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A software system to manage swat results (bsb.dbf and rch.dbf) has been developed on a multi catchment's scale. Regions such as Sardinia, Sicily, Portugal etc are, in fact, characterized by a large variety of ecosystems within complex catchments. The AVS2000 interface deals with one catchment's at a time, but the integration of the swat results of adjacent basins may be necessary for an integrated water resources management. To achieve this goal, an ArcView extention, called multi-catch.avx, has been developed.
The extension allows the user to select the subbasins within the basins under investigation and obtain statistical reports of the model outputs chosen, from the rch and bsb tables in the form of charts, statistics and maps. The rch and bsb files on a monthly basis are spatially disaggregated; one file is created for each model output of interest chosen by the user for each subbasin. Each created file is printed in the form of a matrix where the columns represents the monthly outputs while the rows are the years of the simulation. Each file is then linked to the geographic location it belongs to. A project is created where all the watersheds under study are added to a View along with their subbasins. The user can dynamically visualize the value distribution of a chosen model output for all the active subbasins within the given basins, with a monthly or yearly time resolution. The results on a subbasin spatial resolution, can be then aggregated to represent the whole basin under study and visualized in a new View. The system manager developed has been utilized to map, and analyze 15 swat projects within the Sardinian Region.

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Towards a process-oriented HRU-concept in SWAT: catchment-related control on base flow and storage of landscape units in medium to large river basins

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Hydrological Response Units (HRU) are used in models to aggregate the spatial characteristics of the landscape. The aggregation concept influences the spatial pattern of the simulated hydrological processes and nutrient transport and thus also affects the simulation quality. Questions arise about how strong these aggregations influence simulation results. Assuming that a more realistic representation of the physical landscape characteristics by the HRU's also leads to an improvement of the simulations, the authors suggest a new HRU concept for SWAT. The concept is based on the integration of basic and most significant spatial landscape units characterized by different hydrological properties and functions. Delineation of these units requires their reproducible description from easily obtained physical parameters and indicators. While solutions must be applicable to different watershed scales, the lack of scale-specific data as well as questions about the definition of the spatial units and the significance of the controlling factors represent major issues to overcome. Some of these issues will be discussed in the presentation. The first step of the approach deals with the delineation of the basic landscape units; valley floors, hill slopes and ridge top areas using the slope position method. The hydrological relevance of the units is proven by using different approaches and tools. A macro model was developed based on the strongest correlated parameters (basin area, channel length, climate index, base flow index, drainage density, and percent proportion of valley floors) to predict basin storage. Different methods are used to quantify the storage volume of the landscape units but especially for valley floors, which is important for an accurate description in the model. Medium to large-scale valley floor storage has been estimated both by calculation of maximum base flow, and by relationships between valley floor area, assumed soil depth, and available water capacity, showing excellent correlation. In addition, valley floor storage has been calculated with a numerical approach on a smaller scale using a recession parameter, bankfull channel width, bankfull channel depth, and specific yield of river valley sections in order to prove the quality of the results obtained by the large-scale approach. The procedures enable the differentiation of essential flow and storage parameters within the model system. The studies are essential for characterizing response units on larger scales and represent the basis of an improved spatial description of hydrology and transport processes for river basin management by modifying the HRU concept in SWAT.

Interfacing watershed models with systems analysis tools: implementation for SWAT

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The use of automated calibration procedures for parameter estimation in watershed models is highly desirable. Among the reasons for this is the limitation in manual calibration due to the complexity of model input-output relationships. As distributed watershed models are often highly over-parameterized, this increases the difficulty of parameter estimation and uncertainty analysis because many sets of parameters can lead to a similarly good agreement of calculated results with measurements. For this reason it is often required that different system analysis techniques are brought to bear for calibration and uncertainty analysis. In this paper, a general interface technique is introduced to make the application of automated calibration possible between different models and system analysis programs. The use of this interface is illustrated by linking the SWAT watershed program with the UNCSIM systems analysis package to calibrate the Chao river basin in China.

Evaluation of models using SWAT 2005

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Worldwide, water quality regulators increasingly rely on water quality models at the catchment scale, such as the SWAT models to aid in decision making. These models are able to integrate several sources of pollution at large scales and to do long term predictions for pollution abatement scenarios. However for the practical use of these models it is important to know the reliability of model results. Traditionally, the reliability is quantified by uncertainty analysis methods within a statistical framework. Whereas a wide range of statistical theories exist, it has not yet been possible to conduct a complete and robust uncertainty analysis for these complex models, as there are too many unknowns associated with the modelling problem. For this reason, we propose evaluation methods that are not based on statistics in order to evaluate the fit-to-purpose of model applications.

Within SWAT2005, both a statistical method for uncertainty analysis, ParaSol, and an evaluation method, SUNGLASSES, are incorporated. ParaSol estimates the uncertainty originating from parameter uncertainty that is associated with the calibration procedure. Poor identification of the parameters is propagated to uncertainty bounds on the model results. SUNGLASSES evaluates the correctness of the model predictions to be used for decision making. Failure of correct predictions results in wider uncertainty bounds on the model outputs.

The application of these methods is illustrated with SWAT2005 simulations for flow and sediment of Honey Creek, a tributary of the Sandusky River basin (Ohio).

Modifications of the Soil Water and Assessment Tool (SWAT-C) for stream flow modeling in a small, forested watershed on the Canadian Boreal Plain.

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The SWAT model was originally developed for simulation of streamflow and water quality for watersheds composed of agricultural crops and rangeland. More recently, efforts have been made to utilize SWAT for hydrologic simulations in forested watersheds. The Forest Watershed and Riparian Disturbance (FORWARD) project is studying the impact of fire and harvesting disturbances on streamflow in several small (6 – 16 km^2) forested watersheds located on the Boreal Plain in central Alberta, Canada. Streamflow simulations using the existing representation of hydrologic processes within SWAT were not completely satisfactory for forested conditions. In order to improve the streamflow simulations, the SWAT model code was modified to better represent hydrologic processes in a forested environment. A surface litter layer under the forest canopy was incorporated into the soil layer representation and a modified version of the SWAT "potholes" facility was used to simulate the effect of water storage and release by Boreal forest wetlands. The prediction of soil temperature based upon solar radiation input was modified to account for watershed aspect, slope and canopy cover because a better representation of soil temperature is particularly important for simulation of streamflow associated with the spring thaw. Finally, the damping effect of the surface litter layer on soil temperatures was incorporated. Model results using SWAT-C (the modified version of SWAT) are presented and discussed in comparison to measured streamflow.

Two-step method for SWAT calibration

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This paper presents a method for parameter determination for the Soil and Water Assessment Tool (SWAT) and discusses the effect on the resulting parameter values of: (1) the constraints and rules for parameter value change within the parameter space during the optimization process, (2) the selected objective function, and (3) the time series data used for calibration and validation. For reasons that will be presented in this paper, the method has been called "Two Step SWAT Calibration Method", or "Two Step Method", for short. Through the development of a software application, this methodology has been included in ArcGIS-SWAT – developed at Texas A&M University – which is a GIS interface, data model and comprehensive set of applications for SWAT that eases the interpretation of its results, and improves its integration with geographic information systems (GIS). The Two Step Method consists of changing the values of a spatially distributed parameter by applying an adjustment rule over the entire system (e.g., multiplication by a number, addition of a number), and then by modifying locally each value within a very restricted range. The rationale of the method is that, even though the parameters are modified by calibration in a first step, the overall structure of values initially proposed by the modeler should be taken as a reliable description of the system. Still, restricted local parameter adjustments are allowed in the second step. In this study, the Shuffle Complex Evolution (SCE) method has been used for finding the global minimum of the objective function. The method is being tested with data of the Lake Lewisville watershed in North Texas, USA, which is an area experimenting significant urban growth in the past decades. This is a research in progress and, at the moment this abstract was prepared, no conclusive results had been found yet.

The power of multi-objective calibration: three case studies with SWAT

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Proper calibration procedures for complex eco-hydrological models should use all available measurement time series that provide useful information about the physical system. This is especially true for distributed models that simulate a variety of hydrological and matter fluxes, such as SWAT. The most general solution of the multi-objective calibration problem assumes that there is no unique solution. Instead, there is a whole set of (Pareto-optimal) solutions with the property that moving from one solution to another results in the improvement of one objective function at the price of a deterioration in another objective function. If a single solution to the multi-objective calibration problem is required, this can be achieved by assigning (subjective) weights to each single objective function. In this contribution, we present three case studies where SWAT is calibrated with a multi-objective approach. In all three cases, we use the MOSCEM-UA algorithm. In the first case study, SWAT is calibrated to percolation, evapotranspiration and nitrate fluxes measured within a lysimeter (1 HRU). With this computationally inexpensive example, we illustrate several important aspects of multi-objective calibration, such as noncommensurabilty of different error measures and required computing resources. In the second case study, SWAT is calibrated to measured discharge from three subbasins of the Dill catchment (Germany). This example shows how multi-objective calibration is used to answer the question whether there is one set of parameters that provide adequate simulations for all three subbasins. In the third case study, SWAT is calibrated to measured discharge and nitrate load at the outlet of the river Dill. This example shows the trade-offs between adequate discharge and nitrate load simulations. We hope that these case studies illustrate the power of multi-objective calibration.

Comparison of optimization algorithms for the automatic calibration of SWAT2000

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This paper compares the performance of multiple optimization algorithms for the automatic calibration of the SWAT2000 model. Performance is measured in terms of both computational efficiency and the best calibration objective function value attained. A novel but simple optimization algorithm called the Global Greedy Search (GGS) is compared with the commonly used Shuffled Complex Evolution (SCE) algorithm in addition to other optimization algorithms. Previous algorithm comparison studies involving SCE for watershed model calibration often show SCE to outperform the alternative algorithms. These SCE comparisons are often for case studies with a relatively small number of parameters considered for calibration and typically are based on SCE optimization trials that are allowed to run to convergence. Since the available computational time (i.e. the number of available model runs) is often limited and varies by case study, algorithm comparisons are presented in this paper from a limited number of model evaluations perspective rather than comparisons based on algorithm convergence. Algorithms comparisons are based on 1000-2000 model evaluations per optimization trial.

The watershed model calibration case study is a SWAT2000 model of the 1178 km^2 Cannonsville Reservoir Watershed in Upstate New York. The mainly forest and agricultural watershed is modeled using 43 subbasins and 758 HRUs. The automatic calibration focuses on measured flow as well as suspended sediment and phosphorus loading. Multiple, single-objective function calibration scenarios are used in the algorithm comparisons. The impact of increasing the number of model parameters calibrated (i.e. increasing the dimension of the problem) on algorithm performance is also evaluated. Results show that the GGS algorithm performs significantly better than the SCE algorithm for most of the comparisons considered. This finding becomes even more evident as the number of model evaluations per optimization trial decreases. Overall, results demonstrate that the GGS algorithm quickly finds good calibration solutions (i.e. the error measure used in the objective function is acceptably small). This finding is particularly relevant for SWAT applications that are computationally demanding.

A comparison of parameter regionalization strategies for the water quantity module of the SWAT with application to the Scheldt River basin

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It is well known that model parameters have to be calibrated for the catchment conditions one wants to model in order to get accurate and reliastic simulation results. One of the goals of an operational model, like the SWAT, is to make extrapolations to ungauged sites and/or to alternative scenarios of land use or climate change. For such applications, a case-specific parameter optimisation is impossible and therefore a parameter regionalisation strategy is needed. This study makes a comparison of 6 regionalisation strategies for the water quantity module of the SWAT with application to 25 subcatchments of the Scheldt river basin. The strategies under consideration are: (1) use of SWAT defaults (2) use of average parameter optima for the entire study region (3) linking parameters to physical catchment descriptors by linear regression (4) linking parameters to physical catchment descriptors with artificial neural nets (5) delineating zones with a uniform parameterisation following a parameter-per-parameter analysis (6) delineating zones based on the parameter set as a whole. The analysis is limited to the 7 most sensitive model parameters. The linking of parameters to physical catchment descriptors by linear or non-linear models results in the highest model efficiency for daily stream flow simulations for more than 60% of the catchments. The delineation of zones based on the parameter set as a whole is the preferred regionalisation strategy for almost 25% of the catchments under study. The use of SWAT defaults or region-wide average parameter values considerably lowers the performance of the model; in particular for the simulation of base flow. In general, long-term average flows are better reproduced than daily stream flow. This trend is more pronounced for the poorest performing strategies, so that the difference in performance of the parameter regionalisation strategies is small for the simulation of 10-year average flows.

Vulnerability assessment of climate change impact on Indian water resources using the SWAT model

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A very exhaustive study was conducted as part of the National Communication (NATCOM) project undertaken by the Ministry of Environment and Forests, Government of India to quantify the impact of the climate change on the water resources of India using a hydrological model. The study uses the HadRM2 daily weather data to determine the control (present) and GHG (future) water availability in space and time. A distributed hydrological model namely Soil and Water Assessment Tool (SWAT) has been used on major river basins of the country. The framework predicts the impact of climate change on the water resources with the assumption that the land use shall not change over time and any manmade changes like dams, diversions, etc. have not been incorporated. A total of 40 years of simulation over 12 river basins of the country (leaving only two major river systems namely Brahmputra and Indus) have been conducted, 20 years belonging to control (present) and the remaining 20 years for GHG (future) climate scenario. Each river basin has also been further subdivided into reasonable sized sub-basins so as to account for spatial variability. It has been observed that the impacts of climate change are not uniform over the country and are varying across the river basins as well as across sub-basins. The initial analysis had revealed that the GHG scenario may deteriorate the conditions in terms of severity of droughts and intensity of floods in various parts of the country and that there is a general reduction in the quantity of the available runoff under the GHG scenario. This paper presents the detailed analyses of two river basins with maximum effect with respect to drought and floods.

Effects of the spatial resolution of input data on SWAT simulations – a case study at the Ems River Basin (Northwestern Germany

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Accurate simulations of hydrology, nutrient balance and matter fluxes require the use of scale-specific spatial and temporal information for model input. This is essential both for the represention of the system dynamics on the different scale levels, and for the minimization of the data-related uncertainties. In relation to that, the used different spatial (relief, soil, land use) and temporal (precipitation, evaporation) input data have to be integrated in a consistent way. In Germany, this is still a challenge, because the needed data sets mostly exist only in different spatial resolutions. The completion of the scale specifc data base will take several years, but it is essential for the implementation of environmental programs such as the EU water framework directive in Europe, or TDML in the United States. Thus, solutions have to be found to process (aggregations, disaggregations) these data in an understandable way. Additionally, the sensitivity of the used models to the input data resolutions has to be checked out intensely. The efficient development of river basin management plans with detailed environmental measures requires the knowledge of the uncertainty range of its tools. Three questions arise in this relation: a) Which effects have different spatial resolutions of the input data on the simulation result?, b) How is calibration of the models influenced by the use of the different spatial resolution, and c) Which data resolution represents best the scale-specifc systems response (efficiency)? The authors try to answer these questions on the example of a case study, using SWAT in the upper Ems river basin in Northwestern Germany. SWAT is a highly parameterized integrated modelling system with high demands to the model input data. The required input data resolution depends on the size of the catchment, and the temporal resolution of simulation. Several data sets with different spatial resolutions have been used as input data. Daily climate data (precipitation, evapotranspiration, temperature, wind speed, relative humidity) are used as temporal input data. Automated delineation of the subbasins by AVSWAT and same parameter adjustments for both data sets have been used at first to enable comparisons between the simulations. The use of different resoluted spatial data leads to a different number of subbasins during the pre-processing. Additionally, different numbers of HRU's are the consequence. Thus, more time and work has to be spent for the adjustment of the HRU- and subbasin parameters by using the finer data sets. As a result, different degrees of uncertainties such as delineated catchment size, or the runoff distribution pattern represented by HRU's have to be faced. A first statistical assessment of the simulated annual and monthly dynamics showed, for instance, that the coarse resoluted data base even improved the simulation quality in comparison to the data base with the higher resolution. In contrast, daily dynamics were presented much better by the higher resoluted data. High resoluted data are essential to compare most efficient the simulation results with measured data. In general, we recommend a detailed preliminary definition of spatial and temporal references for the simulation and the use of adequate spatial and temporal input data. This procedure should result in more efficient model calibration and simulation procedure and to a better representation of the scale specific system dynamics.

Application of water management models to Mediterranean temporary rivers

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The application of water quality models to areas characterized by periods without runoff and extreme first flush effects with the beginning of the rain period is the aim of the EU project TempQsim. More in detail, it deals with the evaluation and the improvement of water quality models for temporary streams in Southern European catchments. To this aim, existing water quality models have been tested to evaluate their suitability to describe the dynamics of temporary streams. Moreover, many efforts have been made to improve the efficiency of tools for the integrated water management in the semiarid Mediterranean river catchments.
Within this research area, our work deals with the application of the Soil and Water Assessment Tool (SWAT-2000) model to a Sardinian catchment, Rio Mulargia. The main objective is to observe and accurately predict movements of sediments and nutrients during water routing. We focus particularly on the first flush events in order to highlight the specific features that have to be added to the model to make its results more reliable in these situations. Rio Mulargia catchment has being chosen for its intermittent character, peculiar of the subtropical areas, with almost no flow during summer time and with intense precipitations variable in space and time. With its reservoir, it represents for the southeast part of Sardinia a significant water resource for urban, industrial and agricultural uses.
Model calibration was done from 1992 to 1997 and model validation covered the period from september 2003 to april 2004. In the validation period the correlation and the Nash-Sutcliffe efficiency coefficient are satisfactory. Simulated average flow matches exactly the measured one, while, looking at seasonal values, model slightly overestimates flow in summer and in autumn and underestimates it in winter and spring, consistently with what happened in the calibration period. Sediment and nutrient loads show a good agreement of the model estimation with measured data. Moreover, in order to evidence the behaviour of the catchment in correspondence of different hydraulic regimes, the flow and the pollutant transfer in the validation period have been separated into low-flow and high-flow periods. Load generated by floods in sediment, total N and total P is little more that 50% of the load generated in all the period.
An insight has been done in three flood events recorded in the same period. The selection of these peaks is due in function of the available reliable measured data. In general there is a very good agreement between the measured and simulated flow in all the three flood events. Simulated concentrations and loads are of the same magnitude order for all the parameters and in most cases the values are very close.
Notwithstanding the SWAT model has been applied to the Mulargia catchment in a situation where available rain gauges data where not so representative of the catchment, the simulation gave results that matched measured data in a satisfactory way.
In conclusion, SWAT model, applied to a truly intermittent river as the Mulargia, showed to be able to catch the behaviour of the catchment and of most of the processes acting in it. Nevertheless, in our work some limitations of the model have been highlighted and discussed in detail.

Runoff-erosion modeling by SWAT of an experimental Mediterranean watershed

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Runoff and erosion in upland watersheds can have significant negative on-site and off-site environmental impacts. The choice and design of appropriate erosion control measures can be aided by reliable predictions of watershed response under different land use scenarios. In recent decades several simulation models have been developed in order to estimate and analyze soil erosion by water. Although many experiments have been conducted to evaluate the use of available watershed models, additional work is needed to assess and improve model reliability in different environmental situations. To this end, a small mountainous watershed, mainly pasture, covering about 130 ha in Eastern Sicily, was equipped some years ago in order to further extend model testing to semi-arid Mediterranean conditions. A 8-year hydrological and land use database is available and soil-vegetation distributed parameters have been stored into a *GIS*. The aim of this paper is to analyze the performance of the physically based model, *SWAT* (1) in the experimented conditions of that site. The watershed was discretized into 31 subwatersheds and 63 *Hydrologic Response Units* in order to simulate the different soil types and land-uses. Two simulation series were performed using daily and subhourly (with a frequency of 15 minutes) rainfall data recorded in three different rainfall gauges. Results of a model calibration and validation, carried out using the runoff depth and sediment yield storm data observed at the outlet of the watershed, were given.

(1) Arnold et al. 1998. American Water Resources Association 34: 73-89.

Comparison of daily runoff responses between SWAT and sequentially coupled SWAT-MODFLOW model

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This study is concerned with comparing SWAT with the sequentially coupled SWAT-MODFLOW for estimating the daily runoff in Bocheong watershed of Korea. In the sequentially coupled SWAT-MODFLOW approach, total daily runoff was determined by adding surface runoff and lateral flow calculated by SWAT to baseflow component calculated by MODFLOW after SWAT and MODFLOW are sequentially simulated. The Bocheong river basin is one of IHP research basins in Korea and the hydrologic data have been collected since 1984. The watershed area being studied is about 347 ㎢ and the average elevation of the watershed is about 283m. The main land use types in the watershed are the mixed forest occupying 63% and agricultural land occupying 26% of the watershed. The daily rainfall data were collected from twelve rain gauge stations within the watershed and the meteorological data were compiled from six weather stations around the watershed. Both SWAT and the sequentially coupled SWAT-MODFLOW models were evaluated against the measured daily runoff at Gidae water stage station of Bocheong watershed. Although the Nash-Sutcliffe efficiency index is about the same between two models, the simulation result suggest that the coupled SWAT-MODFLOW model is better than SWAT model in calculating the average daily runoff and SWAT model underestimated the average daily runoff. However, it is very difficult to calibrate and verify the coupled SWAT-MODFLOW model for medium to large watershed because different sets of parameter values and model conceptualization yield similar response and there exist lack of available input data necessary for spatially distributed model of MODFLOW.

Hydrological modeling for effective management of a small agricultural watershed using SWAT

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A model, called Soil and Water Assessment Tool (SWAT) was tested on daily, monthly and seasonal basis and applied for developing management scenarios for the critical sub-watersheds of a small agricultural watershed (Nagwan). The watershed and sub-watershed boundaries, drainage networks, slope, soil series and texture maps were generated using GIS. Supervised classification method was used for land use/cover classification from satellite imageries. Manning's roughness coefficient 'n' for overland flow and channel flow and Fraction of Field Capacity (FFC) were calibrated for monsoon season of 1991. The model was validated for the year 1996 and 1997 using the respective rainfall and temperature data. Nutrients such as organic nitrogen and phosphorous in sediment and NO_3-N and soluble P in runoff were also considered for model validation. The observed and simulated nutrient losses were compared for twelve events during the monsoon season of 1997. Observed and simulated means of organic nitrogen, phosphorous, NO_3-N and soluble P showed good agreement. Simulated monthly runoff and sediment yield for the intermediate period between calibration and validation (1992-1995) compared well with their observed counterparts. Capability of the model for generating rainfall was also evaluated for the period of 1996 through 1998. The model simulated daily rainfall was having close agreement with that of observed rainfall. Also the model predicted daily and monthly runoff and sediment yield using generated daily rainfall compared well with observed runoff and sediment yield during simulation period of 1996 through 1998. The critical sub-watersheds were identified on the basis of average annual sediment yield and nutrient losses during the period of 1996 through 1998. The calibrated and validated model was used for planning and management of critical sub-watersheds. The ranking of different critical sub-watersheds was done according to the annual sediment losses for developing management plans. The sub-watersheds WS12, WS9, WS7, WS10 and WS6 were found to be critical. For all critical sub-watersheds, runoff, sediment yields and nutrient losses showed similar trend. WS7 was selected as a sample critical sub-watershed for evaluating the management scenarios. Sixty combinations of treatment options were considered which included selected crops (rice, maize, groundnut and soybean), tillage (zero, conservation, field cultivator, M.B. plough and conventional) and levels of fertilizer (existing, half of recommended and recommended). The existing management practice was considered as the base for evaluating other management practices for rice crop. The results showed that rice crop can not be replaced by other crops since these crops resulted in higher sediment yield as compared to rice. M.B. plough had considerable impact on sediment yield and nutrient losses since it increased sediment yield by about 39% and decreased nutrient losses by about 22% N, 50% P, 3% NO_3-N and 37% soluble P as compared to the conventional tillage for the existing level of fertilizer treatment. The decrease in sediment yield as compared to conventional tillage was found to be about 19, 11 and 10%, respectively for zero tillage, conservation tillage and field cultivator. The impact of zero and conservation tillage on nutrient losses for all levels of fertilizer doses was found to be more than that of the other tillage treatments. Considering both sediment and nutrient losses together, field cultivator followed by conventional tillage was found to be better than the other types of tillage considered. Field cultivator gave sediment losses less than the conventional tillage and nutrient losses within the permissible limit. A dose of 40:30 kg/ha of N:P fertilizer proved to be appropriate for rice with either conventional tillage or field cultivator.

An Analysis of the 2004 Iowa Diffuse Pollution Needs Assessment using SWAT

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The U.S. Environmental Protection Agency (USEPA) is required to perform a periodic national Clean Watersheds Needs Survey (CWNS) in response to directives that were established in the 1972 U.S. Clean Water Act. The purpose of the survey is to identify all existing water quality or publich health problems, and the corresponding mitigation costs, that would quailfy for funding from the Clean Water State Revolving Fund (CWSRF). Categories eligible for CWSRF funding include wastewater treatment systems, sewer and conveyance systems, storm water management programs, and non point (diffuse pollution) sources. The most recent CNWS assessment was performed in 2000, which projected that the total cost of CWSRF eligible projects was $181.2 billion, of which $13.8 billion was attributed to diffuse pollution sources. The costs of most of the CWSRF categories were determined via direct cost estimates submitted by different states and territories. However, the costs of diffusion pollution source abatement were calculated on the basis of a simulation study. The Iowa Department of Natural Resources (IDNR) has expressed concern that the diffuse pollution cost estimate procedures used in the 2000 CWNS greatly underestimated the true total cost of addressing water quality problems originating from diffuse pollution sources. In fact, IDNR staff hold the conviction that the costs of mitigating diffuse pollution in Iowa alone could easily require several billion dollars. Thus the IDNR desires to have a more accurate accounting of how much it will cost to overcome Iowa diffuse pollution problems, for the next USEPA CWNS that will be released at the end of 2004.

To address these concerns, the Center for Agricultural and Rural Development (CARD) will perform a cost assessment of diffuse pollution abatement for Iowa by interfacing economic models developed in-house at CARD with SWAT. The simulations will be peformed with a modeling framework developed for the Upper Mississippi River Basin (UMRB), that facilitates the input of data from the U.S. Department of Agriculture (USDA) National Resources Inventory (NRI) database, the USDA Cropping Practices Survey (CPS), climate and soil data, and other key input data sources into SWAT. Additional NRI and other data, for the western part of Iowa that lies within the Missouri River Watershed, will be grafted into the system to provide a complete coverage of the state of Iowa. The analysis will be performed by simulating the adoption of conservation practices, such as conservation tillage, terraces, in-field buffer strips, and contouring, for specific NRI cropland points using discrete choice economic models developed in-house at CARD. The conservation practice adoption rates will be estimated within a suite of scenarios designed to reduce sediment and nutrient losses from agricultural landscapes. The economic cost of conservation practice adoption within each scenario will be projected by the economic models. The water quality benefits for each scenario will in turn be predicted with SWAT at the U.S. Geological 8-digit watershed level. The analyses of the scenarios will be performed in an iterative fashion until the desired water quality standards set by the IDNR are reached. The underlying assumptions of the analyses will be presented along with both the environmental and economic impacts of different scenarios.

Potential accuracy of water quality estimates based on non-calibrated SWAT simulations

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The SWAT model can be used to analyze the impact of alternative management practices on stream flow and water quality indicators; it has been shown to be a good predictor of these indicators when it is calibrated with local flow and water quality data. One draw-back is the need for flow and water quality data that is not always available. The intent of this study is to investigate the possibility of using SWAT for assessing the effectiveness of the environmental and conservation programs when no calibration data is available. The Miami Creek and the Long Branch watersheds in west and north Missouri, respectively, were modeled with SWAT when no flow data was available. The models were developed in close cooperation with local stakeholders and validated using regional flow data, correlations based on drainage areas, county crop yields, and the results of pesticide analyses in nearby watersheds. Since then flow data was collected in both watersheds and the models were calibrated using this data. The analysis compares the goodness of fit of the model results with the measured flow and the corresponding sediment, nutrient, and chemical loadings when the models are calibrated and when they are not. It also examines whether the calibration of the models leads to different answers in terms of the effectiveness of alternative management practices. Results indicate that average annual flow values predicted by the non-calibrated models were within 15% of the values predicted by the calibrated model; sediment loadings were within 20 to 30% of those predicted by the non-calibrated models, and pollutant loading differences varied from 15% to 50%. In spite of the large differences of results from the calibrated and non-calibrated models, the predicted efficiencies of no-till practices and reduced applications of atrazine are similar with both models. Additional conservation practices such as nutrient management, pasture and grazing management systems, filter strips, and conservation crop rotations will be investigated.

Assessing SWAT model performance in the evaluation of management actions for the implementation of the Water Framework Directive in a Finnish catchment

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The ecological status of the lake Pyhäjärvi, located in south-western Finland, may be classified as moderate due to its elevated nutrient concentrations and algal biomass production. Therefore, the Eurajoki river basin, including lake Pyhäjärvi, has been chosen as the Finnish test catchment for the EU-funded project Benchmark models for the Water Framework Directive (BMW). One aim of the project is to test the suitability of models for the assessment of management options needed to meet the surface water quality requirements. The Finnish test case is based on linking models: first the lake model LakeState (Statistical Lake Assimilation Capacity Analysis Model) is used for setting the targets for the loading reduction for lake Pyhäjärvi. Based on these results, the catchment model SWAT (Soil and Water Assessment Tool) is used for analysing the effectiveness of proposed measures to reduce agricultural and sparse settlement nutrient loading. The SWAT model is applied to the river Yläneenjoki catchment draining directly to the lake Pyhäjärvi and contributing over 50% of the phosphorus load reaching the lake. The modelling approach comprises three distinct phases: 1) the evaluation of the SWAT model utilising the available monitoring data along the Yläneenjoki reach and its main tributaries, 2) linking the SWAT model to the lake model to evaluate selected management options, and 3) participation of the Finnish national and local stakeholders in the modelling process and communication of the analysis results. The third phase is particularly important since the Yläneenjoki catchment has been intensively studied by local water managers and thus one additional aim is to utilise the stakeholder know-how in data interpretation and model parameterisation, and finally for the interpretation of results. This process includes interviews and roundtable discussions. In this paper the overall process is described and results for the phases 1-3 are presented.

Application of SWAT Model to the Decision Support Framework of the Mekong River Commission

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The Mekong River Commission (MRC) has been established since the Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin was signed in April 2004 by Cambodia, Lao PDR, Thailand and Viet Nam. According to the Agreement, a Water Utilization Programme (WUP) was established with aims to formulate "Rules for Water Utilization and Inter-Basin Diversions". To help the rule formulation and implementation, the WUP has recently completed the development of a computer-based system collectively known as Decision Support Framework (DSF). There are five main components in the DSF, namely a Knowledge Base (KB), three Simulation Models (SMs) and a set of Impact Analysis Tools (IATs), amongst which data and information can be intensively shared. The SWAT model was selected as the Hydrological Model of the DSF to generate the runoff in sub-basin and provide inflow to the Basin Simulation Model and Hydrodynamic Model. The model was initially set-up using dominant Hydrologic Response Unit (HRU) option based on GIS digital elevation data, a single land use map and soil map classified according to FAO 1988. The SWAT is applied for a total of 138 sub-basins in the Lower Mekong Basin (LMB) covering almost Lao PDR, the Northeast part of Thailand, catchments around the Great Lake in Cambodia and the Central Highland of Vietnam. The observed daily data used for model calibration including flows from limit number of gauging stations especially on tributaries with some uncertainty of rating accuracy, rainfall from gauging network, sparse in mountainous areas and climate from small number of stations. SWAT model parameters for the headwater catchments were calibrated against gauged flows and transferred to the ungauged sub-basins based on proximity and similarity of soil types and land uses. The good results from combined SWAT - Basin Simulation Model calibration show that the values of Nash-Sutcliffe Coefficient greater than 0.9 and volume errors within ±1% range can be found at all key monitoring stations on the mainstream of the Mekong River. The SWAT model and the DSF have been being applied for the impact assessment of various basin scenarios including climate change, catchment cover change and development scenarios of the Basin Development Plan (BDP). Additionally, the DSF outputs can also be used in further planning and analytical activities of various MRC programmes, i.e. Fishery, Navigation, Flood Management, Environment, Water Resources, etc.

Effects of the new European Common Agricultural Policy on water fluxes in a low mountainous catchment of Germany

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European agricultural policy for the 21st century will have major influence on future land use and management practices in many regions of Europe. So far, agricultural products were subsidized per yield. This lead to intensive production systems characterized for example by high fertilization rates, unadjusted pesticide application, or exhaustive water use. Having in mind a more sustainable land use and management, agricultural ministers of Europe agreed to reform the Common Agricultural Policy (CAP). The new CAP gives EU farmers the freedom to produce what the market wants. To avoid abandonment of production single farm payments are allowed by Member States. These payments are linked to environmental, food safety, animal and plant health and animal welfare standards, as well as the requirement to keep all farmland in good agricultural and environmental condition.

The scope of the Collaborative Research Centre 299 is to develop concepts for land use in peripheral regions. Peripheral regions in this context are regions which have economic structural or/and ecological drawbacks for agricultural production. The Dill catchment, a mesoscale catchment of approx. 693 km^2 in Germany, is characterized by small acreages, steep slopes unsuitable for large machinery production, and shallow, rocky, poor soils. The portion of fallow land of up to 10 % is hence larger than anywhere else in Germany. It is assumed that more and more farmers will quit agricultural activity in future. This in turn will lead to more uncultivated land, with effects e.g. on diversity, or cultural landscape amongst other landscape services. The new CAP policy could be a chance for farmers to continue agricultural production. But what are the consequences of changes in land use and management for economic and ecological objectives?

Under the premises of the CAP policy, the agro-economic simulation model ProLand is used to predict a feasible land use distribution and management strategy for the Dill catchment. ProLand is an agro-economical model that predicts optimal production systems, such as intensive and extensive rangeland, mother cow production, dairy, a variety of croplands, or forest, for any given location. It accounts for different natural, technical, economic and political premises and assumes that farmers act to optimise their land rent. In addition to economic measures for the investigated area, ProLand also delivers spatially differentiated land use maps.

The eco-hydrological model SWAT is used to investigate the effects of the CAP policy on water and matter fluxes. The ProLand derived map of the CAP scenario as well as the current land use distribution act as main inputs. In the frame of this presentation results for hydrological objectives of the CAP scenario are compared to the current land use. Further, an uncertainty analysis based on Monte Carlo simulations is conducted to investigate the significance of changes in various hydrological components such as discharge, groundwater recharge, or direct runoff.

On the use of SWAT for the identification of the most cost-effective pollution abatement measures for river basins

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In order to reach the water quality objectives, as set by the EU Water Framework Directive, discharge loads of pollutants have to be reduced basin-wide. Hence, river basin management plans have to be set up by 2008. Based on a pressure and impact analysis, potential pollution abatement measures have to be identified and the unitary costs and effectiveness of these measures must be assessed. Finally, the least-costly (or most cost-effective) set of potential measures for reaching good water status has to be identified. In this paper, a methodology to set up and evaluate cost-effective pollution abatement plans is proposed. As a study area, the Nete river basin, located in Belgium is used. It is a subbasin of the international river basin district of the Scheldt and one of the pilot basins to implement the Water Framework Directive.

For the identification of the least-costly set of measures, the cost-effectiveness of each pollution abatement measure - or of a combination of measures - is assessed. Hereby, cost-effectiveness is defined as the annual cost for each removed pollutant unit (e.g. x Euro / kg N removed). To identify the most cost-effective set of measures, a linear programming framework is used with cost-effectiveness as the objective function. Hereby, SWAT is used to assess the effectiveness of measures on the in-stream water quality (e.g. x kg N removed). Thereby, measures having a local impact are combined with measures having a basin-wide impact. Each measure or combination of measures is ran by SWAT as a different scenario. For the scenarios that reach good water quality, cost-effectiveness is calculated and compared to alternative scenarios. Large differences in financial and environmental effects in different subbasins are expected.

A Cursory Look at Downstream Stream flow and Sediment Response to Conservation Practice Implementation

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Recent interest in tracking environmental benefits of conservation practices on farms and ranches throughout the United States has led to the implementation of a multi-agency effort referred to as the Conservation Effects Assessment Project (CEAP). Headed by the US Dept. of Agriculture (USDA) National Resource Conservation Service (NRCS), the primary focus of the CEAP effort is to produce an assessment of environmental benefits derived from implementing various USDA conservation programs. Tracking the environmental benefits of these programs will allow policy makers and program managers to implement and modify existing programs and design new programs that more effectively meet goals to protect the nation's soil and water resources. Although it is well recognized that a number of conservation programs have been designed to protect agricultural lands from soil erosion, conserve water use, enhance water quality, and promote wildlife habitat restoration, the environmental benefits derived from these programs have not been well quantified to date. In order to develop quantitative relationships between water quality, soil quality, and water conservation and the benefits derived from conservation practices, the CEAP effort will utilize USDA Agricultural Research Service (ARS) experimental watersheds to make watershed scale on- and off-site assessments. One of the particular objectives of these watershed assessments will be to quantify the net cumulative effects of conservation practices within a watershed. In this study a cursory investigation is conducted to determine the downstream effects on streamflow and sediment load of implementing a particular management practice at various intensities in the upper reaches of an experimental watershed. The setting for the study is a 136 km^2 drainage of the Ft. Cobb Watershed referred to as the Lake Creek subwatershed. Five years of precipitation and streamflow data are used to calibrate parameters in the Soil and Water Assessment Tool (SWAT) that govern the streamflow and sediment response of the model on the watershed. SWAT is then used to simulate thirty years of hydrologic data to evaluate changes in annual, monthly, and daily streamflow and sediment due to hypothetical changes in land cover on the watershed from peanuts and winter wheat to Bermuda grass. Proposed changes in land cover on the upper most portion of the watershed are implemented at various intensity levels, and resultant changes in streamflow and sediment responses are simulated at multiple locations downstream of the proposed changes. This investigation provides preliminary information that quantifies the relative changes in streamflow and sediment loading that would be expected to occur well downstream of conservation practices that are implemented on the watershed.

Development of Complex Hydrologic Response Unit (HRU) Schemes and Management

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The majority of SWAT applications over the past decade have involved modeling of nutrients and sediment, often in support of developing best management practices to reduce the loading of these non-point source pollutants. Recently, in the United States, there has been an increasing interest in applying SWAT to assess levels of exposure to agricultural pesticides. Modeling pesticide exposure presents unique challenges that are not often encountered when modeling nutrient or sediment loads. These challenges arise because evaluating pesticide exposure requires an assessment of the frequency and magnitude of short duration peak events, as opposed to an assessment of longer duration load totals, typical for nutrients and sediment. Modeling short duration peak events requires more precise data concerning the pesticide application parameters of timing, rate, and area of application. Customized model data input procedures were created to accommodate the more rigorous input requirements of modeling pesticides to evaluate exposure and the effects of best management practices. Two different applications will be discussed, one in which spatially distributed daily pesticide application input data was available, and one in which daily pesticide application data was inferred from more general crop planting data. In both cases, capturing the temporal and spatial variability of pesticide applications required a sub-HRU approach that was flexible enough to allow subbasin-dependent HRU splitting. This presentation will consider the strategies used to develop the complex HRU and management schemes required for pesticide modeling, review the results of several model applications, and touch upon strategies used for the evaluation of best management practices.

Poster Presentation Abstracts

Global Climate Change and Future of Water Resources in Bangladesh

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The Ganges Delta in Bangladesh, a richly fertile green region, is the major supporter of life in Bangladesh. It's water resources are enormous but it is now faced with large-scale environmental degradation due to many causes. Changing sea levels related to global climate change are a particular threat with potentially large-scale loses of fertile lands. Air pollution is becoming a major threat to water quality and Dhaka City has overtaken Mexico City for the intensity of urban air pollution, particularly with respect to lead. The southern region is increasingly threatened by serious and worsening salinization derived by salt water intrusion. Water loss in the upper reaches due to increasing riparian consumption is impacting water flow and hydrology and the coastal mangrove forest "Sundarbhan", a World Heritage Site, is dying. The only surface water irrigation project has become a liability and arsenic pollution of surface aquifers has become a grave threat requiring emergency international intervention. Because, arsenic in groundwater is present in excess of the safe limit set for Bangladesh. It is now recognized that arsenic is a serious health hazard. The waters here also suffer from intensification of agricultural yields with excessive, even indiscriminate, application of pesticides, herbicides and chemical fertilisers resulting in increasing levels of nutrients. The polderization of wetlands in a large Dutch embankment plan that once gave magnificent crops has now failed and has contributed to a major loss of wetland environment. As a consequence of these and even other issues there is a clear need for management intervention based on environmental and economic sustainability. For this to be achieved there is an urgent need to focus the general public to develop a social awareness movement to influence policy decision towards sustaining the natural resources of Bangladesh.

Nitrate pollution of groundwater in central Iran

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The increasing interest among both the public and researchers in maintaining the quality of our ground and surface water resources, it is of great importance to understand the potential role of agricultural and industrial activities that effect water quality. These activities have altered the natural background of NO_3 concentrations of water sources in many areas. The objective of this study was to determine spatial and temporal variations in nitrate contamination of groundwater in agricultural, industrial, and urban regions of Isfahan province. Isfahan province is located in arid and semiarid region of Iran. Water samples were collected from more than 200 wells every month for three years (1998 to 2001). All water samples were analyzed for NO_3-N, Cl, SO_4, HCO_3, CO_3, Ca, Mg, Na, K, EC, and pH. Nitrate-N values of all samples ranged from 1.1 to 103 mg L^-. The mean NO3-N concentration was 11.5 mg/kg, with 55% of wells exceeding the USEPA maximum concentration level of 10 mg/kg. In general, the greatest NO_3-N concentrations were in wells from agricultural regions. The farms in the region on average use 5 to 10 times more nitrogen fertilizer than necessary. In the presentation spatial and temporal variation of nitrate and other chemicals in the region will be discussed.

Mapping risk of cadmium and lead contamination to human healthin soils of Central Iran

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In order to map Cd and Pb contamination in the soils of the region of Isfahan, Central Iran we performed indicator kriging on a set of 255 top soil samples (0-20 cm) gathered irregularly from an area of 6800 km^2. The measured Cd concentrations exceeded the Swiss guide value in more than 80% of the samples whereas Pb concentrations exceeded the respective guide value only in 2% of the samples. Based on the simulated conditional distribution functions, the probability of exceeding the concentration of Cd and Pb from the specific threshold was computed. The results indicated that in most part of the region the probability of contamination by Cd is very high whereas it is low for Pb. Based on a misclassification analysis, we chose the probability of 0.45 an optimum probability threshold to delineate the contaminated from uncontaminated areas for Cd. In addition, we performed a loss analysis to separate risks to human health from potential losses due to remediation costs. Based on this analysis a probability threshold of 0.8 was found to be an optimum threshold for the classification of contaminated and uncontaminated area in the case of Cd. Health risks were found to be higher in the western parts of the region. Misclassification analysis was sufficient for risk mapping in the case of Pb as its concentration did not reach risk levels for human health. A probability of 0.7 was found to be an optimum threshold in the case of Pb.

SWAT modeling response of soil erosion and runoff to changes in precipitation and cover

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Global climate has changed over the past century. Precipitation amounts and intensities are increasing. In this study, we investigated the SWAT model response to a few basic precipitation and vegetation related parameters using common data from one semi-arid rangeland watershed in Arizona. We compared it to the response of six other models. The seven models: SWAT, WEPP, LISEM, MEFIDIS, RUSLE, STREAM, and KINEROS were calibrated using flow data and sediment loadings from three storms. Information on topography, soils, land use, land management, and weather was provided to the modelers but no calibration criteria and application style was specified. Perturbations were made to inputs for rainfall intensities and amounts, and to ground surface cover and canopy cover. The model response to an input perturbation was quantified by its sensitivity expressed as percentage change in either runoff or sediment response relative to percentage change in input value. All models were sensitive to rainfall depth, rainfall intensity, and ground cover. They were less sensitive to canopy cover. Sensitivities were generally larger for the smaller events even though the magnitude of change was larger for the larger events. In spite of the differences between the models in terms of process descriptions, data sets to develop and validate the models, and differences in the modelers' application style and calibration criteria, the similarities in the responses of these models give credibility to the use of such models for studying climate change impacts on runoff and erosion.

Crop coefficients of sugarcane (Ratoon) in Haft Tappeh of Iran

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Crop coefficients of sugarcane are necessary for the water requirement estimation in irrigation water planning and management. This study has been initiated to determine the crop coefficients (Kc) of sugarcane (Ratoon) in Haft Tappeh sugarcane area, Khuzestan province, Iran. Main objectives of this research were, 1- to measure the crop evapotranspriation (ETc) using lysimeters 2- to estimate the reference evapotranspriation (ET0) using the pan evaporation method and 3- to compute the crop coefficients of sugarcane. The relationships between Kc, ETc/Ep, length growth of sugarcane, days after cutting (DAS) and percent days after cutting (%DAS), were also investigated. Results show the seasonal ETc for sugarcane (Ratoon) in the study area with an eight months growth period was 1925 mm and the pan evaporation method was preferable for estimating ET0. The mid-season and late-season Kc values for sugarcane were 1.45 and 1.14, respectively. These values are somewhat higher than those values that recommended by FAO. The ratio of ETc/Ep varied between 0.64 to 1.10 from the beginning to the end of the growing season The maximum ratios of ETc/ET0 and ETc/Ep occurred at a length growth of 126 cm. Furthermore, second order polynomials were presented to predict the Kc values from days after cutting (DAS) and percent days after cutting (%DAS).

Keywords: Sugarcane, Haft Tappeh, Crop coefficient, Irrigation and Evapotranspiration

Floodwater effect on infiltration rate of a floodwater spreading system in Moosian

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Uneven rainfall distribution in time and space as well as the low amount of rainfall has made the farmers to overuse the ground water in order to manage more reliable farming in the southwestern plain of Ilam province in Iran. In this scenario, ground water recharge has an important role in the farming security. One way to increase ground water quality and quantity wherever accepted good quality floodwater is available for recharging is a recharging system. However in practice, like many other natural resource projects, this system has some real difficulties. Among the main difficulties is clogging phenomenon, which occurs through sedimentation by fine particles over the surface of water spreading systems. In this study a floodwater-spreading system was selected to measure and monitor the variation of the infiltration and clogging phenomenon. The vertical variation as well as flow direction variation of the infiltration is studied. The vertical variation of infiltration of the sediment is measured at five surfaces. To monitor infiltration in the flow direction, infiltration is measured in the desilting basin, spreading channel, spreading basin, and control points. The statistical analysis showed that the sedimentation siginficantly decreased the surface infiltration of the desilting basin when compared with the data obtained from the control points. The control points were selected of the intact area where the soil and geomorphic surface were similar to the selected sites. With removal of the top 10 cm of the natural surface beneath the sediment showed that the infiltration rates were significantly increased. Therefore, in order to decrease the adverse effects of sedimentation on reduction of the infiltration rate in the desilting basin, the results of the experiment recommend removing the recent sediment of the basin and also plowing the top 10cm of the natural surface below the removed sediment.

Keywords: Floodwater spreading, Infiltration, clogging.

A Decision Support System based on the SWAT model for the Sardinian Water Authorities.

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Sardinian Regional Authorities, such as *Assessorato della Difesa dell'Ambiente*, have the awkward problem of water management and protection. Targeted to their specific needs they use alternative applications and models for their specific tasks and little communication is usually achieved. Black box models, in the past, have been the most commonly used approach to describe the hydrological cycle. Despite their wide use, these models have shown severe limitations to take into account land use and climate changes. Physically based models, then, can make better prediction when different combination of soil and land use, within the basin, have a significant effect on the hydrological cycle. The variety and complexity of alternative environmental problems found in the island, which vary from the impact of the agro-zootechnical to the industrial compartment, have suggested that empirical models are less suitable to predict the environmental dynamics at the catchment's scale. Regional Authorities enact Regional Directives to enforce different European Directives, and no absolute limits can be drawn to separate their alternative field of application. The *Piano di Tutela delle Acque (PTA)* Regional Directive aim to enforce water policy in terms of definition on where and how water resources must be used and those water protection actions that need to be enforced to improve water quality of rivers, lagoons, groundwater lakes etc.. In this context the hydrological physically based SWAT model has been chosen and applied to estimate both the water budget of the main catchments of the island and the impact of land management practices on downstream water bodies. The performance of the model has been, therefore, evaluated on several stream flows monitoring gages and then applied to evaluate water management scenarios. The model has been also applied to estimate the water budget under drought period and to predict the impact of alternative land management practices on water and agricultural chemical yield.

Scale issues hydrological pathways, and nitrogen runoff from agriculture- results from the Mellupite catchment, Latvia

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A comparison of measured N loads in small agricultural catchments in the Nordic and Baltic region has revealed large differences which could not be explained only by differences in agricultural practices. This poster will present the results of measurements on nitrogen runoff in relation to the hydrological processes in a Latvian catchment. Measurements were carried out at three spatial scales, i.e. plot, drainage field and catchment scale. The nitrogen concentrations and - runoff decreased with an increase in scale. Hydrological pathways might be a contributing factor in this. Comparison of runoff showed a delayed response in runoff at increasing scale while recession curve analysis revealed an increase in residence coefficient, indicating the possible presence of different flow paths involved in nitrogen runoff generation. The poster wants to highlight the importance of understanding the hydrological flow processes across spatial scales in catchments, and the possible effects this can have on nitrogen transport and loads into surface waters. The results suggest that the hydrological processes and scale issues need to be carefully considered when *(i)* designing monitoring strategies in the implementation of the WFD, and *(ii)* defining measures to control diffuse N losses.

Spatially differentiated calculation of the water balance in a part of the Treene watershed (Northern Germany)

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The EU Water Framework Directive (EU-WFD) considers mesoscale hydrological models as tools for decision support in the context of water resources and quality management. The local implementation and application of the respective models is a basic step for this special purpose. SWAT (1) offers the potential to fulfil the requirements of the EU-WFD and is currently considered as one of the contemporary EU methodologies for quantifying diffuse nitrogen and phosphorous losses (www.euroharp.org, date of access: 14.09.2004).

The aim of this study was to apply the SWAT2000 model in the part of the Treene watershed (federal state of Schleswig-Holstein, Germany) which is unaffected by tidal range. We focused on the calculation of the water balance as a first step. The catchment area spreads over 517 km² and is mostly characterized by moraine landscapes. Land use is dominated by agriculture (40 %), grassland (37 %) and forest (11 %). We apply the model SWAT (1) for this purpose. Model application is challenged by the influence of low hydraulic gradients originating from the flat land surface. Further, hydrological modelling is limited by inaccuracies of the elevation model (vertical accuracy ± 4m) and automatic elimination of sinks during DEM pre-processing. Measured runoff-data is available for 8 gages in the basin over a period from 1.11.1984 to 31.1.2001. Calibration was performed manually for the period 1994/95 using a multi-step procedure starting with the upper reaches and ending with the main outlet of the catchment.

The largest discrepancy between measured and predicted runoff is found in the extremely dry year 1996 showing 41 % less precipitation than the longterm average. Calculated runoff of the following years 1997-2000 shows a Nash-Sutcliffe index of 0.80 and a correlation coefficient of 0.90, which is considered a satisfying model performance under these conditions. Future research should focus on a better understanding and description of the local groundwater dynamics, which is the most important flow path in the catchment. Further, input data with higher spatial resolution and based on better knowledge concerning local hydrological questions in the catchment should be provided particularly with regard to modelling water quality issues.

(1) Arnold, J.G. et al. 1998. *Journal of the American Water Resources Association* 34(1): 73-89.

Distributed Watershed Modeling of a mountainous catchment

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Watershed management has been recognised as a widely accepted approach for optimal use of soil and water resources. Therefore. watershed-modelling: incorporating hydrological processes takes a crucial role for proper planning and development of these local resources. Invariably, one of the major difficulties encountered in the use of hydrological models is the requirement of calibration of the model on the target area. One of the hydrological model is named SWAT(Soil and Water Assessment Tool) model has been identified and implemented on Tehran-Amameh. mountainous, snow bound. 37.20 sq km watershed in Iran. The study has provided an in-sight into the working of the continuous, distributed water balance model, SWAT. The major objective of the study has been to assess the applicability of the model on ungauged watersheds. which has become a necessity in view of the fact that it shall be impracticable to gauge the small watersheds which are accepted as the viable planning and management units in all the countries around the globe. How data (about one year), the model performance has appreciably enhanced. It is therefore inferred that the character of the watershed, which is reflected through the observed flows. Is not attainable through any other form of information. The capability of the model to simulate the sediment yield has also been proven. It was very interesting to note that the improvement in the water yield simulation kept on bringing about the corresponding improvement in the sediment yield. This proves the capability of the model for sediment yield simulation beyond doubt. The capability of SWAT model to generate various management scenarios has also been explored. The impact assessment due to changes in rate of grazing. duration of grazing, and crop rotation, as well as changes due to utilization of fertilizer (Nitrate and Phosphate), has been evaluated on the catchment. However, it may be said that this ability of the SWAT model shall go a long way in enhancing the acceptability of the model with the end-users and shall make the model very effective tool of the future.

Keywords: SWAT model, Simulation, Distributed Watershed Modeling, Amameh, Iran.

SWAT model development for a large agricultural watershed in Iowa

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The SWAT (Soil and Water Assessment Tool) water quality model is designed to assess nonpoint and point pollution and conduct agricultural management scenario comparison. The model's simulation accuracy is evaluated with hydrologic monitoring data collected from the South Fork watershed in Iowa. This watershed represents the most intensive region for row-crop and livestock production in the Midwest. The model in its latest version is being applied using AVSWATX, the interface with ArcView 3.3 GIS software. AVSWATX provides an extendable environment including the optional usage of SSURGO data maps and derived soil parameters. Land use-land cover input maps and classes are primarily based on the NASS Crop Data Layer 2002 enhanced by Iowa Gap analysis data. Climate data from 1990 to 2004 are incorporated. Three years of crop rotation and conservation practice data are combined to establish management scenarios' effects on the impairment of South Fork watershed waters. Initial results of hydrologic and water quality validation will be presented.

Depasturtation effects on soil physical and chemical properties in Isfahan and CharMahal Bakhtiari Region

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Land use conversion of pasture to cropland is named depasturation. Studying soil properties during the processes of depasturation could be helpful to solve some soil and water conservation problems. A study was established in 2002 to evaluate the effects of depasturation upon soil physical and chemical properties of various regions in Isfahan and CharMahal Bakhtiari provinces. Nine regions were selected to investigate soil characteristics, including sites of :i) virgin pasture (P); completely destroyed pasture (D); and pastures which were cultivated and cropped (C). Soil samples were taken from depths (0-10). Soil organic matter(OM), bulk density (BD), pH, EC, available cations (AC) and available anions (AA), aggregate uniformity coefficient (AUC), plasticity index (PI), and tilth index (TI) were all measured. Depasturation and tillage practices caused a 20 percent increase in bulk density of the forest soil when cultivated compared to the undisturbed pasture soil. Due to the tillage practices and exposure of pasture soil to the atmosphere a 30 percent decrease in OM, and a 10-15 percent decrease in AC and AA were observed. Total nitrogen of the pasture soil at surface (0-10 cm) was almost twice as the cultivated and pasture soil. Plasticity index of the pasture soil was 10-30 percent higher than that of the disturbed soil. The tilth index in pasture soil was 25 and 15 percent higher than depasturated and cultivated pasture respectively. Depasturation and disturbing the pasture soil caused eroding of the thin top soil, loss of productivity and thus, could perhaps leave the soil with no use for several years.

The study of the non-point source pollution in Heihe River Basin

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Selected as the study area, Heihe river basin is the mainly runoff supply of the source in the Yellow river basin, and it is also a typical stockbreeding area in China. The SWAT model and its typical parameters in the Heihe river basin is analyzed and examined in this paper. The data of runoff silt and nitrogen pollution in 1998 is used to calibrate the SWAT model. The pollution load and transportation rules such as nitrogen and phosphorus are illustrated. In addition, the non-point source pollution load is calculated in this paper; especially the research focuses on the change of the non-point source pollution load with the change of the stockbreeding policy. The lost coefficient in the basin (LC) for non-point source pollution load is introduced, and the LCs of farmland, town, grass, bush and forest are calculated under different precipitation. The comparative study of the nitrogen pollution LCs calculated by two methods (SWAT method and Output coefficient method) shows that the two methods are feasible and valid; the correlation numbers are up to 0.9.

The paper concludes that the sensitivity analysis with different scenarios results in the order of the degree of sensitivity: scenario1> scenario3>scenario4>scenario2. The nitrogen LC is different according to different precipitation and type of land use. The adsorptive nitrogen LC order of different land use is farmland, town, grass, bush, forest, and the dissolve nitrogen LC order of different land use are: farmland, grass, bush, forest, town.

Key words: non-point source pollution, SWAT model, lost coefficient, Heihe river, Yellow River Basin

Modeling soil erosion in a sub-humid tropical environment at the regional scale

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There is an expanding research community using the SWAT model because there exist very few models which are suitable for distributed continuous modelling of soil erosion and water quality processes at the regional scale. In this study which is part of the German integrated water ressource management project IMPETUS the version AVSWAT 2000 was used to quantify soil degradation in a 14.000 km^2 catchment (Upper Ouémé, Benin). After calibrating and validating the model for recent conditions (1998-2004) the model has been used for calculation of different scenarios for climate and land use changes until 2025.
Until now there are very few applications of the SWAT model in tropical catchments mainly because of a missing knowledge about crop growth, soil distribution and discharge processes in the tropics. For this study an existing soil-type map at the scale 1:200.000 was referred to representative soil profiles and refined using information from a landuse map derived from Landsat/TM, a digital elevation model and field investigations using a catena approach. Special attention has been given to the delineation of the hydromorphic soils in the inland valleys because of their high relevance for hydrological modelling. SWAT landuse types were roughly modified for adaption tropical savannah formations. The calibration and validation of runoff processes with discharge measurements at catchments of different sizes showed good agreements, the validation of the sediment budget will be carried out with continuous measurements of suspended sediment concentration at four outlets of the catchment. For the scenario analysis spatially explicit projections for possible future landuse and climate condition from other project members were available. The combination of the modelling results for soil erosion with indicators for soil fertility (e.g. fertility capability classification) will enable spatial conclusions about the future development of soil fertility under the different scenarios. If the parameterisation of a crop model for all dominant crop types is successful a coupling with the erosion model would allow to study the effects of changes in soil fertility to crop yield considering different agrarian management strategies. First results for the improvement of the soil map and the erosion modelling under present and future conditions are presented.

Modeling water quality issues in the Treene catchment in northern Germany

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In a recent paper we have shown that the implementation of river water quality modelling issues in mesoscale watersheds models suffers from a lack of testing of the combined watershed/water quality approaches such as SWAT, ESWAT, and HSPF (1). Following the claim to extend knowledge of the models' applicability in practice we present a sample application of the QUAL2E water quality routines implemented in SWAT 2003.
SWAT 2003 is applied in the Treene watershed (federal state of Schleswig-Holstein, Germany).The watershed covers an area of 517 km2. It is located in a rather flat landscape (< 80 m elevation difference) leading to comparably small flow gradients, thus challenging the model's capabilities to simulate water balance. Land use is dominated by agriculture (40 %), grassland (37 %), and forest (11 %) offering a considerable source of diffuse pollution while no major point sources like industrial sites or wastewater treatment plants are located in the area (share of urban sites: 3.3 %).
Water quality data at different sampling intervals (minimum: 4 samples/yr, maximum 12 samples/yr) are available for three runoff gages at the Treene and its tributaries since the mid of the 1970s. The gages cover 50 km^2, 75 km^2, and 480 km^2 of the watershed area, respectively. Information on physical and chemical water characteristics includes temperature, pH, electrical conductivity, dissolved oxygen, nitrogen, and phosphorous. Modelling uses these data for simulation of major nutrient dynamics and comparison of the output with nitrogen and phosphorous data from original data set.

(1) Horn et al. 2004. *Phys. Chem. Earth*, 29: 725-737.

Soil physical and chemical properties as indicators of the degree of land degradation in Kuhrang Area, Zayandehrud Watershed

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Water, soil, forest and pasture are important parts of a natural ecosystem. Unfortunately, these resources are subject to degradation in many countries. The objective of this research was to investigate land degradation in Kuhrang area, located in Zayandehrud basin, Iran. Water erosion, which is accelerated by overgrazing, land use change and dry land farming, is the most important agent of land degradation. Land degradation factors were investigated on Quaternary sediments and Cretaceous limestone. Three different land uses including pasture, cultivated pasture and degraded pasture were selected on each formation and three soil samples were taken from 0-10 and 10-20 cm depths. Soil physical properties (bulk density, infiltration rate, saturation moisture content, mean weight diameter, plasticity index, and erodibility factor) and chemical properties (OM, total N, and available P) were measured. The results showed a significant difference ($P<0.05$) for bulk density and plasticity index of degraded sites. Significant decreases in the OM, total N, saturation moisture content, and mean weight diameter values were observed at degraded sites. Phosphorus values did not show significant difference in the land uses of the two selected formations. The pattern of infiltration rate was similar for the formations. Infiltration of cultivated areas was high at the beginning but it decreased with time. Soil erodibility factor in the degraded sites of Quaternary sediments showed a significant difference ($P<0.10$) relative to other land uses. The highest erodibility factor was measured for degraded sites. Land use change has caused soil classification change from Mollisol to Alfisol on degraded sites. On the basis of the prepared soil erosion map, 3% of lands had very high erosion and degradation, 40% high erosion, 39.5% moderate erosion, and 17.5% low erosion and degradation. The results indicated that this area is susceptible to erosion and land degradation and conservation measures have to be implemented to prevent further losses.

An assessment of alternative conservation practice and land use strategies on the hydrology and water quality of the Upper Mississippi River Basin

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Nitrogen loads discharged by the Mississippi River have been implicated as the primary cause of the seasonal oxygen-depleted hypoxic zone occurring in the Gulf of Mexico. The Upper Mississippi River Basin (UMRB) is dominated by agricultural land use and is a major source of the nitrogen loadings transported to the Gulf. An integrated modeling framework has been constructed for the entire UMRB using the Soil and Water Assessment Tool (SWAT) model, the interactive SWAT (i_SWAT) software package, and other supporting software and databases. The simulation framework facilitates execution of alternative policy scenarios for the region by incorporating detailed crop rotations and an array of nutrient and tillage management schemes, derived from the USDA National Resources Inventory (NRI) database and other sources, which accurately reflect current practices in the UMRB. Calibration and validation of the SWAT model will be performed for the entire UMRB by comparing simulated flow, sediment and nutrient levels with corresponding measured data at the watershed outlet and several points upstream. Following the calibration and validation phase, a suite of scenarios will be simulated to investigate the how shifts in conservation practices and land use will impact water quality in the UMRB stream system, in terms of both reduced in-stream levels of sediment and nutrients in the UMRB stream system and the potential implications for the Gulf of Mexico seasonal hypoxic zone. The scenario mix will include the effects of shifting into greater adoption of notill and mulch tillage throughout the region, increased use of other conservation practices such as terraces and contouring, improved efficiency of fertilizer and manure inputs, shifts in crop rotations grown in the region, and increased adoption of Conservation Reserve Program (CRP) land. The results of the calibration and validation phase of the study will be briefly reported, followed by more extensive presentation of the scenario results, including which land use and management strategies would yield the greatest environmental benefits relative to current conditions.

Macro-scale catchment modeling in North-West Russia

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The aim of study is development of the model of phosphorus balance in large "rivers-lakes" system and its testing for water system of Lake Ladoga and Neva Bay of the Gulf of Finland.

Lake Ladoga is the largest European lake with surface area about 18 000 km^2. The catchment of Lake Ladoga has an area more than 280 000 km^2 and 20% of this area is located in Finland. The Neva bay (400 km^2) is a freshwater part of the Gulf of Finland of the Baltic Sea connected with Lake Ladoga by Neva River. Water quality and ecological state of the Neva bay depend on Lake Ladoga outflow and impact of St.Petersburg. There are about 50 000 lakes and 60 000 rivers at this area and traditional structure of catchment model included slopes (or homogeneous sub-catchments) and river channels can not be used in this case.

Phosphorus is an element which defines the eutrophication of studied freshwater system. That is why a special model of total phosphorus (P_{tot}) balance in studied macro-scale water system was developed. 5 main water bodies (lakes Saimaa, Onega, Ladoga, Ilmen and Neva bay) and 5 sub-catchments were selected as a main units for the modeling. For each sub-catchment phosphorus load on catchment surface water was calculated as a sum of point sources load, emission from various land covers and atmospheric deposition. Phosphorus balance of water body was calculated taking into account the following fluxes: input from catchment area, input from upper parts, input from lower parts, input from bottom sediments (internal load), atmospheric deposition, direct point sources inputs, retention in water body and output. Phosphorus retention in catchment surface waters and in water bodies was calculated using relationship between annual runoff, catchment area and water surface area.

Modeling was made for period 1980 – 2004. The comparison between calculated and measured P_{tot} concentrations in Lake Ladoga shows that the model is quite adequate. Decrease of P_{tot} concentration in Lake Ladoga can be explained by decrease of components of external load. Main reasons of this decrease were effective environmental protection measures in 80th and economical crisis in 90th. Using the developed model the following applications were made: assessment the role of different parts of studied system in P_{tot} retention, dividing the external P_{tot} load on Lake Ladoga on natural and anthropogenic components and assessment of Lake's response on dynamic of these components, assessment of future changes of P_{tot} content in Neva bay under possible modification of waste waters treatment plants of St.Petersburg.

Application of AVSWAT2000 to simulate the various management scenarios on the Lake Balaton watershed, Hungary

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Soil erosion has special importance in the watershed of Lake Balaton, Hungary, since the sediment rich in organic matter and nutrients can accelerate eutrophication of the lake. Non-point source pollution of the lake has become recognized as an important environmental problem associated with agricultural production. The agricultural diffuse phosphorus loading of Lake Balaton must be further decreased in order to maintain the good water quality. Modelling phosphorus (P) loss from agricultural watersheds is key to quantifying the long-term water quality benefits of alternative best management practices. The goal of the 3/024/2001 NKFP project is to develop policy scenarios that may result significant reduction of P load. Three major objectives were set: i) the mechanism of phosphorus transport should be clarified and modelled in the basic research part since it is not sufficiently known. ii) the second objective is to build a coherent watershed database and to publish it on the homepage of the project so that it can meet different levels of demand on information. iii) the third objective is to develop these new services, to work out environmental friendly farming alternatives and to test the farmers` acceptance. The Soil and Water Assessment Tool (SWAT) was chosen to study soil erosion in a study sub-watershed on long-term simulations for management purposes. The model requires satisfactory information of spatial data on topography, hydrography, land use, soil characteristics, management, etc. GIS together with large-scale spatial information on soil properties, which significantly affects formulation of runoff and soil loss, can provide suitable information with the expected accuracy. To create DDM and to compilation of land cover map we used 1:10,000 topographic map. To compilation of soilscape and generate soil input parameters 1:10,000 soil map and the National 1:25,000 Scale Spatial Soil Information System was used as basic information of soil characteristics with new laboratory data from the area. Process of map compilation and results of soil input parameters generation achieved in a pilot area in the Lake Balaton watershed are presented in this paper. Due to model calibration three characteristic study catchments, which are represent the sub-watersheds, were selected and equipped with automatic flow meter, rainfall meter and even with sediment samplers.

Impact of precipitation data interpolation on the quality of SWAT simulations

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Precipitation is the most important driving factor for rainfall-runoff models. Typically, only point measurements made with rain gauges are available. Interpolation is required to estimate precipitation in other parts of the catchment. The current version of SWAT uses a nearest neighbourhood approach. However, many other interpolation methods are available (inverse distance weighting, inverse square distance weighting, kriging with a time-averaged variogram, kriging with daily variograms). All these algorithms can be applied for the entire domain or locally. The first objective of this work was to compare the interpolation accuracy of the 9 abovementioned interpolation methods through cross-validation. Daily rainfall time series from a network of eighteen rain gauges in the Lahn-Dill region (Germany) were used in this study. The cross-validation exercise showed that all interpolation schemes had a similar accuracy, except for the nearest neighbourhood interpolation that had a lower accuracy. The second objective was to analyse the impact of different interpolation schemes on the quality of automatically calibrated SWAT simulations both with respect to different components of the water cycle and the optimised model parameters. The 9 interpolation methods were used to generate precipitation fields for the Aar catchment, a 134 km^2 catchment within the Lahn-Dill region. The interpolation methods resulted in different water balances. Against our expectations, the automatic calibration was not able to compensate for the differences in the precipitation fields. Therefore, there were differences in the quality of the model simulations, even after model calibration.

Modeling of hydrology and water quality in the Thur River Basin

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The primary goal of this research work was to mitigate the degree of accuracy the integrated water quantity and quality modeling approach can produce and how the results of the detailed mechanistic modeling could improve our knowledge and understanding the mechanisms and dynamic of the physical and chemical processes within the alpine/pre-alpine Thur River basin (total area 1,700 km^2). Being a Swiss part of the Rhine Basin, the Thur basin is located in the north-east part of the Switzerland. The upper part of the Thur watershed is a high mountains/hilly-dissected terrain, whereas lower part is presented by relatively flat area. The elevation ranges from 350 m to 2,500 m a.s.l. The research work employs a GIS (Geographic Information Systems)-integrated physically-based distributed SWAT (Soil and Water Assessment Tool) model in order to simulate climatic, hydrologic, and water quality conditions in the Thur River basin. Calibration of the model was done manually, with adjusting relevant parameters sensitive to flow, suspended sediment and nutrient loads. Model performance criteria such as linear regression (Spearman's correlation coefficient - R) and Nash-Sutcliffe model efficiency coefficient (NS) were used to compare simulated data with the observed data at basin's outlet. The calibrated parameters were used in the model validation. The model is capable to predict 14-day, monthly and annual streamflows and nutrient loads with acceptable degree of accuracy. The results from model calibration and validation show a good agreement between simulated and observed discharges (R= 0.92, Nash-Sutcliffe (NS) = 0.80 for R=0.95, NS=0.84 for validation time period) and between predicted and measured 14-days averages total suspended sediment loads (R=0.79, NS = 0.61 and R=0.94, NS=0.40, respectively). Performance criteria for nutrient simulations indicate good model efficiency in predicting the loads, e.g. for nitrates - R_{14days} =0.60, NS =0.27; R_{14days} = 0.62, NS = 0.33 for calibration and validation time period accordingly, total nitrogen - R_{14days} =0.78, NS =0.58; R_{14days} = 0.83, NS = 0.66 and total phosphorus - R_{14days} =0.63, NS =0.21; R_{14days} = 0.86, NS = 0.58. Overall, this study demonstrated the effectiveness of using detailed mechanistic modeling (SWAT model) in characterizing the water balance and water quality conditions in the Thur River basin. The calibrated model can further be applied to the analysis of non-point source pollution in the basin, agricultural management scenario analysis, land-use change impacts on water quantity and quality etc.

Keywords: hydrological modeling, water quality modeling, calibration, validation, SWAT

Hydrologic modeling semi arid region (Brazil)

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Salitre River Watershed is located in the semi-arid State of Bahia (Brazil) and presents problems related to the water availability because of the small amount and the irregular seasonal distribution of the rain. It is notable that in this region, the data from streamflow is scarce, making it difficult to measure the water availability in the basin. Studies from mathematical rain-flow models are necessary to resolve this problem. This research presents an application of the hydrologic model Soil Water Assessment Tool – SWAT, associated with the Geographic Information System-GIS in the Watershed of Salitre River. The simulated results were compared to the observed data at select point on the basin and the results were satisfactory. The monthly time series comparison of measured and predicted stream flows at Junco gage explains the general trend of the time series very well with in correlation coefficient of 80% and determination coefficient of 78%. The results demonstrate that this model can represents well the climatic and physical conditions of the semi-arid regions Brazilian.

Evaluation of the soil nitrogen balance model in SWAT with lysimeter data

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Eco-hydrological simulation models such as SWAT are essential tools for decision support in water resources planning. They can be used to simulate the effects of land use scenarios on both water and matter fluxes, provided that all relevant key processes and interactions of the soil-vegetation-water-system are considered and valid.
A data set of monthly records from three long-term German lysimeter experiments (1) was used to evaluate the soil nitrogen balance algorithms in SWAT on the scale of an HRU. An artificial catchment was created, with soil physical parameters, weather records and crop management data supplied by (1). The model efficiency of simulated and observed actual evapotranspiration ranged between 0.78 and 0.81 for each lysimeter. The cascade water balance model of SWAT reproduced the observed percolation reasonably well. However, monthly simulated nitrate leaching was underestimated by one order of magnitude, which could not only be attributed to the performance of the water balance model. Although the amount of seasonal crop nitrogen uptake seems to be realistic, the uptake on days with fertilization is highly overestimated.
In SWAT crops can adjust the nutrient deficiency immediately, when growth within the precedent period was nutrient limited. Hence, on days with fertilization where nitrate is readily available, crops will take up as much nitrate as needed to compensate for the nutrient deficit. SWAT simulated daily uptake rates of up to 70 kg N ha^{-1} in the lysimeters. Furthermore, the kinetics of denitrification is not limited in SWAT. Within SWAT denitrification will occur, if soil moisture is above 95 % of field capacity. In addition, water can only percolate in the cascade model, if field capacity is exceeded. Hence, denitrification and nitrate leaching are two competing processes within SWAT. Since denitrification is calculated first in the order of the code, it is the dominant leakage for the nitrogen balance (116 kg N ha^{-1} per year). Since the nitrate pool drains so quickly by denitrification, the rate of mineralization is the only process, which controls the rate of the remaining nitrogen fluxes.
In this study we will implement algorithms based on a detailed, process oriented nitrogen balance model (DNDC) proposed by (2) to overcome the aforementioned problems in SWAT. DNDC considers gross mineralization, ammonification, nitrification, denitrification, nutrient uptake by plants and leaching. The simulated nutrient uptake by crops in DNDC depends on both, the extractable nitrogen content of the soil and the nitrogen demand of the crop. Furthermore, DNDC uses a detailed approach to simulate denitrification. A comprehensive comparison of the two proposed soil nitrogen balance models will be given, and both models will be tested with the observed lysimeter records.

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Modeling soil carbon cycle for the assessment of carbon sequestration potentials at the river basin scale

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The global rising of CO_2 emissions and the resulting negative consequences thereof lead to the necessity for reducing these emissions. Besides reduction of emissions each country has the possibility to implement land use management practices that promote sequestration of CO_2 in soils and vegetation (e.g. Kyoto Protocol Article 3.3 and 3.4). In this context soils are of importance, because they contain twice the amount of carbon than stored in plant biomass.
To investigate effects of different land use management practices and land use changes on carbon fluxes in river cathments, we developed an integrated model by integrating a soil organic matter model (Soil-Carbon-Nitrogen model, a submodel of the forest growth model 4C) into the ecohydrological river basin model SWIM (Soil and Water Integrated Model). The extended integrated model combines hydrological processes, crop and vegetation growth, carbon, nitrogen, phosphorus cycles and soil organic matter turnover. It is based on a three level spatial disaggregation scheme (basin, subbasin and hydrotopes), whereas a hydrotope is a set of elementary units in the subbasin with a uniform land use and soil type. The direct connection to land use, soil and climate data provides a possibility to use the model for analyses of climate change and land use change impacts on hydrology, vegetation growth (e.g. crop yield) and soil biogeochemistry.
Aim of this study was to test the model performance and its capability to simulate carbon pools and fluxes in right magnitudes and temporal behaviour at the regional scale. As a first step, a sensitivity analysis has been performed and the model has been parameterised and verified for conditions in East Germany, using values known from literature and regionally available time series of carbon pools and fluxes. This provides verification of carbon pools and fluxes in the landscape and verifies the correct representation of the environmental processes therein. Additionally uncertainty analysis on model results have been performed using a Monte Carlo type approach. This led to a quantification of uncertainty bounds attached to spatial and temporal model results.
Based on this, different land management strategies and land use change options (e.g. conversion of agricultural areas to forest or to set-aside areas) can be simulated to assess the behaviour of water and carbon fluxes as well as carbon sequestration options within the river catchment or at the landscape level.
For agricultural areas impacts of land management changes and land use changes on the carbon balance have been investigated. Land management significantly influences soil carbon stocks and changes the carbon balance. For land management changes in cropland the influences of different soil tillage operations, crop rotations, harvest management and fertilization regimes on soil carbon stocks and soil respiration have been studied. Additionally the soil carbon balance for recent decades have been compared to future land use scenarios driven by different anticipated European Union agricultural policies regionalised to Eastern German conditions.

Evaluation of soil infiltration in furrow irrigation and determination of Kostiakov& Kostiakov - Lewis equations coefficients

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A major step in the design and evaluation of furrow irrigation system is the determination of infiltration function. The purpose of this study is to compare infiltration measurement results, using double ring and inflow-outflow method following consecutive irrigation events. Study of bulk density variation after each irrigation was another aim of this investigation. Experiments were conducted on a site near agriculture faculty of Shaheed Chamran University in Ahwaz. Results indicate that correlation coefficient in the first irrigation period is low in comparison with the others periods. Cumulative infiltration is reduced in the second irrigation in comparison with the first irrigation 180 minutes after irrigation started. Cumulative infiltration is also reduced in the third irrigation in comparison with the second irrigation. During the fourth irrigation, cumulative infiltration increased in comparison with the third irrigation which was due to weed growth in the furrows. Results show that calculated basic infiltration rate using inflow-outflow method is 4.4 times greater than double ring method .Results also show that for short time periods (less than 180 minutes), Kostiakov method is in a better agreement with Kostiakov-Lewis method. Cumulative infiltration was shown to be higher using kostiakov-lewis method in comparison to actual measurement for long time periods (more than 180 minutes).

Key Words: Furrow irrigation, Infiltration, inflow – out flow method, double rings, kostiakov& kostiakov - lewis equations

Assessment of agricultural management practices in the Upper Maquoketa River Watershed Northeast Iowa: using two modeling approaches

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A validation study was performed with SWAT for the Upper Maquoketa River Watershed (UMRW), which drains over 16,000 ha in northeast Iowa. Corn and soybean account for over 65% of the total UMRW land use; other land use includes woodland (9%), alfalfa (7.5%), Conservation Reserve Program (CRP) land (4%), and pasture (4.0%). A total of 90 UMRW operations were identified in a 1999 survey as having one or more types of livestock, with production focused primarily on swine, dairy cows, beef cattle, feeder cattle, and/or calves and heifers. Surface water monitoring at four sites during 1999-2001 showed elevated levels of nitrate-nitrogen (NO_3-N) and phosphate-phosphorus (PO_4-P), depending on the flow conditions. Tile drains are a key conduit of NO_3-N to the UMRW stream system.

The SWAT validation study builds on a previous UMRW study, in which a nested APEX-SWAT modeling approach was used. The nested approach was used to take advantage of enhanced manure management simulation capabilities in APEX and was executed by: (1) simulating the crop fields associated with the livestock operations in APEX (almost 30% of the cropland area), (2) inputting the APEX-estimated edge-of-field flows, sediment losses, and nutrient losses (resulting from the fertilizer and manure applications) into SWAT at the subwatershed level, and (3) routing these flows and pollutant losses to the watershed outlet along with the flows and losses estimated for the rest of the watershed. In the current study, the entire UMRW cropland area was simulated in SWAT (SWAT-only approach). This required converting the crop fields originally simulated in APEX into SWAT hydrologic response units (HRUs), including the manure and fertilizer applications and other management practices that were previously simulated in APEX. The current validation focused on comparing predicted flow and NO_3-N loadings with corresponding in-stream measurements at the watershed outlet. The SWAT-only approach resulted in r^2 values of 0.92 and 0.81 for the predicted average monthly flows and NO_3-N loads, respectively, indicating that SWAT accurately tracked the monthly flow and NO_3-N loss trends. These results were also stronger than the corresponding r^2 statistics found with the APEX-SWAT approach, which were previously reported as 0.79 and 0.74 for the average monthly flow and NO_3-N loads. The results of this study and the previous study indicate that both the APEX-SWAT and SWAT-only methods can be viable simulation approaches, but that the SWAT-only approach may be better suited for investigating the long-term watershed-level impacts of agricultural management practices due to less complexity in terms of managing model input and output when compared with APEX-SWAT approach. Further details regarding this issue between the two modeling approaches will be discussed, and additional results of the current SWAT-only application will also be reported.

Using SWAT model to assess vegetation change effects on runoff volume in a semi arid watershed in Northern Mexico: I. model calibration and validation.

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The goal of this study is to assess SWAT model performance across watershed sizes, and to assess the effect of using different map set resolutions and basin configurations on runoff volume. SWAT model is a distributed parameter, continuous hydrologic simulation model designed to simulate the effects of land-use practices on runoff volume, soil erosion and sediment yield on rangelands watersheds. Sextin River, a tributary of Nazas river basin, in Northern Mexico, was chosen as study area. Sensitivity analysis showed that Curve Number (CN) parameter was the most important in defining runoff volume and peak runoff rate. Model calibration performance was measured primarily by the Nash – Sutcliff coefficient of efficiency for total annual runoff and for maximum annual peak runoff rate. Runoff volumes model efficiencies obtained were very good for the Sextin river watershed. In general, this model trends to over predict runoff volume for small rainfall events, and under predict for large rainfall events. The results showed that watershed configuration complexity significantly alters the model results on large watersheds, and can be attributed to the improved representation of spatially distributed watershed features with increased geometric complexity.

Evaluation of SWAT stream flow components for the Grote Nete River Basin

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A simulation study using the Soil and Water Assessment Tool (SWAT) model was initiated to estimate daily flow components in the Grote Nete River basin, Belgium. The parameters of hydrologic models often are not exactly known and therefore have to be determined by calibration. In the current study, the procedure considers multiple calibration objectives including calibrated components flow, such as the total flow and base flow, considering indirectly the overland flow component being the difference between total and base flow. Model calibrations were pursued on the basis of comparing the simulated output with the observed total and base flow using qualitative (graphical) assessments and quantitative (statistical) indicators.
This analysis is conducted in order to obtain some insight into relative importance of the surface and base flow components of observed hydrographs in an effort to improve the predictive capability of the model for the study site. The study was conducted using a 10-year historical flow record (1986-1995); in which the period 1986-1989 for calibration and 1990-1995 for validation. The predicted daily total flow and base flow matched the observed values, with a Nash-Sutcliff coefficient of 0.62 during calibration and 0.77 during validation, and with a Nash-Sutcliff coefficient of 0.56 during calibration and 0.65 during validation, respectively. Analysis of high flow and low flows indicated that the model is unbiased.
The results indicate that the SWAT model is a suitable model for use in the basin of the Grote Nete River given that the calibration focuses on matching simultaneously the total and base flow has a very good potential for being used as tool to study stream flows in Belgium.

Application of AVSWAT2000 to Fairchild Creek, Grand River, Ontario

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The objective of the present study is to evaluate SWAT (Soil and Water Assessment Tool) hydrological model for Fairchild Creek watershed, a tributary of Grand River, Ontario. This watershed drains an area of 391 km^2. The area is mostly rural and farmed with a number of live stock operations and wetlands. The study was conducted using 10-year historical flow record (1990-1999). The record for 1990-1995 was used for calibration of the model and record for 1996-1999 was used for validation of the model. The results indicate that SWAT simulates stream flow very well. The Nash-Sutcliffe coefficient used to evaluate the performance of SWAT was 0.52 for calibration and 0.50 for validation. The sediment yield, nutrients loads are also simulated in this study. Analysis of evaluation of SWAT for water quality simulation is under progress. Detailed results of the study and potential use of the model are presented and discussed in the paper.

Key words: SWAT, Calibration, Validation, Watershed

Investigation of the effect of land use change on simulating daily discharge flow using SWAT (case study: Kasilian catchment area)

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There are several methods to estimate runoff from rain in catchmants.One of this mothods is hydrological models. Hyrologic models by simulating hyrological process make it possible that is evaluated runoff from rain or other systems in at least time and lowest costs.
However there isn't possibility the measurement of all case in all cachments, so it's necessary to chose the models that they can evaluate hydrological process with at least parameters. One of these models is SWAT model. This model is developed by Arnold in 1972.and is perfected by Arnold & Wiliams in 1996. Model receives daily raifall, dailydebi and daily evatranspiration, after optimized parameters. Study carry out in Kasilian cachment in iran.Results of this study showed that the value of determination coefficient is satisfactory fore cachment. And the result test of model showed that ABF, CN2 and REVAPC parameters are most sensitive among other parameters. Finally the effect of hyrological parameters is evaluated on the streamflow. The model simulated the hydrological processor for agriculturale and rangeland land use better than forestry land use.

Keywords: SWAT model, Kasilian, Simulation, Hydrological parameters, Runoff, Iran.

Water-salt balance in large catchments

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The effects of improper anthropological activities on natural conditions of catchments have caused the abnormal alterations in water and soil sources in these catchments. To repair of this incorrect trend, recognition of the present conditions and the effects rising from human activities on these sources is very important. One of the tools that can be trouble-shooter and useful, is using of water-salt balance models in large scale catchments, modeling the water salt balance of watershed basin is complex problem, one of the biggest obstacles on this way is lack of various and precise information on these models. Especially when we want to work on large catchments. lack of enough information from one hand and their imprecision from the other hand, causes some difficulties when these models are used. Therefore, in this study we tried to offer the simple models with moderate precision to be used in managing the large catchments. The model is based on a set of balance equations using empirical and semi-empirical dependencies. This model of water-salt balance has been investigated on both agricultural lands (WSBI)and river fields (WSBII). The final model (WSBIII) is a combined one derived from the both mentioned areas.

A modeling approach for evaluating the water quality benefits of conservation practices at the national level

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The United States Department of Agriculture has initiated the Conservation Effects Assessment Project (CEAP) including a modeling effort to quantify the environmental benefits of conservation practices at the national scale in the United States. This paper focuses on the modeling approach consisting of the data sets, modeling components and scenarios being used in the CEAP national assessment study. Data sets including weather, land use, soils, management practices and farmer's survey are used to develop model inputs for the conterminous United Status. The modeling approach includes the farm-scale model Agricultural Policy/Environmental Extender (APEX) and the Soil and Water Assessment Tool (SWAT), along with the GIS databases. The APEX model is used to simulate conservation practices for cultivated cropland. Farmer surveys conducted on a subset of National Resource Inventory sample points provide information on current farming activities and conservation practices for APEX. Output from APEX will be input into the watershed scale model, SWAT in the HUMUS (Hydrologic Unit Modeling for the United States) system for routing the pollutants to the 8-digit watershed outlets. HUMUS/SWAT will be calibrated and validated using observed streamflow from the United States Geological Survey's gaging stations and streamflow and pollutant data generated by the SPAtially Referenced Regressions On Watershed attributes (SPARROW) model. The modeling system will be used to simulate in-stream effects for (1) a baseline scenario with conservation practices and (2) an alternative scenario without conservation practices. The off-site water quality benefits of conservation practices will be determined by comparing outputs of these scenarios at each 8-digit watershed. Benefits will be reported as reductions in in-stream concentrations and loadings of sediment, nutrients and pesticides, and reductions in the number of days that concentrations exceed human health and ecological thresholds.

Creation of monitoring system of the Dnipro River Basin to protect environment and public health

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The Dnipro river's water is the main source of water supply for Ukraine. But water quality is not correspond to sanitary standards and state standards. The monitoring programs are not coordinated and using the results of different monitoring services.

The paper is aimed at creation of effective system of water quality monitoring and improving of the effectiveness of water management in the region, it will positively influence the ecological situation of the river. Improving of ecological situation should be achieved by reduction of harmful discharges into the river.

The main goals of the "The Dnipro River Pollution Monitoring" were:

- Evaluation of existing infrastructure of the basin of the river, identification of the pollutants;
- Investigation and implementation of water quality analysis aimed at the main sources of pollution;
- Creation of computer database on the basis of information which was gathered in the process of project's implementation;
- Identification of the critical levels of pollution;
- Organization and implementation of the seminar based on the results of investigations;
- Working out recommendations aimed at water management improvement;
- Distribution of positive experience through mass media and via electronic media.

The Dnipro river is the main source for water supply in Ukraine and 1/3 of the population's use water from the Dnipro river basin. Thus water quality should correspond to state and international standards.

During the first stage of project's implementation working group have achieved such results:

- Analysis of the exiting situation on enterprises-pollutants;
- Investigation of water quality of the river Dnipro;
- Performing of accounts as to the pollution index;
- Organization of monitoring activity aimed at investigation of social ecological problems.

This project work is supported by Embassy of the United Kingdom (FCO) in Kiev, Ukraine. Duration:2003-2005.

Transport and uptake of Cd, Cu, Pb and Zn in Calcareous Soil of Central Iran under wheat and safflower cultivation – a column study

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Continual anthropogenic release of heavy metals (HM) into the environment has led to a buildup of these HMs in soils. On one hand, uptake and accumulation of toxic metals in crop plants may lead to transfer to humans through the food chain, on the other hand HM leaching into the subsurface may result in groundwater contamination. As little is known about such risks for the arid soils of central Iran, the objective of this study was to investigate the plant uptake and mobility of Cd, Cu, Pb and Zn in a typical calcareous soil of Central Iran under two major crops with different rooting systems, i.e. wheat (*Triticum aestivum*) with a fibrous root system and safflower (*Carthamus tinctorious*) with a taproot system. Column experiments were performed with 24 undisturbed soil cores of a Typic Haplocalcid taken from neighbouring fields which had been previously under cultivation with these two crops plants. The top 10 cm of the soil columns were first removed, half of them contaminated with Cd, Cu, Pb, and Zn with concentrations of 15, 585, 117 and 1094 mg kg^{-1}, respectively, and replaced. Controls were prepared in the same way but without adding metals. Three contaminated and 3 uncontaminated columns were planted with wheat and 3 each with safflower, according to their previous cultivation history. The other 12 columns were left fallow. Leachate was collected continuously and analyzed for HMs. After the crops were harvested, soil samples were collected at 10 cm intervals and analyzed for water-, HNO_3- and DTPA-extractable HM concentrations. Also metal concentrations in plant tissues were measured. Results showed artificial contamination of topsoil significantly ($p<0.05$) increased the accumulation of all four metals (Cd, Cu, Pb, and Zn) by both plants. The highest metal concentrations were always measured in roots in both plants. In contaminated situation, wheat could absorb and translocate more metals than safflower from the soil to aerial parts and was more sensitive than safflower. Metal accumulation in plant tissues decreased significantly dry biomass (50%) and also evapotranspiration rate (14%) in wheat. Contamination led to significant transport into the subsoil. More transport occurred in the presence of plants than in fallow soils. On the average, HMs in safflower planted columns show larger mobility than in wheat. This could be due to deeper safflower roots and so more physicochemical effects of roots through the soil profile than wheat and therefore larger soluble and DTPA-extractable metal concentration in safflower columns. In contaminated fallow soil, more Cd and Cu were transported in soil previously cultivated with wheat than with safflower, while we found the opposite effect for Zn and no difference for Pb. The results show that crop plants have substantial influence on metal mobility in these soils despite the low solubility of the metals, both through their effect on soil structure as through actual root activity. The differences in mobility effects between metals suggest that micro-distribution of the metals with respect to preferential flow pathways and roots play an important role.
Keywords: Heavy metals, Transport, safflower, wheat, calcareous soil, central Iran

Prioritizing watershed development programs in developing countries

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The complexities associated with implementation of watershed development programmes (WDP) in India, coupled with scarcity of financial resources make it essential to prioritise the programmes undertaken under the watershed approach. In this context, the degree of ecological and socioeconomic fragility of respective regions can be the basis for prioritizing allocation of funds. The focus of this paper is to come up with a framework for prioritizing the watershed development programmes and to empirically assess whether selected watershed programmes have been prioritized as per any norm of requirement of different regions. *Need based indices* indicating natural resource base, demographic aspects, status of economic living standard and overall index of fragility have been developed by using Principle Component Analysis. The exercise has been attempted both across agro-climatic zones/ states at the macro-level and across villages at the micro-level. While published data sufficed for developing need-based index at the macro-level, remote sensing data, along with some secondary data was used to carry out this exercise at the micro-level. Prioritisation accorded in watershed projects were evaluated by taking into consideration 1) Spatial coverage and per hectare financial allocation *at the macro level* and 2) Year of implementation of the project in villages within the duration of the IWDP implementation *at the micro level*. The study comes up with the conclusion that one of the important reasons for inconsistent impact of WDPs across regions could be rooted in ad-hoc allocation of resources for watershed management in India.

Monitoring and evaluation of integrated watershed development programs in India: a case study of Dangri Watershed, Haryana

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The poster is an attempt to demonstrate a method to evaluate and monitor watershed development programmes particularly in developing countries using geo-spatial tools as Remote Sensing and GIS. It looks into aspects of natural resource management and enhancement and livelihood status changes within the Dangri watershed in Haryana, India, as a result of implementation of the IWDP programme implemented there. The poster attempts to compare the relative changes achieved within the IWDP and non-IWDP villages between the four year period (per- and post implementation).

The study uses satellile data for two periods, two seasons each (28th Feb, 2003, 21st Sept. 2001, 2nd Feb, 1998 (IRS 1D, LISS III), 15th Oct 1997 (Landsat TM)) along with socio-economic and metereological data from different sources. The study integrates the use of digital supervised classification, yield modeling from satellite data sources, soil erosion modeling in a GIS environment and relevant statistical tools to derive the conclusions.

The contribution of the poster is more in terms of monitoring the watershed programme rather than its assessment as the programme is relatively new. The study concludes that Dangri watershed is an area undergoing rapid agricultural transformation in recent years. In spite of a lower level of development base, the WDP villages (particularly the ones with earlier implementation) have kept pace with the non- WDP villages in terms of some of the important development indicators. For example, increase in cultivated and cultivable land has been higher in WDP villages with earlier implementation compared with the ones without implementation. Overall, the WDP villages have shown higher consistency in the pattern of change compared to non-WDP villages.

Application of Meso-Scale Land Cover Information for Nonpoint Source Pollutant Modeling of Yongdam Dam Watershed Area, Korea using AVSWAT

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This study was performed to evaluate feasibility of applying meso-level land cover class maps over macro-level data in estimating waste load from a watershed area. Macro-level land cover maps divide area into six categories including water, mountain, agriculture, paved area and wetland while meso-level cover maps have twenty two categories. Yongdam Dam basin in the upper stream of the Geum River, Korea was selected as a study site. The area was divided into 11 sub-watersheds as was done for implementation of Total Waste Load Management Act by Korean government. AVSWAT2000 was used to model flow, CBOD, TN and TP at the mouth of the study site. DEM and land use information were extracted from the above land cover map and soil information and weather information was obtained from each related data providing center. Calibration was done using trial and error method. Sum of mean square errors between observed data and calibrated results were calculated. Flow calculation results were similar to each other for both cases due to forest and agricultural area dominated characteristics of the study area. However, significant improvements in calibrations were observed when meso level land cover information was used. This study suggests that AVSWAT may be used efficiently in estimating nonpoint source load effect in Yongdam Dam watershed area, Korea and thus to develop watershed scale water quality management strategies.

Climate change impacts on the hydrology and water quality of the upper Mississippi River Basin

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The Intergovernmental Panel on Climate Change (IPCC) periodically conducts a comprehensive state-of-the-art assessment of global and regional climate change and resulting impacts. The most recent assessment (the Third Assessment Report) was issued in 2001 and the Fourth Assessment Report will be issued in 2007. The two major U.S global climate modeling centers (National Center for Atmospheric Research, Boulder, CO and the Geophysical Fluid Dynamics Laboratory, Princeton, NJ) are now preparing to run suites of ensembles of simulations of future climates for a variety of emission scenarios to provide global datasets as a basis for climate-change impacts studies for the U.S., as part of the fourth IPCC Assessment. These global datasets will be used as boundary conditions in several regional climate models, including a model at Iowa State University (ISU), to produce fine-scale climate information (sometimes known as dynamically downscaling) for different subregions of the U.S. Future climate scenarios will be generated at ISU based on a hierarchy of the two Global Change Models (GCMs), the regional climate model, and different atmospheric CO_2 emission rates. Scenarios will also be generated from GCM contemporary climate datasets and from reanalyzed observed climates.

The impact of several of these future climate scenarios on the hydrology and water quality of the Upper Mississippi River Basin (UMRB) will be evaluated using SWAT. This study will build on two previous UMRB hydrologic impact assessments, which were performed as a function of a single future climate scenario in the first study and a climate sensitivity analysis in the second study. This study will also incorporate more detailed land use data provided by the USDA National Resource Inventory (NRI) database, as opposed to the relatively simplistic land use data that was obtained from the USEPA Better Assessment Integrating Point and Nonpoint Sources (BASINS) package for the first two studies. The refined land use data will facilitate a more accurate water quality analysis of the UMRB stream system. Comparisons between global and regional model results, and between both types of models versus observations of current climate, will enable robust assessments of not only likely (mean) outcomes but also the associated uncertainty in this study. Changes in flows, sediment loads, and nutrient losses at the UMRB outlet near Grafton, Illinois and at other upstream locations will be presented.

The sensitivity of SWAT to the variation of management parameters

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SWAT has been developed for the simulation of land use management on hydrological processes and nutrient transport in large complex watersheds over long periods of time (Neitsch et al. 2001). The existing parametrization of the model is based mostly on studies of North American rural catchments. The required input data base has mostly to be aggregated to a certain level (e. g. daily resolution of climate data etc.). In addition, the management parameters can be included in a high resolution and in detail. The application of SWAT to catchments with different land-use patterns raises questions about the suitability of the currently implemented parameters that describe the management practices and operations.

Thus, the aim of this study is to analyse the sensitivity of SWAT model outputs to the variation of management parameters for a small agricultural catchment in Eastern Germany. The catchment has a size of around 315 km² and is cultivated by integrated management practices. As with most catchments in Europe, the cultivation strategies that are applied in study area and thus their description by certain parameters differ from the situation of typical catchments in the US. The fields are much smaller and heterogeneously cultivated, e.g. with different crop rotation regimes. Thus, is has to be checked, a) in how far the existing parameter set has to be modified and b) how sensitive the simulation results are to the variation of certain management parameters. Both studies are essential to evaluate the uncertainty of potential measures in river basin management that are based on the implementation of alternative management operations.

We present the analysis of the sensitivity of SWAT to three different management parameters. By varying tillage practices, fertilizer application and crop rotation regimes, we investigate their effect on relevant model outputs, such as water and nutrient fluxes. On the basis of the results, we suggest potential simplifications of the parameterization for agricultural management in SWAT when applying the model to small-scale structured agricultural catchments. For example it is not necessary to specify more than one tillage operation besides plowing.

Model for nitrogen leaching from a watershed using field scale models

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In many countries, non-point source pollution from agriculture represents the major source of nitrate pollution. Therefore there is a need to understand and predict the influence of agricultural practices on nitrogen export from catchments. Modeling is a cost-effective means of determining the impact of management alternatives on river water quality. Many comprehensive models have been developed for use at the small scale (field, patch), however, there is a need of models applicable to the watershed scale. Usually the modeling of nitrogen leaching includes modeling of water fluxes (because water is a carrier of nitrogen) and modeling of the nitrogen fate.

Most conceptual hydrological models cannot provide the data needed to calculate the nitrogen transformations in soils, and it is difficult to couple them with the existing nitrogen-leaching models. Furthermore, some researchers show that the mobile-immobile water concept, or a division of the soil pore space into a slow and a fast flowing regions can improve the results of nitrogen modeling. Hydrological models developed for watersheds usually ignore the non-equilibrium water movement. Jarvis developed a MACRO model for water and solute transport that takes into account the non-equilibrium fluxes of water in soils with macropores. This model has been elaborated for use on the field scale and it is coupled with other well-known field scale model SOILN, which simulates nitrogen turnover and leaching.

The objective of the presentation is to show that field scale models may be adapted to watershed scale. The differences between the small homogeneous fields and the heterogeneous watersheds are very significant.

1. The zone of aeration extends from the surface to the water table. It is usually thin in areas located close to permanent streams, and quite thick in areas located far from streams and especially on hills. The soil profile with a thin zone of aeration will be saturated very quickly, and will start producing the surface runoff. On the other hand, the soil profile with a thick zone of aeration needs much more water for saturation and very rarely produces surface runoff. This study considers the way allowing taking into account this factor.
2. The discharge at the watershed outlet depends on the performance of its river system. The larger the watershed, the more time is needed for water to reach the outlet. This leads to differences in the time lags between water flows to the outlet of a small field and to the outlet of the whole watershed. The time lag may vary from several hours for small watersheds with areas of several square kilometers to several days for watersheds with areas of several thousands a square kilometers. Moreover, the river system usually acts as a chain of reservoirs that smooth variations in water flow and quality. The method is proposed, which allows the description of the processes in the river system.

Two different field scale models were tested on watershed scale. One of them is based on the mobile-immobile water concept and other one ignores the non-equilibrium water movement.

A procedure to compute groundwater table depth using SWAT

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A procedure to compute perched groundwater table depth, using SWAT inputs and outputs, is proposed based on the theory used by DRAINMOD, in order to expand SWAT capabilities. SWAT was calibrated and validated for streamflow for three watersheds, and for groundwater table depth for three soils, at sites located within the Muscatatuck River Basin in southeast Indiana. The Nash-Sutcliffe model efficiency (R^2_N) for monthly streamflow was 0.49, 0.61 and 0.81 for the three watersheds for the validation period (1995-2002). SWAT predicted groundwater table depths provided R^2_N values of 0.61, 0.36 and 0.40 for the three soils in the calibration period (1992-1994), and 0.10, -0.51 and 0.38 for the validation period (1995-1996). Even though the model performance for predicting groundwater table depth was not as good as for streamflow, SWAT predictions resembled the seasonal variation of the groundwater table with correlation coefficients (r) of 0.68, 0.67 and 0.45 for the three wells during the validation period.

Calibration and validation of the swat model to predict atrazine in streams in northeast Indiana

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SWAT was calibrated and validated to predict atrazine loads in streams for the period 1996-2004 at eleven sampling sites, in northeast Indiana. This study was carried out within a comprehensive water quality monitoring and BMP research and assessment project, led by the USDA-ARS National Soil Erosion Laboratory (West Lafayette, Indiana), for the Source Water Protection Initiative in the St Joseph River Watershed (268,000 ha).

SWAT performed well in predicting the general trend of atrazine concentration in streams over time, for daily and monthly time intervals, and daily streamflow calibration and validation had to be accomplished before starting pesticide calibration. During the validation period, Nash-Sutcliffe values varied from 0.33 to 0.60 for daily streamflow and between 0.64 and 0.74 for monthly streamflow. Even though the model was not accurate for predicting atrazine levels at specific points, showing low Nash-Sutcliffe values, SWAT was consistent in presenting high coefficients of determination (R^2), but over or under predicting observed values. Monthly predictions were better than daily predictions, but three month running averages were not better predicted than monthly average concentration.

During the calibration period, monthly atrazine concentrations were predicted with an average R^2 of 0.60 and an average Nash Sutcliffe coefficient of 0.38. In the validation period atrazine was predicted with an average R^2 of 0.49 and an average Nash-Sutcliffe value of -0.91. Large watersheds were not consistently better predicted than smaller watersheds, or vice versa. After validation, the total mass of atrazine released by the whole basin between 2000 and 2003, for the period April-September, was closely predicted by the model in two of the four years. The observed average amount of atrazine released during the four seasons was 1002.1 kg/season, and SWAT predicted 950.1 kg/season.

Method for analyzing parameter uncertainty in SWAT 2003

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Natural variation in any agricultural ecosystem impacts the degree to which a simulation model can accurately and precisely represent the system. However, due to time, expense, and repeatability limitations with field work, simulation modeling is often the most practical technique for predicting and comparing watershed-scale land management impacts on downstream water quantity and quality. Thus, it is important to understand, as fully as possible, the uncertainties within model input parameters and how these uncertainties affect model outputs. Of particular interest are surface and subsurface hydrologic parameters to which previous studies have found a particular model is sensitive. The aim of this study is to develop a method for determining the uncertainty of SWAT 2003 output with respect to degrees of uncertainty within multiple input parameters. The autocalibration routine in SWAT 2003 will be used to determine solutions that fall within a user-specified range of the optimal solution. Associated values of the sensitive input parameters can then be determined. Output from this uncertainty analysis method will provide uncertainty ranges for selected parameters for a range of near-optimal solutions. Plots of the parameter versus solution ranges will help improve understanding of the sensitivity of model predictions to values of the input parameters. The paper will apply and evaluate the method for flow predictions for several ARS watersheds. Selected parameters include curve number, surface lag time, and parameters relating to ground water movement.

The TERRACE project: SWAT application for diffuse chemical pollution modeling

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SWAT has been adopted as the diffuse-source component of the European Chemicals Industries Council (CEFIC) Long-range Research Initiative (LRI) environmental modelling suite. In order to make SWAT applicable across Europe, the diffuse-source LRI project (TERRACE) has identified a number of consistent data sources at a European level which could be used to generate model parameters and driving variables. In addition, linkages have been built with other LRI model components, specifically the point-source river model, GREAT-ER and the atmospheric model, ADEPT.

The linkage with ADEPT is fairly straightforward with contaminant inputs being applied to the land either by dry deposition or with rainfall on a temporally and spatially varying basis. Linkage with the river model is more complex because of a dichotomy in modelling approaches between SWAT and GREAT-ER. GREAT-ER is a steady-state stochastic model where contaminant concentrations are modelled for different flow percentiles whereas SWAT is dynamic. The solution to interfacing these different models was to generate a series of flow and contaminant-transfer probability distributions using SWAT, to calibrate the flow frequency distributions used by GREAT-ER using the SWAT flows and then to use the contaminant transfer distributions as inputs to GREAT-ER. The link developed between these models opens possibilities for other dynamic-stochastic model linkages, and for the way in which SWAT is calibrated and validated. The model was tested for the Exe catchment in south-west England and results of this test are presented.

Catchment scale modeling of pesticide losses with imperfect data – a case study from the UK

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SWAT has been applied to a range of river basins across the UK, ranging in size from 141.5 ha to 1264 km^2. The basins represent a range of environmental conditions from the far north-east (the Tees) where land use is largely un-managed moorland, through the intensive agriculture of the East Anglia region (Colworth, Wensum, Ant and Bure), to the dairy cattle dominated south-west of the country (Exe and Axe). Due to the range of land use, soil, climate and resultant hydrological response SWAT has faced some major challenges.

In addition the objectives of the studies have been very different. We have looked at the complexity of sub-catchment/HRU definition, the modelling of nutrients, pesticides and other chemicals, the impacts of climate and land use change, and the modelling of sediment yield.

The studies have enabled us to draw conclusions about the way that we need to define and parameterize inputs, and to make recommendations for model calibration and validation. The outputs are being built into a SWAT modelling strategy for the UK to enable others to use the model in a comparable way so that a body of experience and model applications can be developed. We have also been able to better define data needs to support modelling in the UK context.

Ensuring appropriate hydrological response for past and future nutrient load modeling in the Norfolk Broads

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SWAT is being used to model past and future land use and climate scenarios for river basins supplying water and nutrients to the ecologically important low-lying lakes of the Norfolk Broads area of eastern England. These lakes suffer from high nutrient loading, both via the groundwater and in surface response in soluble and sorbed forms. Eutrophication and sedimentation in the shallow broads are of major concern.

One problem with using the nationally available crop type and soil data for England and Wales is that data are supplied in grid format with an associated dominant crop type or soil group, and a range of sub-dominant classes. In this context dominant is used in a spatial sense rather than a hydrological one, but sometimes a soil or crop which covers less of the area is more important in controlling either hydrological or erosional response, or both. As this study is focussed on potential future conditions it is essential that past and current conditions are modelled as accurately as possible, and that we ensure that the responses we get at the sub-basin and basin level actually reflect the processes we expect to find.

Techniques to define the controlling soil-vegetation cover from within the range of possible combinations have been developed and tested. The importance of such care in model set-up will be discussed in the context of the nutrient modelling required for these basins.

Groundwater resource management in the urban environment

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The study area, Dire Dawa town and its vicinity, is found in the Eastern part of the country at a distance of 520 Km from Addis Ababa, 18km away on the Harer-Jijiga high way, at latitude 9^0 11` N, and longitude $41^0$ 52`E within the Awash River basin at the foot of Wabi shebelle-Awash Basin divider escarpment.

Dire Dawa is one of the oldest urbanized towns in the country, where the population is increasing constantly, and has reached 270,000 in 2003. As a result, some of the boreholes that are sources of water supply of the town are contaminated with different sources of pollutants such as urbanization of domestic and industrial wastes. The coverage of population in Dire Dawa with safe water is about 68% and urban sanitation 75 % coverage level.

The chemical, physical and biological processes in addition to the geological formation and man-made factors influence the hydrochemical variation of groundwater both spatial and temporal in quality directly and indirectly. As a result of disposal of liquid, gaseous and solid wastes, chemical substances and/or waste generated from industries, agricultural activities, households, market centers, institutions, garages, fuel stations and the health centers are the main sources of pollutants that may affect the quality of water in the area

Due to the fact that, the upper sandstone aquifer at Dire Dawa town is vulnerable to pollution due to the high to moderate permeability of the alluvial sediments overlying the main aquifer. High concentration of nitrate is directly related to high population density, urban agriculture and industrial areas. The high concentration plume is flowing along the groundwater flow direction, mainly at shallow well of the alluvial aquifer in the inner part of the town. So modelling is very important to identify the extent and contaminant zone of the aquifer in order to take remedial measures by the concerned organization.

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