INTERNATIONAL SOIL AND WATER ASSESSMENT TOOL CONFERENCE

SWAT 2018

19-21 September / Brussels, Belgium

Book of Abstracts

VUB VRIJE UNIVERSITEIT BRUSSEL

The Soil and Water Assessment Tool (SWAT) is a public domain model jointly developed by USDA Agricultural Research Service (USDA-ARS) and Texas A&M AgriLife Research, part of The Texas A&M University System.

SWAT is a small watershed to river basin-scale model to simulate the quality and quantity of surface and ground water and predict the environmental impact of land use, land management practices, and climate change. SWAT is widely used in assessing soil erosion prevention and control, non-point source pollution control and regional management in watersheds.

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Foreword

The organizers of the 2018 International SWAT Conference want to express their thanks to the organizations and individuals involved and their preparation and dedication to coordinate a successful conference. We would also like to thank the Scientific Committee for their support in preparing the conference agenda and allowing for scientists and researchers around the globe to participate and exchange their scientific knowledge at this conference.

A special thank you to the Vrije Universiteit Brussel (VUB) along with Ann van Griensven, Veronica Minaya, and the rest of the local organizing committee in Brussels for their countless hours and efforts to host the SWAT Community. On behalf of the SWAT Community, we extend our sincere gratitude to you and your university for the kind invitation and welcoming hospitality.

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

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

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Utilizing the New SWAT+ Structure to Improve U.S. National Conservation and Environmental Assessments

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Abstract

SWAT+ is a completely restructured version of SWAT, written in a more modular format, with input files structured in a relational format. The new structure will facilitate code development and maintenance; support data availability, analysis, and visualization; and enhance the model's capabilities in terms of the spatial representation of elements and processes within watersheds. SWAT+ also offers more flexibility than SWAT in defining management schedules, routing constituents, and connecting managed flow systems to the natural stream network. These improvements have allowed us to downscale the CEAP (Conservation Effects Assessment Project) national assessment and improve modeling of the sediment and nutrient budgets based on more a detailed framework of process based watershed connectivity, taking into account sources (fields and first order streams) and sinks (valley accommodation and reservoirs). The CEAP project was developed to guide the design and implementation of conservation programs across the U.S. In the downscaled version of CEAP, representative fields are modeled with a gully, ditch or swale connecting the field to the first order channel. The first order channels are connected to the main channel of each 12-digit hydrologic unit (there are 86,000 12-digit watersheds in the U.S. with an average area of 90 km^2). Each 8-digit watershed will comprise a SWAT+ simulation with flow, sediment, and nutrients passed in a daily recall file to downstream 8-digits. There are 2,100 8-digits with an average size of 3,500 km^2. In past national assessments, small scale processes were lumped explicitly with a delivery ratio or implicitly with the MUSLE equation. Simulating transport processes down to first order streams allows realistic simulation of the entire sediment/nutrient budget including simulation of riparian buffering, structural controls, bank stabilization, and incorporation of wetlands on lower order streams. Other improvements will be discussed including soft calibration of the water balance and the use of decision tables in SWAT+ to simulate management.

Keywords

modular SWAT code, national assessments, small-scale processes

Using Soft Data to Calibrate SWAT+ Models

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Abstract

During calibration for hydrological models such as the Soil and Water Assessment Tool (SWAT), model performance statistics such as Nash-Sutcliffe efficiency and P-Bias are used to assess how accurate a model is. However, models that pass as 'good' do not always well represent the water balance of the area under study. Thus, a positive evaluation of calibration does not guarantee that the processes in the landscape are properly represented. When such models are used for scenario investigation, the results can be unrealistic. This can be avoided using a soft calibration technique that quickly calibrates the model against user specified water balance proportions derived from soft data such as literature and remotely sensed products. In this study, a soft calibration method was developed that uses linear regression to set parameters that minimise the difference between the basin and the user specified water balance components. The output is a calibration file which lists the calibrated parameters. A SWAT+ model was setup for the upper Blue Nile and the soft calibration method was applied on the model. Initial results show that it takes less than 20 simulations to complete the soft calibration. The soft calibration also improved the overall performance of the model when compared to observations. We conclude that soft calibration is a very efficient way to calibrate the components of the water balance as it requires few simulations compared to hard calibration. We recommend that a hard calibration should be done after soft calibration. Once a correct water balance is obtained from the soft calibration, there will be an improved reliability of the model in scenario investigations. Furthermore, soft calibration does not rely on a time series, which facilitates and improves calibration of SWAT+ models in data scarce areas.

Keywords

SWAT+, Soft Calibration, Soft Data, Hydrological Models

Exploring the capabilities of SWAT+ in a rural lowland catchment in the North of Germany

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Abstract

SWAT+ is the latest version of the Soil and Water Assessment Tool that features several improvements compared to previous versions of the model. Currently, SWAT+ is being tested in various catchments in the United States. The Kielstau Catchment in Northern Germany is about 50 km^2 large. Its hydrology is characterized by near-surface groundwater tables and extensive tile drainage. Since 2005 continuous measurements as well as intensive field campaigns are carried out in the Kielstau Catchment. The excellent availability of input and calibration data represents ideal conditions for model testing. SWAT has been applied successfully to the Kielstau Catchment, especially after the representation of groundwater processes was improved by dividing the shallow aquifer into a fast and a slow shallow aquifer. In this study, we assess the performance of SWAT+ in comparison to previous SWAT applications in the Kielstau Catchment. Furthermore, we explore the capabilities of SWAT+ in terms of watershed configuration and simulation of landscape processes by comparing two model setups. The first setup is comparable to previous SWAT models for the catchment. HRU yields are summed at subbasin level and added directly to the stream. In the second SWAT+ model, subbasins are divided into upland areas and floodplains and runoff is routed across the landscape before it reaches the streams. We discuss the general applicability of SWAT+ to tile-drained lowland areas and the suitability of the different watershed configurations for the Kielstau Catchment. The outcomes of this study are expected to further prove the applicability of SWAT+ and provide useful information for future model development.

Keywords

SWAT+, model comparison, tile drainage, Germany

Modeling Strategies for a Groundwater Dominated Headwater System

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Abstract

Modeling watersheds in coastal Alabama, USA, presents unique challenges pertinent to a low gradient coastal plain system including gentle slopes, high water table and significant groundwater interaction. Observed flow data from one such watershed draining into a headwater slope wetland in the city of Foley in Baldwin County, AL showed very high baseflow contribution leading to overall flows in excess of precipitation within the watershed - an issue common in coastal plain regions where topography is flat and water tables are shallow. In this study we investigated approaches by which the Soil and Watershed Assessment Tool (SWAT), a ubiquitously used watershed model, could be used to predict and calibrate flow from a small watershed where groundwater input was so large that total flow exceeded precipitation. SWAT simulated flow for the watershed was limited by precipitation which is the major driver of SWAT's water budget, and consequently simulated flows were several times smaller in magnitude than observed flows (E_{NASH} = -0.57, R_{BIAS} = 82%). Our approaches involved 1) a separate baseflow and stormflow calibration followed by a manual magnification of baseflow (E_{NASH} = 0.67, R_{BIAS} = 14%), 2) adapting SWAT to simulate upwelling groundwater discharge instead of deep aquifer losses by assigning a negative value to parameter β_{deep} instead of its default positive value (E_{NASH} = 0.75, R_{BIAS} = 3%), and finally, 3) investigating the use of Artificial Neural Networks (ANN) in conjunction with SWAT in further improving the calibration performance (E_{NASH} = 0.89, R_{BIAS} = 1%). The methods investigated in this study can be used to navigate similar flow calibration challenges in other groundwater dominant watersheds which can be very useful tool for managers and modelers alike.

Keywords

headwater, ANN, deep recharge, wetland

Nearest Neighbor and Inverse Distance Weighting for rainfall estimation in SWAT application

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Abstract

Precipitation is one of the primary inputs in distributed hydrological models. Quality and knowledge of the spatial rainfall patterns improve the accuracy of streamflow prediction. The Soil and Water Assessment Tool relies on one precipitation gauge for each sub-basin (the closest to the sub-basin's centroid: Nearest Neighbor – NN). This configuration leads to a simplification of the rainfall records even if there are multiple gauges per sub-basin. To investigate the impact in the addition of gauges composing a larger network, this study performed the Inverse Distance Weighting (IDW) method to interpolate daily data and used it as input in the setup model. The accuracy between methods was evaluated in a daily basis using records from a different gauge arrangement. Located in southern Brazil, the Ivaí River was selected as the study area and the highest density of interpolated rainfall station was used for SWAT calibration. The difference between NN and IDW areal rainfall estimation was also assessed in the simulation of streamflow. The result of this difference suggested that the precipitation variability was better represented using IDW than NN, although zero precipitation values decreased considerably. The general applicability of these results should mitigate the link between model behavior and consist of an alternative way of representing precipitation distribution under NN restraint. Furthermore, since Ivaí River is situated in the transition between tropical and sub-tropical climate, the investigation was performed considering five sections covering the basin heterogeneity.

Keywords

rainfall estimation, interpolation, streamflow prediction

Evaluating the Impact of Different Input Datasets and Model Configuration Uncertainty on Streamflow Simulations by Using SWAT Model

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Abstract

Performance of the watershed modeling studies is closely associated with the model input datasets. Currently, numerous databases are existing and freely available to the modelers in global or regional scale. However, these datasets provide required input data to run models, their resolution and accuracies are needed to be investigated. This study is conducted to evaluate the impact of the different input datasets and model configuration (in the context of subbasin number) on streamflow simulations by using Soil and Water Assessment Tool (SWAT). For this purpose, Melen Watershed which is located in western Black Sea coast of Turkey is chosen as a study area. Two climate databases, three land use dataset and three subbasin levels (7, 50, 252 subbasins) are used to build model setup. 18 different model configurations are performed between the years 2000 and 2013. Calibration and validation procedure are conducted by using SWAT-CUP software with the SUFI-2 algorithm based on monthly river discharges. Model performance evaluated by comparing simulated and measured streamflow data in the watershed. The model results revealed slightly different streamflow simulations for different subbasins numbers. The climate datasets showed significant differences in streamflow estimations whereas the land use datasets yield quite similar results for the application SWAT model in Melen Watershed.

Keywords

modeling, Melen Watershed, SWAT, SWAT-CUP, SUFI-2, input data uncertainty

Optimization of SWAT performance using a Python tool

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Abstract

The current modeling philosophy considers fundamental the calibration, validation and uncertainty analysis of complex models. There are several algorithms available focusing on the supply of this demand. They differ from each other in their underlying assumptions made and selecting the ideal algorithm for a specific problem may not be a trivial task. Often, the users choose a given algorithm for its availability and not for the benefits of the methodology. The Statistical Parameter Optimization Tool for Python (SPOTPY) is a Python tool that enables the use of diverse techniques for calibration, uncertainty and sensitivity analysis of models in general. The tool is an open-source package that runs on Windows, Linux, and Mac. Once the user connects the model with SPOTPY, testing the effect of different strategies is straightforward. Additionally, the possibility of running SPOTPY in parallel is crucial when dealing with complex projects. This study presents a short way to link SPOTPY and the Soil and Water Assessment Tool (SWAT), version 2012, and shows the outcomes of this integration. As a study area, we choose the Vollnkirchener Bach Environmental Observatory in Germany to estimate discharge and water quality data. Our results illustrate the benefit of having one versatile tool at hand to quantify different sources of uncertainty throughout the modeling.

Keywords

SWAT; SPOTPY; sensitivity analysis; calibration; uncertainty assessment; Python; parallel process

Analysis of the land-use and climate changes on sediment discharged from cultivated field in a rural hilly basin in Italy

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Abstract

The social and economic development, which took place during the past sixty years in many regions of Italy, has led to a change in traditional activities and population to a gradual abandonment of rural areas in favour of those more urbanized. These factors, accompanied by the Italian and EU agricultural policies, have determined significant changes in land use and management practices. In particular, the development of mechanization of agriculture led to the replacement of small heterogeneous cultivation patterns with large extension of homogeneous cultivations and to the reduction of the extension and intensity of drainage system, thus reducing the effectiveness of its function. Consequently, the introduction of modern land-use management techniques has led to an increase in soil erosion, with both on-farm and off-farm impacts. This paper presents the methodology for quantifying and analyzing the erosive responses to land use and climate changes by means of ArcSWAT model. The case study was the Elsa river basin which were analysed by climate and land use change along more than fifty years (1954-2007). The results indicated that under the same climatic conditions, changes in land-use and management increase the runoff formation and may have larger impacts on sediment discharges from cultivated field. This type of analysis proved to be effective in analysing past and future hydrological dynamics of the basin. Therefore, this approach could help policymakers integrate climate and land use change into land planning and rural development programs.

Keywords

Rainfall pattern; land use change; soil erosion; ArcSWAT model

Integrating landscape metrics and hydrologic modeling to assess the impact of natural disturbances on ecohydrological processes in the Chenyulan watershed, Taiwan

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Abstract

The Chenyulan watershed, located in the central mountain area of Taiwan, has been suffering from several typhoons and heavy rainfalls in the past decades. The sequential natural disturbances had accumulated impacts on the watershed, leading more fragile and fragmented land cover, and losing capacity of soil water conservation. In this study, Soil and Water Assessment Tool (SWAT) and landscape metrics tool (FRAGSSTATS) were used to assess the impact of natural disturbances on ecohydrological processes of the Chenyulan watershed. A total of 7 SPOT images during 2008-2013 were analyzed by using Nearest Feature Line Embedding Approach (NFLE) and reclassified into six land use types: forest, agricultural land, grass land, river, landslide, and built-up. Forest was found to have the largest patch size, indicating forest is more resilient to disturbances, while agricultural land tended to expand away from the river side towards the hill. The SWAT model performed better for sediment exports with dynamic land use change (R^2=0.66, NSE=0.62, PBIAS=10.5%, RSR=0.62) than with constant land use (R^2=0.61, NSE=0.54, PBIAS=-17.3%, RSR=0.68), indicating long-term land use change should be considered in hydrologic modeling. Landslide and grassland were the most unstable and fragmented land uses, resulting more fluctuated ecohydrological processes in upstream subbasins. Generally, the Chenyulan watershed has good recovery from disturbances, but the impact of natural disturbances on ecohydrological processes could be enlarged by anthropogenic development. The results were useful for assessing the effects of land cover change in the Chenyulan watershed and highlighting subbasins that require careful management to increase resilience to disturbances.

Keywords

Image classification, Land use change, Landscape metrics, SWAT model, Watershed management

Comparative assessment of SWAT-Twn model performance for simulating erosion and sediment transport in two distinct basins in Taiwan

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Abstract

Taiwan, a new-born terrain divided by the Central Mountain Range into the East and West, has heterogeneous topography and geology. In this study, we selected the Zhuoshui River Basin (ZRB) in the central region and the Hualian River Basin (HRB) in the eastern region for assessing their mechanisms of streamflow, erosion and sediment transport. During 1998-2016, the average annual flows at the outlet of ZRB and HRB were 142.3cms and 104.5cms, respectively, while mainly due to landslide the sediment concentration reached up to 105,500ppm and 33,400ppm at ZRB and HRB, respectively. The R^2 of rating curve for the outlets of ZRB and HRB were 0.8 and 0.7, respectively, indicating a good relationship between sediment export and streamflow at the daily scale. In order to improve the simulation of erosion and sediment transports, we adopted the Taiwan Universal Soil Loss Equation (TUSLE), and the modified SWAT model (SWAT-Twn), coupled with TUSLE and landslide simulation, was calibrated and validated by using SWAT-CUP. The preliminary results showed that the SWAT-Twn model could simulate more accurate amount of sediment exports than SWAT model. Thus, application of the SWAT-Twn model with a set of sediment rating curves, sediment-related SWAT parameters and sediment transport equations were suggested for future sediment simulation in basins of heterogeneous geomorphology in Taiwan.

Keywords

SWAT, SWAT-Twn, erosion, sediment transport, landslide

Assessing relative impact of change in soil infiltration and plant transpiration on the catchment water yield component and water scarcity in the Tropical Lowland Rainforest Transformation Systems (Sumatra, Indonesia)

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Abstract

The water ecosystem services can be classified into three principal areas: water provision (quantity), water flow regulation (timing), and water purification (quality). The ecosystem service of the water flow regulation is defined as the ability of a watershed to capture and store water from rain storms, reduce the direct runoff and flood peaks as well as release water more slowly so that flows are sustained into or through the dry season. The ability to store and release rain water is an important ecosystem service because the amount of water, which is available for people's use on a sustainable basis, from water supply systems, is directly related to the volume and evenness of the flows. Conversion of the tropical forests into the plantation crops can alter soil infiltration and plant transpiration rate which are critical in terms of the volume and evenness of the flows. We measured soil infiltration across different land use types including forest, rubber and monoculture oil pam. We found that soil infiltration under oil palm plantation is significantly lower compared to those from other land-use types. Soil degradation and compaction can be the reason for the lower infiltration in oil palm plantation. In addition, according to the results of the transpiration analysis, oil palm showed higher transpiration rate compared to that of the other land-use types. Many researchers and local inhabitants claimed that transpiration rate increase in oil palm plantation bring about local water scarcity problem in the study area. The research question is, do the increased transpiration and reduced infiltration had caused significant impact to the catchment water ecosystem service? For this purpose, we calibrated and validated catchment hydrological model (SWAT) and upscaled relative impact of change in plant transpiration and soil infiltration on the catchment water yield component. The calibration and validation of the model showed NSE of 0.75 and 0.80, respectively. The result of this study confirmed that transpiration rate increase in oil palm plantation alone had minor impact on the catchment water yield. But, the combination of transpiration rate increase and infiltration rate reduction had caused sharp water yield reduction during dry season. The findings help us to formulate effective mitigation option to reduce impact of monoculture plantation crops on the catchment water ecosystem service.

Keywords

catchment water ecosystem service, infiltration rate, oil palm plantation, SWAT model, transpiration rateSession

Using SWAT and other models for simulating ecosystem services and trade-offs – A critical reflection

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Abstract

The presentation discusses the current studies on using SWAT and other models for simulating ecosystem services and trade-offs and identifies their current strengths and weaknesses, such as considering only a low number of ecosystem services, methodological varieties, missing quantification of processes and trade-offs, and insufficient involvement of stakeholders and poor implementation in resources management. By discussing promising examples, the presentation provides eight recommendations to improve these shortcomings.

Keywords

Ecosystem services, trade-off analysis, modelling

Land sparing or sharing or something in between? Multi-objective land use optimization based on scenario analysis.

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Abstract

The BiodivERsA project TALE builds upon the land sparing vs. land sharing debate and develops procedures to quantify synergies and trade-offs among different ecosystem services and biodiversity for different agricultural landscapes across Europe. In the German case study, we used the process-based Soil and Water Assessment Tool (SWAT) to simulate agricultural yield, stream flow and water quality. To capture biodiversity, we developed statistical (random forest) models predicting the breeding habitat of 13 bird species. SWAT and the bird habitat models were applied to stakeholder-defined land use scenarios referring to either land sparing or land sharing or business-as-usual for the year 2030. The scenarios differ in terms of land use and agricultural management, e.g. crop composition, fertilizer application and tillage practices, as well as in the amount of linear elements such as tree rows, hedges and filter strips.

Among the scenarios, land sharing has been evaluated best for providing bird habitats and water in good quality. However, this came at the cost of a significantly decreasing gross agricultural margin. Furthermore, we coupled our models with a genetic algorithm (NSGA-2) to explore pareto-optimal land use strategies where the different scenarios can be spatially combined. Our results indicate numerous solutions which might improve the provisioning of ecosystem services (agricultural yield, water quality) and biodiversity (bird habitat) at the same time.

Keywords

land use scenarios; ecosystem services; biodiversity; integrated modelling; multi-objective optimization

Using SWAT modeling to quantify water regulation functions in South-Western Europe watersheds

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Abstract

Water regulation services, provided by riparian ecosystems, are essential for the sustainability of socio-ecosystems and are very sensitive to anthropogenic pressure. The evaluation of these services is urgently needed and must be based on the quantification of ecological functions. For this purpose, it is essential to develop tools based on modelling approaches that allow us to quantify the spatial and temporal distribution of ecological functions. In the present study, we aim at quantifying regulation functions for the water resource quantity and quality that will be used for ecosystem services evaluation. This study explores the spatial and temporal dynamics of nitrate uptake, denitrification and sediment retention from 2000 to 2010 at the monthly scale, in order to define hot spots and hot moments of these functions. We use the widely known SWAT model (Soil and Water Assessment Tool) which aims to simulate nutrient and sediment transfers both in rivers and lands at the scale of the watershed. A total of 216 subsystems over 81 water catchments was investigated in South-Western Europe. We integrate agriculture management practices, water resource management practices and cities' effluent releases to assess water regulation functions that may serve in watershed manager decision-making. A medium-sized watershed, Garonne (France), is used to develop the methodology for the entire South-Western Europe. We show that ecological functions vary along an upstream-downstream gradient and are controlled by the climate. For example, nitrate removal increases from upstream to downstream and with a warmer and dryer conditions. Finally, comparing simulations with and without anthropogenic factors allows quantifying the effects of human activities during low flow periods. Indeed, agriculture, cities and industries influence and water resource management (dams) impair landscapes and influence ecological functions.

Keywords

water quality, water regulation services, ecological functions, rivers, nitrate, sediment, South-Western Europe

Impact analysis of land management scenarios on ecosystem services using SWAT

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Abstract

Sustainable ecosystems provide multiple services for human wellbeing. However, conflicts between ecosystem services emerge if the enhancement in one service results in the degradation of another service (e.g. food provision versus nutrient regulation). A balance between ecosystem services is crucial to maintain the sustainability of ecosystems. In this study, we assessed agricultural landscape management impacts on food provision, water quantity, water quality, erosion, and climate regulation in a catchment in Western Switzerland.

SWAT (Soil and Water Assessment Tool) was parameterized for daily flow [m^3/s], monthly nitrate load [kg N/year], and annual crop yield with actual land management of the Broye catchment. To account for model uncertainties, 233 sets of parameters and 10 replicates of land management specifications were used. Two extreme land management scenarios (land sharing versus land sparing) were fed into the parameterized SWAT model and results were compared with a baseline scenario (actual land management). Assessed outputs in this study are low flow [m^3/s] (5^{th} percentile of daily flow for whole simulated period), average yearly nitrate concentration [mg N/l], yearly transported sediment [t/ha], agricultural benefit [Mio CHF/year], and greenhouse gas (GHG) emissions [CO_2 eq. kt /year]. Agricultural benefits are estimated from arable and livestock production minus cost of applied fertilizer. Results revealed that the land sharing scenario was most beneficial for nutrient and climate regulation services with lowest food provision, and the land sparing scenario had the highest food provision with the highest diffuse pollution and GHG emissions. The performance of the baseline scenario was in between the two extreme scenarios. Food provision, water quality and climate regulation are the services most affected; water quantity and erosion regulation services were hardly sensitive to considered land use and management changes. The largest uncertainty source was model parameterization uncertainty, while uncertainty of land management specification played a minor role for most outputs. Changes in land management scenarios could not reduce the conflict between ecosystem services, but only led to a shift in trade-offs.

Keywords

land sharing, land sparing, model parameterization, water quantity, water quality, greenhouse gas emissions

Runoff determination in glacierized basins, using SWAT-GERM framework

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Abstract

Ice melt plays an important role in the hydrological cycle of glacierized catchments. It is an important source of water for hydropower generation, irrigation and drinking water supply. Mass balance of alpine glaciers composed of “Accumulation” due to deposition of solid precipitation and “Ablation” due to the melting of ice and snow. SWAT does not consider the mass balance of glaciers in runoff determination. This normally leads to underestimation of summer water balance in glacierized catchments in which ice melt from glaciers generates hydro peaks. In this study, we prepared a framework and linked the state of the art Glacier Evolution Runoff Model “GERM” with SWAT. In SWAT-GERM framework, decadal to semi-centennial ice volume changes obtain from repeated digital elevation maps of glacier surface is resolved to daily mass balance time series. The surface topography of ice is updated annually based on the ablation and accumulation amounts and implementing the empirical method. We tested the model for Aletschgletscher in the Swiss Alps. Results show an improvement in the calibration of runoff at the outlet of the basin. The framework is user-friendly and could be used in other catchments.

Keywords

SWAT, Glacier Evolution Runoff Model (GERM)

Advancing coupled water-energy-carbon processes within SWAT toward improved watershed sustainability assessment

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Abstract

As a widely used watershed model, Soil and Water Assessment Tool (SWAT) depicts complex terrestrial (e.g. grassland, forests, and cropland) and aquatic ecosystems (e.g. streams and wetlands), as well as their interactions with the human system. Here, we will provide a review of recent development of coupled water-energy-carbon processes across both terrestrial and aquatic ecosystems within SWAT, including physically based soil moisture routing, freeze-thaw cycle, soil carbon and nitrogen cycle, processed based forest growth and development, and aquatic carbon cycle. Using observations from multiple field data networks (e.g. USDA-LTAR, USDA-CEAP, NSF-LTER, AmeriFlux, and remote sensing products), we evaluated model performance regarding hydrology, soil temperature, plant biomass and biogeochemical cycle. We also discuss the potential implications of the above improvements for enhancing SWAT's simulation of water quantity and quality. These advancements are expected to further the capability of SWAT to explore sustainable pathways for achieving human needs (e.g. clean drinking water, food and energy), while minimizing negative impacts on land and water resources (e.g. greenhouse gas emissions, soil degradation, and water quality deterioration).

Keywords

carbon cycle, energy balance, greenhouse gases, plant growth, soil moisture, watershed sustainability

Implementation of a recursive numerical filter for updating individual flood hydrographs

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Abstract

Real-time flood forecasting is a challenging concept in hydrological Communities which still has not been solved completely. Climate change and growing urbanisation have caused potential issues in changing the hydrological cycle on the earth. This process has led to unexpected events in urban areas such unanticipated flood events which can cause most difficulties for people and destruct the urban facilities and infrastructures. Hence considerations to establish a series of precautionary approaches before fall out such the events have been increased among hydrologists and urban planners. To cope with unexpected hydrological changes, an accurate flood forecasting model should be updated continuously. In recent years, different types of numerical models has been developed to configure the hydrological models according to the different types of hydrological changes which occur abruptly. The Kalman filter is one of the famous numerical filter which developed base on a recursive algorithm. The simple version of Kalman filter has been applied extensively as an optimal estimate for linear hydrological models to update the system during a time series. Also, in the case of non-linear models, two version of Kalman filter, Extended Kalman Filter (EKF) and Ensemble Kalman filter (EnKF) can be applied to reach more accurate results. The current study has been assigned to introduce a brief description about the performance of Kalman filter during the hydrological model updating. Also, a new modification of the IHACRES model was selected to combine with the Kalman filter for updating a number of individual flood hydrographs. After the updating process, it was confirmed that, the new hybrid model can be mentioned as an efficient model to use in model updating and flood forecasting process.

Keywords

recursive numerical filter, hydrological model updating, flood forecasting

Modification of Infiltration Characteristics of Natural Ground Formations using Horton's Model

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Abstract

Infiltration is the term applied to the process of entry of water through the soil strata. This movement of water through the soil surface is known as infiltration and plays a very significant role in the run-off process by affecting the timing, distribution and magnitude of the surface run-off. Further, infiltration is the primary step in the natural groundwater recharge. The infiltration characteristics of the soil are one of the dominant variables influencing irrigation. Infiltration rate is the soil characteristic determining the maximum rate at which water can enter the soil under specific conditions, including the presence of excess water. Water logging is a frequent occurrence noticed just after a heavy downpour, particularly in areas where efficient drainage facility is not available. It has been noticed earlier that in any natural groundwater formation when perforations are made, they tend to increase the infiltration capacity of the soil. However, a comprehensive study has not yet been taken up to quantify the effect of such an exercise. In present study the effect of perforations in terms of parameters like f_c, fo and k as described in Horton's model are quantified and a *generalized model* representing various infiltration capacity models has been developed. Experiments were done in the lawn in front of main building of WALMI, Patna, Bihar, India with different perforation conditions for various depths and for different number of holes by a 3 mm iron rod. Mathematical models have been developed for deciding the trends of variation of different parameters of Horton's model and Generalized Infiltration Model because of these variations in depths and number of holes. A simulation study has also been carried out to find a relation between *time, t* and s*oil storage space available at that time,* S_t using the equations of both Horton's and Generalized infiltration model (GIM). A computer program has been developed in FORTRAN based on least squares method to analyze the Generalized Infiltration Model. The computer programme developed here for infiltration can be incorporated into SWAT model for studying the effect of modified infiltration characteristics on surface runoff and ground water recharge.

Keywords

Infiltration, GIM, water logging, perforations, Simulations, FORTRAN, SWAT MODEL

Impact of different types of meteorological data inputs on predicted hydrological and erosive responses to projected land use change

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Abstract

Hydrological responses to land use/land cover (LULC) changes are complex in nature and tend to have an impact on the hydrological cycle, affecting the livelihood of the inhabitants. Rainfall-runoff models, such as the Soil and Water Assessment Tool (SWAT), were used in the past to unravel the interactions between the impacts of climate and land use changes. However, the sensitivity of the model outcome, in terms of the hydrological and erosive response to climatic data derived with different methods has not been fully understood. We carried out hydrological simulation using (a) Climate Forecast System Reanalysis (CFSR) dataset, which synthesizes outputs of global climate models along with gauged weather information and has a global coverage, and (b) purely weather station-based gridded climate data provided by Indian Meteorological Department (IMD). A possible LULC scenario for the year 2020 was created using the combined Cellular Automata-Markov model. The model was validated for 2001-03 with annual average (also area averaged) rainfall of 1666 mm and 1345 mm for CFSR and IMD respectively for the validation period. Application of both climate datasets resulted in modest increase in the predicted streamflow and sediment yield as a response to the probable development scenario in 2020. However, marked variations emerged in the location and monthly pattern of significant changes in the surface-runoff and sediment yield in response to the likely LULC scenario for 2020 vis-à-vis 2010.

Keywords

CFSR; Indian Meteorological Department Gridded Rainfall; Discharge; Sediment Yield; Prediction; SWAT; LULC Change Prediction

Water environmental capacity calculation based on SWAT model in Xiangxi River Watershed, China

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Abstract

Nowadays, management of the water environmental contamination have received much focus, particularly for non-point source (NPS) pollution due to its complexity and uncertainty in the environmental. To improve the water quality, a lot of measures, including best management practices (BMPs), have been done on controlling the discharge of NPS pollution. However, whether using these measures were appropriate and how many measures should be used in a specific area were not considered in most studies. To solve this problem, water environmental capacity (WEC) was calculated to quantify the total amount of pollutants allowed to be discharged into the water volume before implementing those BMPs. While nowadays, the method used to calculate the WEC was too simple. The complex degradation of the pollutants and the interaction between different pollutants in the channel was lack of consideration.

In this study, Xiangxi River watershed was selected as the study area. A new method was put forward to calculation the WEC for nitrogen and phosphorus in a more detailed way, considering the interaction of pollutants and dynamic change of the input conditions. The SWAT model and The differential evolution (DE) algorithm was couple to calculate the WEC in a daily step. The outputs of the SWAT model including flow, water temperature were directly used as the inputs of DE algorithm to calculate the WEC. What's more, the WEC of nitrogen and phosphorus in organic and inorganic species was calculated separately instead of only calculating the WEC of the total nitrogen and phosphorus.

The results showed that the WEC showed the smallest value in wet season. The WEC of nitrogen and phosphorus in organic species was more affected by seasons change than that of nitrogen and phosphorus in inorganic species. Spatially, the channels in the middle and southeast of the study area had the smallest WEC and negative values even occurred. The results indicated that much attention should be paid to the control of NPS pollution in the wet season, and organic nitrogen and phosphorus should be set as the priority control pollutants. Compared to the methods used before, the calculation was more detailed, automatic and the dynamic change of the input conditions were better considered.

Acknowledgement

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Keywords

water environmental capacity; non-point source pollution; SWAT model; differential evolution algorithm

Deriving water quality indicators from essential water variables with SWAT

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Abstract

Essential Variables (EVs) are being defined by different expert groups in Earth observation as intermediate variables that connect field and remote sensing observations with the calculation of environmental policy indicators. EVs have been primarily defined in Climate (ECV), Biodiversity (EBV) and Water (EWV). In the European GEOEssential project (www.geoessential.eu), we propose a method to extract inputs and outputs from a pan-European SWAT model, assign them to their corresponding EWVs, expose the resulting variables as data web services in a Spatial Data Infrastructure, create a workflow in virtual cloud infrastructure to calculate water quality indicators from EWVs according to the European framework directive, make available the SWAT outputs and outputs as data web services, and display the derived EWVs and the resulting indicators in the GEOEssential project dashboard as graphics and story maps. We believe that this approach is what is needed to accelerate the creation of existing policy indicators from scientific observations and models, and to improve the understanding of synergies and tradeoffs by policy makers. The proposed framework can be used for all water indicators at various scales, as well as for indicators in other fields such as biodiversity and climate. It represents a general framework on how to automatize the creation of indicators such as those needed for Food-Water-Energy nexus approaches or those defined for the Sustainable Development Goals.

Keywords

Essential Water Variables, Spatial Data Infrastructure, European SWAT model, Environmental Policy Indicators

Integrated Water Resources Management (IWRM) of Kosi Basin for Regional Economic Development

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Abstract

Integrated water resource management (IWRM) is a process to improve the planning, conservation, development, and management of water, forest, land, and aquatic resources in a river basin context, to maximize economic benefits and social welfare in an equitable manner without compromising the sustainability of vital environmental systems. IWRM means that all the different uses of water resources are considered together. Water allocations and management decisions consider the effects of each use on the others. They are able to take account of overall social and economic goals, including the achievement of sustainable development. The basic IWRM concept has been extended to incorporate participatory decision-making. Different users' groups (farmers, communities, environmentalists etc) can influence strategies for water resource development and management which brings additional benefits, as informed users apply local self-regulation in relation to issues such as water conservation and catchment protection far more effectively than central regulation and surveillance can achieve. North Bihar, India has an area of about 5.4 million hectares. It is playfield of 8 major rivers – Gandak, Burhi Gandak, Adhwara group of rivers, Bagmati, Kamla, Bhutahi Balan, Kosi and Mahananda. It is worth mentioning that 17 per cent of the total flood affected area of the country is in Bihar, 57 per cent of the total floods affected people in the country belong to Bihar, out of which 76 per cent reside in north Bihar. 76 per cent of the land in north Bihar is flood affected and approximately 86 per cent of people depend on agriculture for their existence. Excessive waterlogging – as per state government's report, approximately 0.8 million hectares of land is waterlogged every year, 15 % of agricultural land is rendered useless affecting livelihood of 6 million people. Northern part of Bihar is hydro-logically fragile as it is the junction where snow-fed rivers originating in the Himalayas and carrying heavy discharge of water and silt lose gradient, slow down, inundate and cause siltation as they flatten out in the plains. As the gradient is gradually increasing due to tectonic movements in the nascent mountains in sub-Himalayan Tibet and Nepal, this is bound to exacerbate over the years. In present paper the state of art of the present status of IWRM in Kosi sub basin has been discussed, the flood frequency analysis at the barrage site in the Kosi river has been carried out, The soil irrigability and land capability classification for Kosi irrigation project has been carried out. The correlation between FAO Penman-Montieth Method and the Hargreave's Method for reference evapotranspiration at stations having shortfall of data in Kosi Command Area has been found. Suitable cropping pattern in Kosi Command Area based on crop water requirement have been suggested. We used CROPWAT 8.0 for Crop water requirement and Irrigation Scheduling. Socio-economic and environmental impacts in Kosi sub basin has been carried out. Scope of applying SWAT and HECRAS models for IWRM in Kosi sub basin has also been discussed.

Keywords

IWRM, CROPWAT, FAO, Floods, irrigability, Siltation, sustainability, SWAT, HEC-RAS, Kosi sub-basin

Integrated Flood Management in Bagmati river basin Using Modern Technology

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Abstract

Integrated flood management (IFM) calls for a paradigm shift from the traditional, fragmented and localized approach, and encourages the use of the resources of a river basin as a whole, employing strategies to maintain or augment the productivity of floodplains, while at the same time providing protective measures against losses due to flooding.Traditional flood management addresses only negative aspects of flooding. The susceptibility to flood provides adhoc reactions and is carried out in isolation. It expresses the risk of flooding simply as the exceedance probability of a flood of a given magnitude on a particular stretch of river. Construction of reservoirs such as dams and barrages on the river at suitable sites and construction of flood embankments on both sides of rivers are being used as long term structural measures for flood management. Land use management, planning of households, villages and other infrastructures above high flood level (HFL), using waterlogged area as detention reservoir for fish production, growing crops which can withstand water logging and to make planning for small dams on upper reach of the tributaries, providing flood proofing platforms, construction of raised platforms above embankments formation level, construction of multi hazard resistant houses, can be adopted as short term measures. Presently anti-erosion works before monsoon period and flood fighting works during the monsoon are done at vulnerable sites by State Water Resource Department. IFM aims at improving functioning of the river basin as a whole, integrating land and water resources development and management in a river basin, maximizing the efficient use of floodplains and minimizing loss of life, managing the water cycle as a whole, managing risk and uncertainty, adopting a best-mix of strategies for flood fighting with traditional and latest techniques for structural and non structural measures, ensuring a participatory approach and adopting integrated hazard management approaches. IFM assumes that floods have beneficial impacts and can never be fully controlled. Emerging issues, such as risk management, urbanization, climate variability and change, and adaptive management are given due considerations. There is an attempt for maximizing net benefits from the use of flood plains, rather than trying to fully control floods. Unpreparedness, failure to give warnings to the people concerned, lack of accurate information regarding the areas already isolated by floods or likely to be affected by floods, inability of administrative machinery to establish immediate contact with the affected areas, time lag in mobilizing resources to face the situation particularly regarding the evacuation of marooned people and reluctance of the people to move out of their houses in spite of advance warning are main causes of damage and suffering particularly to the population affected by floods. In present study SWAT and HEC-RAS models have been used for web-based real time flood forecasting, flood inundation modeling, flood plain mapping and flood hazard zoning for Bagmati river basin of Bihar, India. Real time data acquisition system (RTDAS) and embankment asset management system (EAMS) have also been proposed.

Keywords

Floods, water logging and drainage congestion, embankments, IFM, SWAT, HEC-RAS, RTDAS, EAMS, Bagmati river basin

Sustainable Watershed Management in Ganga river basin Using SWAT Model

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Abstract

Watershed projects have not only meandered through the degraded landscapes in the country during the past three decades but have grown from being mere technical interventions for restoring degraded lands and vegetations to more specific poverty alleviation initiatives and enhancing livelihood options of the local community. Concerns related to the equity and bringing the stressed households into mainstream are being addressed through watershed programs. In its third phase where amalgamation of the 'top-down' & 'bottom-up' approaches for watershed management has taken place, the rural development programs are also being formulated and launched through watershed programs. In absence of an integrated monitoring and evaluation framework for the health of watershed and its community, measuring levels of success or failure of such watershed programs is not feasible. The existing qualitative techniques for the evaluation of watershed program do not address the objectives of the watershed program properly. The study presents a watershed based sustainable livelihoods framework which analyses the livelihoods of watershed community, evaluates watershed interventions and establishes linkages between livelihoods and hydrological components. A methodology is proposed for quantification of the socio-economic aspects, which is found effective in measuring the impacts of watershed program on local community. The SWAT hydrological model with ArcView GIS interface has been used to simulate various watershed interventions for water and sediment yields. The Geographic Information System has played an important role in database creation, data processing and analysis. The methodology is employed on Bagmati watershed in Ganga river basin in Bihar, India. The SWAT model predicts decrease in surface runoff and sediment loading. Ponds are effective measures in augmenting ground water and reducing soil erosion process. Check dams serves as water harvesting and recharge structure. Heavy losses in surface runoff may deteriorate the water availability to down stream area stressing water demands especially during the water stressed months. The proposed methodology can be used for livelihood analysis. Statistical analysis like factor and regression modelling can be used to establish linkage between livelihoods and hydrological components. There is a need to mobilise the resources in more effective manner at local level for the sustainability of watershed programs. Community participation in watershed development and management plays vital role. There is need to register water user's associations and provide local controls..

Keywords

SWAT, GIS, sustainability, community participation, livelihoods, Ganga river basin, Bagmati watershed

Model-based reconstruction and projections of soil moisture anomalies and crop losses in Poland

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Abstract

Evidence shows that soil moisture (SM) anomalies (deficits or excesses) are the key factor affecting crop yield in rain-fed agriculture. Over last decades, Poland has faced several major droughts and at least one major soil moisture excess event leading to severe crop losses. This study aims to simulate the multi-annual variability of SM anomalies in Poland, using the SWAT model and to assess the effect of climate change on future extreme SM conditions, potentially affecting crop yields in Poland. A crop-specific indicator based on simulated daily soil moisture content for the critical development stages of investigated crops (winter cereals, spring cereals, potato and maize) was designed, evaluated for past conditions against empirical crop-weather indices (CWIs), and applied for studying future climate conditions. The study used an ensemble of nine bias-corrected EURO-CORDEX projections for two future horizons: 2021-2050 and 2071-2100 under two Representative Concentration Pathways: RCP4.5 and 8.5. Historical simulation results showed that SWAT was capable of capturing major SM deficit and excess episodes for different crops in Poland. For spring cereals, potato and maize, despite a large model spread, projections generally showed increase of severity of soil moisture deficits, as well as of total area affected by them. The signals of change in soil moisture excesses for potato and maize were more dependent on selection of RCP and future horizon. Presented results form the basis for future studies on potential adaptation options such as irrigation, drainage and other land and water management practices mitigating SM anomalies and thus reducing cropy yield fluctuations on a sustainable basis.

Keywords

soil moisture, drought, water deficit, water excess, crop yields, climate change

Projections of climate change impact on wetland habitats within Natura 2000 in Poland

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Abstract

Climate change is expected to impact the water cycle through changing the precipitation levels, river streamflows, soil moisture dynamics and therefore pose a threat to groundwater and surface-water fed wetlands and their biodiversity. This article examines the past trends and future impacts of climate change on water dependent habitats within the Special Areas of Conservation (SAC's) of the Natura 2000 network located within Odra and Vistula River basins in Poland. Hydrological modelling using SWAT was driven by a set of nine EURO-CORDEX Regional Climate Models for a historical period (1971-2000) and two future periods (2021-2050 and 2071-2100) under two Representative Concentration Pathways (RCP's) of greenhouse gas concentration trajectories: 4.5 and 8.5. A habitat assessment was carried out to distinguish groundwater and surface water fed wetlands. By establishing threshold values of streamflow at bankfull flow flood events were identified. Changes in frequency of the floods informed about the alteration to the water supply for wetlands reliant on inundation. The groundwater-fed wetlands were assessed on the basis of the soil water content. Projected precipitation increase was the dominant factor causing increased water supply to both surface water and groundwater fed wetlands. The results were compared to the information included in the Natura 2000 standard data form of SACs about the conservation of those habitats and their threats to maintaining a good habitat condition. An assessment was carried out to identify habitats which might be negatively or positively impacted by climate change.

Keywords

SWAT, modelling, climate change, wetlands, Natura 2000

Understanding the climate model uncertainty in streamflow projection

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Abstract

The impacts of changing climate poses a crucial threat to the seasonal distribution of water availability. Hydrological models forced with the climate data from the climate models have been widely employed for projecting the streamflow. But a major cause of concern in such an analysis has been the suit of uncertainties inherent in the modeling chain, beginning from climate models and ending with hydrological models. Utilizing an ensemble of climate models is imperative for studying the range of projections. But in this process, the same ensemble leads to uncertainties which are found to be contributing the maximum, among the various other sources. Here we analyse the streamflow projection from a hydrological model developed using the Soil and Water Assessment Tool (SWAT) and forced with an ensemble of six regional climate models (RCMs). The monthly projections are found to have a wide spread causing large uncertainty, especially in some of the seasons. The values of the ensemble members are not found to have a uniform spread across the range of projections. Rather, the modeling results are identifiable in different groups by virtue of the driving climate model. The results from the groups of climate models are found to be statistically dis-similar for majority of the months. It is concluded that the type of climate models in the ensemble governs the extent of uncertainty. The analysis is carried out on the hydrological model for the Magpie River located in northern Ontario.

Keywords

Climate Change, Hydrological model uncertainty, RCM, SWAT

Water quality regulation functions under future climate change in South-Western Europe catchments

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Abstract

Climate change is expected to modify precipitation and temperature regimes in South-Western Europe, with impacts on hydrological regimes and water resource availability. However, few is known about the impacts on water quality regulation functions, that are essential for the sustainability of socio-ecological systems and are very sensitive to multiple anthropogenic pressures and climate variability. It is thus essential to develop tools based on modelling approaches to quantify the spatial and temporal distribution of ecological functions, and their evolution under future climate and management scenarios. In this study, we use the model Soil and Water Assessment Tool (SWAT) accounting for anthropogenic pressures (dams, nitrogen fertilization, sewage inputs, etc.), and aiming at simulating water, nutrient and sediment transfers in soils and rivers at the catchment scale. We use a set of bias-corrected CORDEX climate projections for precipitation and temperature to investigate the impact of future climate change for 2040-2050. This study allows quantifying the evolution of water regulation functions (e.g. water accumulation, nitrate and sediment retention, denitrification) and identifying hot spots and hot moments of these functions in the South-West of Europe. The results constitute a basis for (i) anticipate/adapt to on-going climate change, and for (ii) the development of a platform for integrated water resources with water management stakeholders in order to reconcile the water needs of societies (drinking water, agriculture, industry, cities, leisure etc.) with the ecological needs of rivers.

Keywords

water quality, climate change, south-western Europe, rivers, nitrogen, sediment

Development of a simple field scale conservation planning tool using SWAT based export coefficients

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Abstract

Conservation planners need simple tools to predict sediment and nutrient losses from agricultural fields to guide conservation practice implementation and increase cost-effectiveness. In this research, we detail the development a simple field scale tool capable of predicting sediment and nutrient loads under various crop systems and conservation practices. This tool uses an export coefficient, and conservation practice effectiveness database derived from millions of SWAT simulations. These data cover the entire contiguous US, and all major cultivated cropping systems.

Keywords

Conservation SWAT

The Use of the APEX Model for the Evaluation of Different Types of Agricultural Land Management

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Abstract

Agriculture releases nutrients and accelerates erosion processes, which threatens the good quality status of surface waters, proposed by the European Water Framework Directive (2000). The purpose of the masters thesis was to define agricultural land management scenarios and to evaluate them, according to their impact on surface water quality. For this purpuse we used Agricultural Policy/Environmental eXtender (APEX) model, which has not yet been tested under Slovenian pedological and climatic conditions. For the experimental area we chose Kožbanjšček watershed site in Goriška Brda region, that covers 14,6 km^2. Using the previously calibrated and validated APEX model, we examined the impact of two alternative management scenarios on the water pollutant content. We found that the replacement of 66,3 ha of forested areas with new vineyards, would increase the content of suspended solids, nitrate and total phosphorus by 24,8%, 17,1% and 10,7% respectively, which is not in accordance with the Water Framework Directive goals. With the implementation of vegetation buffer strips as a mitigation measure, we could reduce the water concentration levels of suspended solids, nitrate and total phosphorus by 17,9%, 11,1% and 3,1% respectively, regarding the baseline scenario. The results confirm our hypothesis that we can reduce water pollution by choosing different types of land management, but we must take into account the uncertainty that comes from the model structure, setting of the input parameters and the manner in which the watershed is represented.

Keywords

modelling, APEX, land management, Water Framework Directive, water quality

Spatio-temporal critical source areas (CSAs) affecting surface run-off of traditional agricultural practices in Riogrande watershed, Colombia.

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Abstract

The critical source areas (CSAs) which are contributing significantly to the high surface water pollution load per unit area have been used to evaluate the effectiveness of BMPs at the watershed level. However, we considered that understanding and defining the spatio-temporal CSAs allows determining BMPs that are more in line with local needs and which, in turn, have a high probability of being implemented and reduce the uncertainty in BMP effectiveness. In this study, a modeling framework to define the spatio-temporal critical source areas (CSAs) of traditional agricultural practices within the watershed was developed. The hydrological/water quality model Soil Water Assessment Tool (SWAT) was used to define the current state (baseline) of the system. Sensitivity analysis, calibration, and validation of the streamflow, sediments, and runoff pollutants (N and P) were carried out. The Load Impact Index (LII) targeting technique (Giri, Nejadhashemi, & Woznicki, 2012) was applied to define the CSAs. In the same vein, the spatio-temporal patterns of the current agricultural management practices of tree tomato, potato and Kikuyo grass in the CSAs defined were identified. This approach provides a clear and organized way to set and to place successful agricultural BMPs to achieve sustainable agricultural development goals at a watershed scale.

Keywords

Critical source areas (CSAs), hydrological model, best management practice (BMP), water quality, Andes watershed, SWAT model.

Lean Six Sigma for Watershed Management

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Abstract

Lean Six Sigma is a methodology that relies on a collaborative team effort to improve process performance by systematically removing waste and reducing variation. Lean Six Sigma has been very successful in different kind of organizations in several industries. However, during the past decade, these process improvement techniques have increasingly been applying outside the production industry, like: energy, financial services, food, government, and healthcare sectors. So the main question is, can it also work in the watershed management sector? I believe that Lean Six Sigma initiatives in the watershed management sector/projects can provide efficient and effective results, such as: i) uncover cost/time savings and operational improvements, ii) reduce business risks, and iii) deliver value for customers and employees. With a presentation on the 2018 SWAT conference in Brussels, I would like to support more process improvement initiatives in the watershed management sector. An example applied in a watershed management process will be presented to show how Lean Six Sigma can be used. If you ever wondered whether your project, team or organization could be more efficient, produce a higher quality product, and reduce lead time, perhaps this option (methodology) can be a starting point to set a clear vision and goal for all the levels within a project, team or organization.

Keywords

Lean Six Sigma, process improvements, customer value, collaborative (project) team

SWAT2012 model evaluation in semi-arid irrigated watershed

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Abstract

The Soil and Water Assessment Tool (SWAT) is a well-established distributed hydrologic model. However, some studies reported that the SWAT irrigation function was unable to represent appropriately the hydrological processes in intensively irrigated areas. In Del Reguero watershed (Spain), the SWAT2005 version did not reproduce correctly the irrigation return flow generated under intensive sprinkler irrigation. Therefore, this version was modified for correctly simulating the main hydrological processes in the study area. The objective of this study was to evaluate the last SWAT version (SWAT2012 revision 664) in the same study area and to correct the identified deficiency in the irrigation algorithms in the case of manual irrigation and water resource originating from out of the watershed. When the original SWAT2012 model was run in the Del Reguero watershed, the irrigation return flows were unreasonably higher than observed values during the irrigation season (63 Ls-1 vs. 202 Ls-1, in average). Although the current version of SWAT2012 includes some modifications for improving the simulation of irrigation water excess and include it in the water balance, the model considers manual irrigation as an automatic irrigation and takes the entire irrigation dose introduced manually as deep percolation. This explains the high values of water flow during the irrigation season. The main model source code modification performed in this work were: (1) To incorporate an algorithm that allow the performance of the manual irrigation operations in the subroutine “subbasin”. And (2) To change the maximum amount of water applied as an irrigation event in the “irrsub” subroutine to the depth of irrigation water applied to each HRU as specified by the user (instead of the amount of water held in the soil profile at field capacity). The adjusted version of the SWAT2012 model was calibrated and validated for streamflow and nitrogen load. Input data from January to December 2008 were considered in the calibration process, while an independent 12-month period was used for the validation process (January to December 2009). Streamflow and nitrogen load calibration and validation in Del Reguero watershed will be presented, along with an estimation of nutrient losses from various agricultural management practices.

Keywords

Water quality modeling, Irrigation return flows, Nitrogen, Hydrologic model, Model modification

AGUAMOD : A decision support system to evaluate water resources during low water period in South-Western Europe catchments

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Abstract

The objective of Aguamod is to work with all stakeholders in water management (managers, economic actors, users and civil society) in South-West Europe (SUDOE) to build a platform for the integrated management of water resources during low water periods.

The Aguamod platform will combine a calculation of the water needed from the watershed (drinking water, agriculture, industry, environmental flows ...), with numerical models simulating the stocks and flows of water in all compartments of the watershed using different model including SWAT model. An economic and social evaluation of water resources and an analysis of the quality of water governance will be conducted for the SUDOE territory as a whole. Different scenarios of climate change coupled with simulations will aim to anticipate future water needs from an environmental, social and environmental point of view.

The Aguamod platform aims to promote a global and shared vision of this resource when water levels are low in the SUDOE territory. It will provide managers and users with tools to support decision-making using complex scenarios, and by 2050 will offer robust and localized information on the dynamics of climate, hydrology, land use, water and modes of governance.

Keywords

A decision support system, water resources, low water, platform

Use of evaporation and streamflow data in hydrological model calibration

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Abstract

The conventional method of hydrological model calibration is based on observed streamflow data at catchment outlets. Nowadays, availability of remote sensing based evaporation data provides additional dataset for hydrological model calibration. The use of two or more observed variables in hydrological model calibration has received considerable attention in recent past. This study evaluates different strategies for using evaporation (ET) and streamflow (Q) data to calibrate a hydrological model. A SWAT hydrological model is developed for the Chindwin River Basin in Myanmar for the application. The ET dataset used is from Global Land Evaporation Amsterdam Model (GLEAM), which is based on remote sensing data.

Calibration with only Q improves the model performance with respect to Q estimates, but with a poor performance with respect to ET estimates and vice versa. When both ET and Q are used for calibration with different weight combinations, we find a range of weight combinations that results in reasonably good model performance with respect to both Q and ET estimates. When calibrated with only Q, the best NSE values obtained are 0.93 and 0.39 on Q and ET respectively. Similarly, when with only ET the best NSE values obtained are 0.75 and 0.30 on ET and Q, respectively. When calibrated with both ET and Q, the weights between 0.3 and 0.7 resulted in the best NSE values of 0.93 on Q and 0.64 on ET. The weight combinations beyond the 0.3 and 0.7 resulted in slight increase of NSE on one variable, e.g. Q, in the expense of considerable reduction of NSE on the other variable.

Keywords

Calibration, Chindwin Basin, Evaporation, Multi-variable, SWAT

Simulating Inbred Corn Yields and Nitrogen Fate with APEX

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Abstract

The Agricultural Policy/Environmental eXtender (APEX) model, designed for simulation of whole farm/small watershed agricultural practices, has extensively been validated for simulating hybrid corns but has not been parameterized or calibrated for seed-producing inbred corn (Zea mays L.). This paper presents 1) parameterization of three commercial inbred lines based on field experiments in the Midwestern United Sates, 2) calibration of inbred corn yield and leaf development using APEX, and 3) analysis of nitrogen balance and fate.

Keywords

APEX, inbred corn, nitrogen

Application of SWAT for the Boone River Watershed in North Central Iowa, U.S.: Implications of Different Nutrient Load Estimation Techniques for Model Testing

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Abstract

Verification of hydrologic and/or pollutant output is commonly performed for applications of the Soil and Water Assessment (SWAT) ecohydrological model (Arnold et al., 1998; 2012) and similar models. Testing of SWAT can be performed using a variety of approaches, and is often conducted using separate calibration and validation phases depending on data availability. In-stream pollutant levels are typically measured in the form of concentrations, which are usually converted to a mass basis using streamflow discharge observations to allow comparisons of SWAT output with measured loads. This is a necessary step for conducting Total Maximum Daily Load (TMDL) assessments and many other water quality analyses. However, one often overlooked reality is that the "measured pollutant loads" are in fact estimates that are based on statistical models. Recent research (Stenback et al., 2011; Schilling et al., 2017) reveals that considerable variability can occur in predicted nitrate loads for stream systems distributed across the state of Iowa, which is located in the western part of the Corn Belt region in the United States. Schilling et al. (2017) further report that different methods may be needed for estimating nitrate loads for different watersheds, rather than relying on the same technique to estimate nitrate loads for all watersheds. Similarly, additional unpublished research indicates that different load estimation techniques may be needed for estimating the loads of different pollutants, even for the same watershed.

Multiple load estimation approaches are investigated using SWAT for this study for the Boone River watershed (BRW), which drains over 2,300 km^2 in portions of six counties in north central Iowa which are located in the western Corn Belt region of the U.S. Nearly 90% of the BRW is managed with rotations of corn and soybean, which are representative of typical Iowa cropping systems. Extensive livestock production also occurs in the BRW, which is dominated by nearly 500,000 head of swine produced annually and the presence of close to 7 million layer chickens. Fertilizer and manure nutrient inputs to BRW cropland result in elevated levels of nutrients exported from the watershed, similar to nutrient pollution problems that manifest across much of the state. Nitrate discharged from the BRW stream system is of primary concern, much of which escapes the cropland via subsurface tiles that drain the predominantly flat landscapes that characterize the watershed. Phosphorus export to stream systems in the BRW is also a problem of considerable concern.

The BRW SWAT hydrologic testing was divided into calibration and validation phases during the 30-year period of 1984 to 2013. The calibration phase was first conducted for the second half of the overall time period (1999 to 2013) followed by the validation phase, which was performed for the first 15-year period of 1984 to 1998. Calibration of the estimated SWAT pollutant loads are presented for the 14-year period 2000 to 2013 based on the loads estimated from measured concentrations and key calibrated parameters. The initial testing of SWAT was focused only on calibration due to the sparse number of pollutant measurements that were sampled near the outlet of the BRW over the 14 years, which were collected at most once a month (with longer gaps sometimes occurring between sample collection). Additional validation of nitrate loads are also reported based on nitrate sensor load data measured during 2012 to 2017. The need for using different load estimation techniques for

different pollutant constituents is discussed as well as the implications of using load estimations for a given pollutant that greatly deviate from other load estimation methods; e.g., Load Estimations (LOADEST; Runkel et al. 2004) nitrate load estimates for the BRW. Graphical and statistical evaluation of the pollutant load estimates are also presented.

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Keywords

SWAT, calibration and validation, tile drainage, hydrologic testing, pollutant load testing

Modeling the efficiencies of check dams on reducing the sedimentation problem: A case study of the Cameron Highlands reservoir in Malaysia

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Abstract

The objective of this study is to evaluate the effect of check dam on soil and water conservation at the catchment scale using the MIKE21 FM models. This paired watershed study includes a watershed treated with two check dams (Habu and Ringlet check dams) and a control watershed which has none, in the Cameron Highlands watershed, Malaysia. MIKE21 FM model was calibrated for streamflow and sediment using field data documented at the study site. The calibrated model was then used to examine the impacts of check dams at the treated watershed. The efficiencies of Habu and Ringlet check dams on reducing the sediment input into the reservoir are estimated as 46% and 79%, respectively. Ringlet check dam has an intrinsically higher trapping efficiency than Habu check dam because the non-cohesive sediment makes up a much higher percentage of the inflow (this in turn is attributable to the Ringlet catchment being steeper). An increase in the check dam sedimentation basins to a larger size will have a large impact in the reduction of sediment input to the reservoir. Construction of check dams in the

Cameron Highlands has enhanced the capacity to control the runoff and sediment into the reservoir.

Keywords

Cameron Highlands; Check dam; Sediment erosion; Soil and water conservation;

Improvement and application of the PCPF-1@SWAT2012 model for predicting pesticide transport: A case study of the Sakura River watershed

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Abstract

The PCPF-1@SWAT model was previously developed to simulate the fate and transport of rice pesticide in watersheds. However, the current model is deficient in characterize the rice paddy area and are incompatible with the ArcSWAT2012 program. In this study, we modified original PCPF1@SWAT model to develop new PCPF1@SWAT2012 model to address the deficiency of rice paddy area and utilizing the ArcSWAT2012 program. Next, the new model was applied in Sakura River watershed, Ibaraki, Japan in order to simulate the transport of four herbicides including mefenacet, pretilachlor, bensulfuron-methyl and imazosulfuron. The result showed that the simulated water flow rate by the PCPF1@SWAT2012 was well predicted with the observed data. The calculated NSE (0.73) and PBIAS (-20.38), suggested the satisfactory performance of the model. Besides, the concentrations of herbicides simulated by the PCPF-1@SWAT2012 model were in good agreement with the observed data. Statistical indices, NSE and RMSE estimated for mefenacet (0.69 and 0.18), pretilachlor (0.86 and 0.18), bensulfuronmethyl (0.46 and 0.21) and imazosulfuron (0.64 and 0.28) indicated satisfactory predictions, respectively. The PCPF-1@SWAT2012 model is capable of well simulating the water flow rate and transport of herbicides in given watershed, comprising different land use types, including rice paddy area.

Keywords

PCPF-1@SWAT2012 model; pesticide fate and transport; Sakura River watershed; rice paddy; model simulation

Modeling the impact of land use change on basin-scale transfer of fecal indicator bacteria: SWAT model performance

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Abstract

The conversion of annual crop to commercial tree plantation can lead to variations in watershed-scale physical processes. In this study we hypothesize that the land use change can lead to changes in microbial transport, which is especially important to understand in developing countries where Fecal Indicator Bacteria (FIB), *Escherichia coli* (*E. coli*) contamination of surface water threatens public health. The Soil and Water Assessment Tool (SWAT) is a useful tool to physically integrate the watershed characteristics and to simulate water and contaminants' fluxes. The objective of this study was thus to assess the comprehensive impact of land use change on microbial transfers from soil to stream, using SWAT. Under the observed weather conditions, the model predicted a decrease from 2011 to 2012 and an increase from 2012 to 2013 for surface runoff, suspended solids and *E. coli*transferred from the soil surface to the stream. The amount of precipitation played an important role in simulating surface runoff, and it consequently altered the suspended solids and bacteria transport. In simulations of identical weather conditions and different land uses, *E. coli* transport was more sensitive to the initial amount of *E. coli* than to its drivers (i.e. surface runoff and suspended solids) and leaf area index played an important role in determining the initial amount of *E. coli* on the soil surface. Based on these findings, this study summarizes several limitations of SWAT fertilizer and bacteria modules and suggest improvement guidelines for further modeling work.

Keywords

Land use change, Soil and Water Assessment Tool, Escherichia coli, Fecal Indicator Bacteria, tropical watersheds

Hydrologic Impact Analysis of Land Use Change on Tropical Coastal Mangrove Ecosystems: Aklan, Philippines

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Abstract

Mangrove forests thriving in intertidal zones in tropical and subtropical regions of the world offer a range of ecosystem services including carbon storage and sequestration. They can regulate detrimental effects of climate change due to carbon releases two to four times greater than that of mature tropical rainforests. Moreover, they are effective natural defenses against storm surges and tsunamis. However, their proliferation depend significantly on the prevailing hydroperiod at the coast. In the Philippines, these coastal ecosystems have been severely threatened with a 50% decline in areal extent observed from 1918 to 2010. Highest decline occurred in 1950 – 1972 when national policies encouraged the development of fisheries and aquaculture. With the intensive land use conversion upstream, changes in the freshwater-saltwater envelope at the coast may considerably impact mangrove growth conditions. This study compares two dynamic watersheds in Aklan, Philippines: (1) a small rural watershed in Ibajay with a natural riverine species-rich 44-hectare mangrove forest; and (2) a developing urban watershed in Kalibo with a 220-hectare mangrove forest replanted for over 30 years. Both mangrove forests are sustainably conserved and declared as protected areas. Hybrid land cover classification technique was used to classify Landsat images for years, 1990, 2010 and 2017. Digital elevation model utilized was Interferometric Synthetic Aperture Radar (IFSAR) with 5-meter resolution to delineate the watersheds. Using the SWAT model, hydrologic analysis on the influence of land cover change to flow and sediment discharges was simulated. While significant land cover change occurred upland, thereby increasing runoff and sediment loads, the mangrove forests abundance adjacent to the coasts for the two watersheds, was somehow sustained. However, significant alteration of the coastline was observed in Kalibo through the years probably due to the massive land-use conversion upstream and significant replanting of mangroves downstream. Understanding the hydrologic response of these watersheds to changing land cover is essential to helping local government and stakeholders facilitate better management of these mangrove ecosystems.

Keywords

Hydrology, Land use change, Mangroves, Philippines, SWAT model

Valuing Hydrological outputs as Water related Ecosystem Services under Present and Future Climate Scenarios for Godavari basin

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Abstract

Water-related Ecosystem services (ES) is deemed to have a significant impact on river basin due to drastic variation in climate. ES such as Provisioning (water yield, water consumption, and hydropower valuation), Regulating (climate stability and flood control) and Supporting (sediment retention, nutrient cycling) are considered for the evaluation and mapping of the socio-economic impact due to variation in climate and land use. Previous studies show the assessment and mapping of water-related ES by using land cover maps with scoring factors and ecological production function based on specific ecosystem service models. In the present study, QSWAT and INVEST (Integrated Valuation of Ecosystem Service and Trade-offs) are integrated as a unique approach for mapping, assessing and valuing ecosystem services. Firstly, in QSWAT model, the future flow regime in the catchment was simulated by regional climate models (RCM's) downscaled and bias-corrected data for quantitative and qualitative outputs such as stream flow, sediment yield, nutrient loss etc., Furthermore on calibration and validation of parameters related to water, soil, vegetation, best management practices (BMP) were done to simulate future scenarios addressing the ES confined in Godavari basin. Secondly, in the INVEST model, water-related ES were quantified based on landscape maps generated by QSWAT combined with inbuilt models such as Hydropower production, Water purification, and Sediment retention. This present methodology of integrating the hydrology of river basin by accounting for ES provides information on present and future flow scenarios in the river and also discusses the perspective of linking of ES with climate model along spatial and temporal variation. Therefore, this approach can serve as a basis for socio-economic valuations to support river basin management for the better decision-making process.

Keywords

Ecosystem services, Regional climate model, QSWAT, INVEST, Godavari basin.

Improvement of Aquatic Ecology Healthiness by Securing Stream Maintenance Flow and Applying Agricultural Best Management Practices

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Abstract

The objective of this study is to estimate the maintenance flow rate for environmental ecology and to suggest agricultural Best Management Practices (BMPs) for improving the ecology health using Soil and Water Assessment Tool (SWAT) separating the normal (2008-2013) and drought years (2014-2015). For the study area, Han River basin of South Korea, the SWAT was spatially calibrated (2008-2012) and validated (2013-2015) at seven locations (HSD, SYD, CJD, KCW, YJW, IPW, and PDD) using daily observed dam and diversion inflows, evapotranspiration, soil moisture, groundwater level and water quality data. The average NSE for the seven locations dam inflow was 0.59-0.88. The average R^2 for the sediment, Total Nitrogen (TN), and Total Phosphorus (TP) were 0.75, 0.70, and 0.73 for each calibration point. For the ecological health, we used aquatic health indices such as Trophic Diatom Index (TDI), Benthic Macroinvertebrate Index (BMI) from 2008 to 2015 and Fish Assessment Index (FAI) from 2008 to 2013. After calibration and validation for SWAT modeling, the aquatic health indices were predicted using random forest (RF) which is one of machine learning algorithms and SWAT modeling results such as streamflow, NO_3, NH_4, PO_4, TN, TP, and water temperature for 237 sub-watersheds. As a result, the accuracy shown 89 % for FAI, 91 % for TDI, and 90 % for BMI, respectively. Next, the maintenance flow for improving aquatic health indices from D or E grades to A or B grades will be estimated with separating downstream and upstream watersheds. In addition, BMPs will be suggested at upstream watershed where the maintenance flow cannot be supplied. This result could be used as a decision data for watershed management including aquatic ecology.

Acknowledgements

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Keywords

SWAT, Aquatic Health Index, Water Quality, Maintenance Flow and Best Management Practice

Calibration and uncertainty analysis of SWAT model for stream flow modelling in the tropical highlands watershed

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Abstract

Stream flow in the Cameron Highlands watershed, covering an area of 25,890.04 km^2, and located at the north western portion of Pahang state, Malaysia was modelled using the Soil and Water Assessment Tool (SWAT). The main objective of the present study was to test the performance and viability of the SWAT model in predicting stream flow in the river basin. The model was calibrated and validated for two periods: 1998-2003 and 2004-2006, respectively, using the program SUFI-2. The Sufi-2 gave acceptable results (NSE>0.50 and R^2 =0.61) for monthly simulation during the calibration and verification processes (R^2 was 0.1 and NSE 0.01). The number of hydrological response units (HRU) in the basin was 116. The decision model sensitivity analyses were based on the HRU's. The result of this uncertainty, the 95% prediction uncertainty (95PPU), bracketed well with the observed emission. All sources of uncertainty captured by bracketing values were higher than 85% of the observed river discharge. All results in the study are important for estimation of water discharge. The calibrated model can be used for further analyses of the impact of climate, land use change, water quality and content of sediment. Furthermore, the model can also be used to plan the construction of dams in future disaster risk management as well as for floods and thus be useful for maintaining sustainable development of the country.

Keywords

Hydrological response units . Stream flow . SUFI-2 . SWAT

Sensitivity of SWAT modeling in the Mediterranean Joumine dam catchment

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Abstract

The diffuse pollution from agricultural land has become one of the most crucial environmental problems through water quality. Hydrological and hydrochemical quality models are useful tools to understand problems and to simulate the influence of land use, soil, agriculture management and climate conditions on flow, sediment and nutrient yields under different temporal and spatial dimensions. The Joumine catchment, located in Northern subhumid mountainous Tunisia is dominated by intensive agricultural production. To represent the hydrological and biogeochemical dynamics, SWAT model was used. Sensitivity analysis, calibration and validation were needed to evaluate the model performance for predicting streamflow and nutrients concentrations. SWAT model contains many parameters that can represent a source of equifinality and complexity in the calibration process. The objective of this study is to evaluate the sensitivity analysis of SWAT for multiple inputs (Rainfall options, PET methods, Land use change and DEM resolutions) over the Joumine catchment, upstream of a strategic dam. Results show a strong sensitivity to spatial rainfall variability. The methods used to calculate Potential Evapotranspiration (PET) integrated in SWAT model did not considerably affect stream flow predictions. The effect of input data resolution was evaluated by running six DEM grid sizes (20, 30, 90, 250, 500 and 1000 m). Runoff simulation results for each DEM resolutions show that finer DEM grid sizes do not give the highest performance. Streamflow simulations were most sensitive to climatic conditions and rainfall options, less sensitive to PET methods and topographical data. The land use change modelling results showed a low effect on the runoff at the Joumine catchment.
The climate variability influenced the hydrological processes more significantly than the land use change and DEM resolutions size in the Joumine catchment.

Keywords

Rainfall variability, Sensitivity analysis, PET methods, DEM grid sizes, Land use change, Runoff

Quantifying the cascade of uncertainty in hydro-climate modeling: a prior step for decision making under uncertain condition

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Abstract

Quantifying uncertainty inherent in projection of climate change impact has become a major concern for the scientific community and policy makers. Uncertainties in hydro-climate projections arise from unknown future greenhouse gas trajectories, errors in global climate models (GCMs), natural climate variability, dynamic or statistical downscaling methods, and hydrological models including model structure, parameterization, and regionalization. Numerous studies have considered multiple sources of uncertainty in climate-impact projections, most of which have reported GCMs as a major contributor to the overall uncertainty. However, there is no agreement on the next major uncertainty sources. For instance, uncertainty due to the choice of downscaling method, greenhouse gases emission scenarios (GGES), and selection of hydrological models have been reported as a second major uncertainty source. Moreover, the uncertainty due to hydrological model parameterization (HM-P) and regionalization (HM-R) has been less considered along with other sources of uncertainty. In this study, we developed an ANOVA-SUFI-2 algorithm to decompose the overall cascade of uncertainty into the contribution of GCMs, representative concentration pathways (RCPs), downscaling methods, and HM-P and HM-R. We used output from nine GCMs under two RCPs. These data, obtained from the Pacific Climate Impacts Consortium (PCIC), were produced for the IPCC Fifth Assessment Report by the Coupled Model Inter-Comparison Project (CMIP5). We chose the 1983-2007 reference (historical) period and selected 2010-2035 (near future) and 2040-2065 (far future) periods for the analyses of future. climate. For hydrological modeling, we chose the semi-distributed agro-hydrological model SWAT (Soil and Water Assessment Tool) with its high capability of parameterization and regionalization. Our results of uncertainty decomposition for water resources in Alberta, showed that GCMs and HM-R and HM_R are major contributors to the overall uncertainty (26-39% each of the sources) followed by RCPs (11-17%), downscaling (14-16%), and interaction of sources (7-10%).

Keywords

Uncertainty decomposition, Alberta, ANOVA, SUFI2, SWAT

Calibration of three basins located in different climatic regions in the state of Pernambuco, Brazil

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Abstract

The Soil and Water Assessment Tool (SWAT) has been used for evaluating land use changes on water resources worldwide, and as many models, SWAT requires local calibration because It has many coefficients and simulated variables from sub-models. However, in Brazil, monitoring climate data to feed mathematical models are very spatially heterogeneous. This pattern can be well explained by the unbalanced allocation of financial resources in the region. Thus, the objective of this study is to compare calibrations of basins in different climatic regions that have distinct precision in their monitoring climate data. We created and calibrated three basins, using rainfall data for the period of 1961-2016; in the semi-arid domain: Pontal (average rainfall of 500 mm; 54% of missing data); in the *agreste* (this is a Brazilian transitional climate zone): Moxotó (1000 mm; 52%); and near the coast: Goiana (2000 mm; 49%). In the semi-arid region, an average Nash-Sutcliffe model efficiency coefficient (NS) was 0.72; for the *agreste*, we obtained 0.77; and finally, 0.82 for the Goiana basin, that is near the coastline. Average NS was 0.77 for all three basins. These are the first calibrations of this project that will have 13 basins also calibrated with Leaf Area Index and Evapotranspiration. We would like to thank the support from CAPES 88881.159220/2017-01 and 88882.176728/2018-01; and Facepe APQ 0646-9.25/16 and BCT 0236-7.06/17.

Keywords

Brazilian environment, hydrology, semi-arid, SUPer

Revisiting SWAT as a semi-distributed saturation-excess runoff model for humid temperate and monsoonal climates

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Abstract

The SWAT model is well established and has been successfully applied all over the world. However, one of its limitations is that it cannot simulate well the process of saturation excess overland flow in hilly and mountainous regions with shallow soils. An example is that this limitation becomes especially restrictive in managing the quality of the water supply in the Catskill Mountains where the land is sloping and the soils are shallow, or in the Ethiopia highlands where a restrictive layer has formed due to land degradation. The objective of this paper is to overcome the limitation of simulating saturated overland excess flow in SWAT. To accommodate this, wetness classes were introduced by the NYCDEP and Cornell team. A wetness class consists of a group of HRUs with similar runoff potential. Wetness classes are positioned in the landscape as a function of the topographic index (defined as the quotient of the contributing area and the slope times the soil depth). This interpretation of distinct HRUs on a hillslope is in contrast to the original SWAT where one HRU can contain several hillslopes. Two new SWAT versions were developed. In the first version, called SWAT-with-impervious-layers or SWAT-wil, the percolation out of the rootzone was restricted and the hillslope length parameter was reinterpreted such that it corresponded to the VSA interpretation of the SCS curve number method. Consequently, SWAT-wil is very similar to the standard SWAT. In the second version called SWAT-hillslope or SWAT-HS, a surface aquifer was introduced that allows exchange of flow between the wetness classes (and associated HRUs) when moisture content exceeds field capacity. A non-linear interflow function governs the amount of water exchanged between wetness classes. In addition, some minor adjustments were made in both versions to increase infiltration in frozen soils and to decrease summer baseflow.

We tested the model for the Town Brook watershed in Catskill Mountains. The results show that the discharge calculated with SWAT-wil and SWAT-HS agreed well with the observed outflow hydrographs. The saturated areas predicted by the two new SWAT versions (the location where saturation-excess runoff was generated) were in agreement with observations. These models are well suited to guide decisions on placement of conservation practices in hilly areas to improve the water quality by decreasing contributions of nutrients and soil in overland flow from the uplands.

Keywords

Satuartion-excess runoff; Variable source areas; hillslopes; shallow soils

Improving the Auto-irrigation Scheduling of SWAT for Effective Agricultural Water Management

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Abstract

Reduced water availability and higher food demand will force more water users to shift to water-efficient irrigation techniques in the near future. Root water uptake is a vital process for simulating the overall water balance of an agricultural catchment. It plays a huge role in simulating the plant water requirement and consequently the irrigation water demand as well as the crop yield. The current research deals with simulating plant water demand and irrigation with the Soil and Water Assessment Tool (SWAT) in four agricultural catchments within different agro-climatic zones. We have found a huge difference in the irrigation water amount simulated using the different irrigation scheduling methods of SWAT, namely plant water stress and soil water deficit scheduling. For this, the SWAT subroutine called .swu has been thoroughly checked and improvements will be proposed by referring to a) the literature, b) experimental results from Germany, and c) comparisons with other agro-hydrological models like SWAP. The results compare how the irrigation amounts simulated by the improved SWAT will differ from the original SWAT under soil water deficit and plant water stress auto-irrigation scheduling. This will help researchers to improve the application of auto-irrigation scheduling, e.g. in climate change impact and adaptation studies for agricultural catchments.

Keywords

Water availability, Irrigation, Root water uptake, SWAT

A Salinity Chemistry and Transport Module for SWAT

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Abstract

Salinization of soil and groundwater systems is one of the main threats to sustainable agricultural production in irrigated regions of the world. Salinization occurs primarily due to the presence of salt minerals and a lack of sufficient irrigated depths and appropriate drainage mechanisms. Loading of dissolved salts in groundwater to nearby streams can also impact agricultural productivity of downstream cultivated areas. Models can be useful in assessing baseline salinity conditions and exploring salinity remediation strategies. In this study we develop a salinity chemistry and transport module for the SWAT model. The salinity module includes the fate and transport of eight major ions (SO_4, Ca, Mg, Na, K, Cl, CO_3, HCO_3) in surface runoff, percolation, lateral flow, groundwater, and streams. The module also accounts for salt equilibrium chemistry reactions, including precipitation-dissolution, complexation, and cation exchange. Four subroutines are added to the SWAT code to implement the salinity module, with other standard subroutines amended to track salt ion mass in the subsurface and surface water systems. One input file ("salt_read") is required to run SWAT with the salinity module, and contains initial concentrations of the ions in the soil system and aquifer of each HRU. The module outputs salt ion concentration and mass data for HRUs, sub-basins, reaches, and the basin in salt output files. The model is applied to a 732 km^2 irrigated agricultural area in the Lower Arkansas River Valley of Colorado, and tested against total dissolved solids (TDS) in the concentrations in the root zone, groundwater salt ion concentrations from a network of monitoring wells, groundwater salt loadings to the Arkansas River stream network, and in-stream salt concentrations and loadings. Results indicate that the model can be a useful tool in simulating salt ion fate and transport in highly-salinized aquifers, with the potential for application to other salt-affected regions worldwide.

Keywords

Salt, SWAT, Irrigation

Developing an integrated surface/subsurface watershed model by coupling APEX and MODFLOW

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Abstract

Assessing the hydrologic and water quality responses of watersheds to natural and anthropogenic perturbations requires capturing the complex interaction between surface and subsurface processes. Specifically, in watersheds where surface and groundwater are in close interaction, lack of a mechanism to properly simulate either may lead to unreliable results. In this study, the agricultural Policy/Environmental eXtender (APEX) model was linked with MODFLOW to create an integrated surface/subsurface watershed model capable of simulating key hydrologic and water quality processes and complex management practices at field to watershed scales. The APEX model serves as the main engine simulating the surface and shallow subsurface processes. The values of deep percolation estimated by APEX are passed to MODFLOW for groundwater simulation, including aquifer recharge, groundwater head, and return flow to streams. The return flow from MODLOW is then passed to APEX channel routines for routing through the watershed. The model is applied to two watersheds: Middle Bosque Watershed in Texas, USA, and Price River Watershed in Utah, USA. The integrated model provides major improvements in more realistic simulation of hydrologic and water quality processes which subsequently will lead to better identifying the effects of watershed management practices.

Keywords

Integrated watershed model, APEX, MODFLOW, Surface/subsurface processes

Modelling the combined effects of land use and climate changes on water availability and quality in the Odense Fjord catchment (Denmark).

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Abstract

Multiple stressors compromise the integrity of water resources and ecosystems. Particularly in lowland areas of northern Europe, high population density, flood protection and, especially, intensive agriculture, are important drivers of water quality degradation. In addition, future climate and land use changes may interact, with uncertain consequences for water resources.

In this work, the impacts of three multi-stressor future scenarios combining climatic and socio-economic changes on water discharge and inorganic and organic nutrient loads to the streams have been simulated using the Soil and Water Assessment Tool (SWAT). The results revealed that the scenario-specific climate inputs were most important when simulating hydrology, increasing river discharge in the “High-tech agriculture” and the “Market-driven agriculture” scenarios (which followed the RCP 8.5), while remaining stable in the “Agriculture for nature” scenario (RCP 4.5). Moreover, discharge was the main driver of changes in organic nutrients and inorganic phosphorus loads that consequently increased in a high emission scenario.

However, both land use and climate changes affected the nitrate transport, and future flow increase might counteract the beneficial effect of a lower level of fertilization, which was seen in the High-tech agriculture scenario. Thus, we conclude that N loads will ultimately depend on future land use and management in an interaction with climate changes, and this knowledge is of utmost importance for the achievement of environmental policy goals.

The Impact of Future Urban Expansion on Stream Flow in Bryan/College Station, TX, Watershed

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Abstract

During hurricane Harvey in 2017, the city of Houston and the surrounding area of coastal Texas was affected by extensive flooding. Such flood risk is likely to increase in the future due to rapid urban development and expansion. Accordingly, understanding the effects that urbanization has on surface runoff is crucial to mitigate the negative socio-economic and environmental impacts that flooding has on a community. In this study, the city of Bryan/College Station located 160 km from Houston was taken as a case study. The cities of Bryan/College Station encompass an area of approximately 250 km^2 and have experienced rapid population growth and urbanization since 1990. Despite projections that the population of Bryan/College Station will double by the year 2050, few studies have been conducted in this area to examine the impact that future urban expansion will have on flooding.

In this study, urban expansion and land cover changes in the Bryan/College Station area was modelled from the present to the year 2050 using the Multi-Layer Perceptron (MLP) land use change model. During this period land classified as cultivated and forest decreased while land classified as urban increased from 57% in 2011 to 70% in 2050. The Soil and Water Assessment Tool (SWAT) was then used to assess the impact of the projected 13% expansion in urban surface on streamflow. Future climate scenarios obtained from the Multivariate Adaptive Constructed Analogs (MACA) datasets were used as inputs for this model. These scenarios were selected to examine a range of the future precipitation and temperature values that may be experienced in the study area. Significant surface runoff increases in 2050 were simulated and the results indicate the need for low impact development (LID) best management practices (BMPs) in this rapidly expanding urban area.

Keywords

ArcSWAT, land use change, surface runoff, climate variability

Assessment of Future Climate Change Impact on Groundwater Behavior of Geum River Basin in South Korea Using SWAT

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Abstract

The purpose of this study is to evaluate the groundwater level behavior of Geum river basin (9,645.5 km^2) in the middle of South Korea under future climate change scenario projection periods (2020s: 2010-2039, 2050s: 2040-2069, 2080s: 2070-2099) using SWAT (Soil and Water Assessment Tool). Before future evaluation, the SWAT was calibrated and validated using 11 years (2005-2015) daily multi-purpose dam inflow at 2 locations (DCD, YDD), ground water level data at 5 locations (JSJS, OCCS, BEMR, CASS, BYBY), and three years (2012-2015) daily multi-function weir inflow at 3 locations (SJW, GJW, BJW). For the two dam inflows and dam storages, the Nash-Sutcliffe efficiency (NSE) was 0.57~0.67 and 0.87~0.94, and the coefficient of determination (R^2) was 0.69~0.73 and 0.63~0.73 respectively. For the three weirs inflow and storage, the NSE was 0.68~0.70 and 0.94~0.99, and the R^2 was 0.83~0.86 and 0.48~0.61 respectively. The average R^2 for groundwater level was from 0.53 to 0.61. Under the future temperature increase of 4.3℃ and precipitation increase of 6.9% in 2080s (2070-2099) based on the historical periods (1976-2005) from HadGEM3-RA RCP 8.5 scenario, the future groundwater level shows decrease of –13.0 cm, -5.0 cm, -9.0 cm at 3 upstream locations (JSJS, OCCS, BEMR) and increase of +3.0 cm, +1.0 cm at 2 downstream locations (CASS, BYBY) respectively. The future groundwater level was directly affected by the groundwater recharge by the future seasonal spatial variation of rainfall in the watershed.

Acknowledgements

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Keywords

SWAT, Climate change, Hydrology, Groundwater, Watershed-scale

Anti-Drought Capacity Assessment by Applying Future Dry Climate Change Scenario for a Multipurpose Dam Using SWAT

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Abstract

In recent years since 2012, South Korea has suffered severe drought due to the lack of rainfall, which resulted in a dramatic decrease of water reserve rates. In particular, the Boryeong Dam watershed (163.6 km^2) located in Geum West River basin has continuously experienced water shortage causing serious damage to surrounding industrial and agricultural areas. In the study, the Soil and Water Assessment Tool (SWAT) model considering future climate change and estimated dam release was used to evaluate the anti-drought capacity of the target dam watershed. In order to improve the model efficiency, daily data of dam inflow and storage for 13 years (2005 to 2017) including drought years (2014 to 2016) were calibrated and verified by comparing with observed data, respectively. Among twenty six CMIP5 GCM climate change scenarios, Representative concentration Pathway (RCP) 4.5 and RCP 8.5 scenarios were anlayzed to derive Standardized Precipitation Index(SPI) for determining extreme drought scenario. On the other hand, Multiple Linear Regression analysis (MLR) based on observation data (2005 to 2017) was performed to estimate outflow for future period (2017 to 2046). The MLR brought out daily dam release equations for each month with R^2 (Coefficient of determination) ranged from 0.44 to 0.9, respectively. In result, future daily dam release was estimated for the future period using the MLR results and the extreme drought scenario. Finally, SWAT simulated hydrological components applying all the factors mentioned above. Using the dam inflow and dam storage from the SWAT results, drought duration, drought magnitude and drought severity will be evaluated using frequency analysis. The evaluation would be utilized for the future database building drought related infrastructure and risk assessment.

Acknowledgements

This research was supported by a grant (18AWMP-B079625-05) from Water Management Research Program sponsored by the Ministry of Land, Infrastructure and Transport of the Korean government.

Keywords

Anti-drought Capacity, SWAT Model, Extreme Drought Scenario, Multiple Regression Analysis, Boryeong Dam

Exploring the sensitivity of upland – floodplain – stream connectivity in SWAT+

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Abstract

Understanding the landscape hydrologic processes that produce the streamflow signal observed at the watershed outlet and how their connectivity varies spatially and temporally is important to explain the hydrologic response of a watershed to rainfall events and critical to guiding model development. SWAT+ is a new version of the Soil and Water Assessment Tool that was designed to improve the model's runoff routing capabilities while maintaining computational efficiency and ease of model use. In SWAT+, subbasins are divided into water areas and one or more landscape units, which contain the HRUs. The delineation of landscape units allows the user to distinguish between upland areas and floodplains, account for differences in their hydrologic characteristics, and route runoff and pollutants across the landscape. This is expected to improve the simulation of hydrologic connectivity in the model. We ran three scenarios representing different extents of connectivity between upland areas, floodplains, and streams in the Little River Experimental Watershed (Georgia, USA). While differences in streamflow were small, the relative importance of flow components and upland areas and floodplains as sources for surface runoff differed between the scenarios. Also, soil moisture in the floodplains was impacted. This has important implications for the simulation of water quality processes and the identification of critical source areas of pollution.

Keywords

connectivity, upland, floodplain, overland routing

Simulation of flooding of riparian wetlands using SWAT+

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Abstract

Riparian wetlands play a key role in the hydrological and nutrient regulation of river basins, but, wetlands are typically not properly represented in catchment model SWAT. One important reason is that wetlands are not interacting with the river in SWAT, hence flooding processes are not represented. We aim to tackle this problem with the new SWAT+ version.

SWAT+ is a new version of SWAT that allows for more flexibility to represent interconnectivity of different types of landscape elements while building SWAT models. SWAT+ has an object-oriented structure, with specific variable definitions and set of processes for each object. Objects can be Hydrological Landscape Units (HRU's), landscape units (cluster of HRU's), channels, groundwater bodies, reservoirs on rivers and reservoirs on landscape (eg. wetlands, ponds, potholes). Objects are linked to each other with high flexibility. The new SWAT+ version makes it easy to interconnect the floodplains and riparian wetlands with upland areas, groundwater resources and rivers.

In this study, we used this flexibility of SWAT+ by representing wetlands as 'reservoir-in-landscape' for the simulation of riverine overland flooding processes. We tested the developments with an application to the Little River Experimental Watershed (LREW), a 334 km2 large watershed located in the Upper Suwannee River Basin in Georgia. The LREW is characterized by broad floodplains and gently sloping uplands. Elevations range from 82 to 148 m m.s.l. The hydrologic behavior of the watershed is strongly affected by the storage capability of the channel alluvium.

The simulation results show that the inclusion of riparian wetland processes influences the hydrology of the landscape and the river. The riparian HRU's are typically wetter when interacting with wetland reservoirs resulting in higher runoff and seepage. The river flow is reduced for the higher peak values.

Keywords

SWAT+ , wetlands, flooding

Evaluation of the Soil and Water Assessment Tool Plus (SWAT+) for Evapotranspiration using Remote Sensing derived products for the Blue Nile Basin

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Abstract

Evapotranspiration (ET) has a large impact on water resources from a global to field scale and accounts for the largest flux in the hydrological cycle. As such, it is central in Water Productivity (WP) studies and the simulation and evaluation of this key variable is important in the reliable assessment of water productivity in a given study area. The new version of the Soil and Water Assessment Tool, SWAT+ separates ET into three components, Transpiration (T), Soil Evaporation (Es) and Canopy Evaporation (Ec). This separation is useful in designating the beneficial consumption in WP studies. However, there is need to evaluate ET simulations from SWAT+ before assessing WP. This study evaluates ET estimations simulated by SWAT+ for the Blue Nile Basin (BNB) with Remote Sensing (RS) derived ET products. A SWAT+ model for the BNB is set up. Calibration of the model is done by the newly developed soft calibration technique (Refer to presentation on Using Soft Data to Calibrate SWAT plus Models). For the calibration, the water balance from observations and RS derived data is used. The model results for ET are evaluated against ET products from GLEAM, ET MONITOR, WAPOR, MODIS and ALEXI. Evaluation is based on basin mean, statistics and spread. As SWAT+ is a semi-distributed model, the results are evaluated spatially using Hydrological Response Units (HRUs). The RS products are aggregated to the same HRU distribution and then evaluated in terms of spread. Expected results should indicate comparable results between SWAT+ simulated ET with RS derived ET for the basin mean, however a larger variation is likely when comparing the spread.

Keywords

SWAT+, Evapotranspiration, Remote Sensing, Water Productivity

Development of the transboundary large river watershed model for hydrology and water quality using modified SWAT setup procedure

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Abstract

The aim of the study is to assess a different approach of SWAT model setup with enhanced HRU definition procedure. The method uses a set of GIS process models based on ArcPy and customizable MATLAB scripts (hence, SWAT-LAB) to produce hydrological response units (HRUs), as defined in SWAT, from a combination of topographic, soil, landuse and administrative unit rasterized datasets. Moreover, the applied approach uses a combination of subbasin and hillslope discretization procedures, with the aim of creating a model setup, which is flexible, can be used for large scale models with substantial amount of subbasins and HRUs. The model input data set assembled, therefore, produce a physically more sound model setup than the subbasin delineation alone would have at an acceptably low increase of the number of land elements (subbasins and HRUs) within the watershed. This method was used to setup, run and calibrate a large-scale transboundary Nemunas River model, consisting of eleven sub-models and link them from upstream to downstream.

Nemunas River is the major contributory that discharges into the Curonian Lagoon, which is the largest European coastal lagoon. Nemunas River basin is shared by Belarus, Lithuania, Poland and the Russian Federation Kaliningrad Oblast. The river basin is under nutrient load pressure from different sources in the riparian countries, nevertheless, the burden of improving the water quality of the river falls mainly on Lithuania (as defined by the HELCOM Nutrient Reduction Scheme).

Currently, a good measure of confidence was achieved in several calibrated sub-models, representing upstream sub-watershed of the Nemunas River basin (48% of the total watershed area), which are situated outside the territory of Lithuania, for hydrology, sediments and nutrients (TN and TP), thus providing insight of the possible hydrology change and nutrient loads to Lithuania from neighboring countries. This ongoing research will further develop the modeling system and use it for assessing the hydrology, sediments and nutrients of the entire Nemunas River watershed under different land management and climate change scenarios, as well as assessing the best management practices for nutrient load reduction.

Keywords

Transboundary watershed, water quality, Nemunas River, Climate change

Comparative study of modelling sediment and nutrient loads of a small semi-arid catchment by the alternative models SWAT and SOURCE

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Abstract

Estimating sediment and nutrient loads derived from catchments is important for pollution control of downstream reservoirs. In this study, the well-established model SWAT and the newly developed model SOURCE have been applied to simulate the daily loads and concentrations of sediments (TSS) and nutrients (TN and TP) of a small (4,300 ha) mix land-uses catchment in South Australia. The land use of the catchment is dominated by forest (54%), residential (22%), and agriculture (25%). It drains into a drinking water reservoir which contributes water supply for the municipal region of the city of Adelaide. The two catchment models are process-based and semi-distributed. Inputs to SOURCE are generated by land-use based Functional Units (FUs), whilst FUs in SWAT are based on land use, soil and slope combinations. SWAT estimates the sediment yield rate (tones/day) by the Modified Universal Soil Loss Equation (MUSLE), and simulates the in-stream TN and TP loads (kg/day) by the Enhanced Stream Water Quality Model (QUAL2E) method. In contrast, SOURCE applies the Event Mean Concentration (EMC) and Dry Weather Concentration (DWC) methods to calculate total TSS, TN, and TP loads as a product of concentration and streamflow. EMC and DMC methods rely on fixed concentrations of EMC/DMC values of land uses, which are assumed to have similar hydrologic behaviour and generates similar rates of sediment and nutrient concentrations over time.

Streamflow at the outlet station of the catchment has been simulated satisfactorily by both calibrated models. Both models simulated well the loads of TSS, TN and TP. Even though the validation statistics of SOURCE looked slightly better, the sediment and nutrient concentrations simulated by SWAT matched better the observed data in terms of peak and baseline values. This finding may suggest limitations of SOURCE by using fixed EMC/DMC values over time. Also, since the SOURCE sediment and nutrient loads result from concentrations and streamflow only, they might be less meaningful spatially. This aspect might be meaningful when in a next step the two models SWAT and SOURCE will be tested for their suitability to run scenarios on future land uses and climate change for policy-making.

Keywords

SWAT; SOURCE; sediment; nutrient; semi-arid climate

Assessing the SWAT model sediment and carbon loads in a tropical watershed: the Red River study case (China and Vietnam)

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Abstract

River organic carbon fluxes to the oceans, estimated at 0.378 Pg yr^{-1} globally, are of prime importance for coastal biological processes. Tropical areas are identified to supply approximately half of the global river organic carbon flux which are influenced by land use changes and climate change, especially in Southeast Asia. This study investigated the 159 000 km^2 Red River watershed, which includes a part of China, Laos and Vietnam, and combines different land uses and is largely affected by human activities. The Soil and Water Assessment Tool (SWAT) was applied to simulate discharge, sediment and carbon fluxes at a monthly scale (from 2000 to 2010), using the Tropical Rainfall Measuring Mission (TRMM) data. Monthly data of discharge and sediment were used to calibrate the model at Son Tay station, the entrance of the delta part. Particulate Organic Carbon (POC) and Dissolved Organic Carbon (DOC) data from 2003 to 2004, and 2008 to 2010 were used for calibration based on new equations developed by Boithias et al. (2014) and Fabre et al. (submitted).

Nash-Sutcliffe Efficiency (NSE) of simulated monthly discharge and suspended sediment concentration at Son Tay station (outlet) were 0.79, 0.53 respectively, representing a good and a satisfactory simulation result respectively. The mean annual rainfall predicted by TRMM was 1507 mm, and was removed dominantly by evapotranspiration (41.5%), following by percolation (26.2%) and lateral flow (1.3%), and yielded 31.0% surface runoff. Simulated mean total water yield at Son Tay station was 748 mm, while the observed value during this period was 729 mm. For the simulation of sediment, the mean annual yield was 34.0 Mt yr^{-1}, and a specific load of 248.0 t km^{-2} y^{-1} (ranged from 145.2 to 396.2 t km^{-2} y^{-1}). The maximum loads (74.0%) are during the flood events (from July to September) and low loads (2.2%) from February to April are from the release of the largest dam called Hoa Binh, located at the downstream of the biggest tributary (Da river).

POC and DOC will be simulated in order to identify the contribution of each tributaries and of the main course and to quantify the annual mean annual fluxes to the sea.

Keywords

Red River, SWAT, TRMM, hydrology, sediment, dissolved organic carbon (DOC), particulate organic carbon (POC).

Land management mitigation scenarios for alleviating impacts on water resources. An application of the SWAT model, part of integrated assessment

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Abstract

This is at river basin level that European policy rules are adapted so as to alleviate the negative environmental impacts regarding water shortage and water quality and climate change.

And this is at this process-based level that biophysical effects can be assessed by SWAT in their spatial and temporal dimensions, in relation to land-use and land cover change (LULC) and climate change (CC) scenarios.

We developed the integrated modeling of agricultural scenarios (IMAS) method, so as to supply water managers with an integrated and collaborative approach to analyzing changes in land use, farming systems, and practices and to assess their effects on agricultural pressure and pesticide transfers to waters, in the context of climate change. The Generator of landuse version 2 (GenLU2) has been adapted, so as to be used within the SWAT management operation module. Two methods have been compared for the SWAT model calibration, the Parameter Estimation and Uncertainty Analysis (PEST) tool and the Sequential Uncertainty Fitting (SUFI2) algorithm.

As a result, the IMAS method has been developed and validated on two drinking water catchment areas affected by diffuse pollution and the methods and tools are transferred to local water managers.

Keywords

Environmental sustainability; Mitigation scenarios; GenLU; SWAT; SWATCUP; PEST; IMAS; Integrated assessment modeling; Water management; land-use/land-cover change

Evaluation of Aquatic Ecology Health Index Using Extreme Gradient Boosting Tree and SWAT

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Abstract

The purpose of this study is to evaluate the health evaluation indices such as Trophic Diatom Index (TDI), Benthic Macroinvertebrate Index (BMI) and Fish Assessment Index (FAI) using Soil and Water Assessment Tool (SWAT) model and machine learning. These indices represent comprehensive ecological health from hydrological, hydraulic factors, water quality and habitat environment. Also, it is the indicator measured by human observation. The directly measuring original method has the limitations like that it is difficult to observe all the points. So, we developed and evaluated new approach using the model and machine learning to overcome the original method. For the study area, Han River basin of South Korea, the SWAT was spatially calibrated (2008-2012) and validated (2013-2015) at seven locations (HSD, SYD, CJD, KCW, YJW, IPW, and PDD) using daily observed dam and diversion inflows, evapotranspiration, soil moisture, groundwater level and water quality data. The average NSE for the seven locations dam inflow was 0.59-0.88. The average R^2 for the sediment, Total Nitrogen (TN), and Total Phosphorus (TP) were 0.75, 0.70, and 0.73 for each calibration point in this study. Next, we implemented ensemble algorithm of machine learning algorithms like eXtreme Gradient Boosting Tree (XGBoost). The ensemble algorithm has the advantages that can reduce the bias of the under-fitting model and the variance of the overfitting model compare to the original algorithm. The XGBoost learned SWAT model results such as streamflow, water quality (NO_3, NH_4, PO_4, Total Nitrogen, and Total Phosphorus), water temperature, and river velocity and then verified TDI, FAI, and BMI. As a result, the XGBoost predicted the accuracy of 72 for TDI, 71 for BMI, and 75 % for FAI. The coupled method between machine learning and SWAT modeling could predict the health evaluation indices with more than 70 % accuracy in ungagged watersheds without direct measuring.

Acknowledgements

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Keywords

SWAT, Aquatic Health Index, Water Quality, Machine learning, Ensenble algorithm, Extreme gradient boosting tree

SWAT application in case of small reservoir watershed, Czech Republic

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Abstract

Outer Western Carpathians is area not suitable for large ground water storage because of predominant flysh bedrock. As consequence there is need of relatively bigger amount of water reservoirs for providing water resources. For case study small reservoir Olešná with watershed area 33 km^2 was chosen. Olešná reservoir serves as source of water for industrial purposes and for recreation as well. In recent years Olešná reservoir suffers by many issues such as drought, big sediment inflow and eutrophication caused by large nutrient inflow and remobilization of nutrients from sediments. Thus there is needed appropriate tool for nutrient input control from watershed. The successful control of non-point source pollution must target the availability of pollutants within the soil (source), as well as potential hydrological controls on their movement (transport). For sources identification data about soils and management with appropriate resolution were collected and for transport modelling SWAT model was developed. Model was calibrated with R package SWATpasteR enabling parallel SWAT execution and sensitivity analysis by STAR sampling to obtain acceptable prediction of water balance, sediment, nitrogen and phosphorus loadings according to measured data for period 2007-2011 and then validated for period 2012-2015. Obtained model is suitable for best management practises efficiency analysis or for potential climate change impact and so on.

Keywords

flysh, nutrients, sediments, small scale

Modelling the impacts of conservation practices on water quality at a reservoir catchment in southern Brazil

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Abstract

The lack of land use planning in combination with agricultural diffuse water pollution can contribute to increase runoff, soil and nutrients losses at the watershed level. Thus, this study aims to assess the effects of multiple conservation practices in reducing runoff, carbonaceous biological oxygen demand (CBOD), sediment, organic nitrogen (N) and organic phosphorus (P) losses at the Vacacai Mirim River Watershed, which drains into a drinking water reservoir responsible for supply approximately 30% of Santa Maria's city water demand. The watershed has been undergoing anthropogenic pressures and agricultural expansion in recent years, resulting in water quality deterioration. The modelling allowed to identify critical land use cover practices at both subbasin and HRU levels, showing that 10% of the watershed area is responsible for 90% of nitrate, 65% of N and 60% of sediment losses. Pasture and rice crops were identified as the most degrading land use practices. As a result, multiple conservation practices aiming to reduce agricultural diffuse water pollution and improve water quality were simulated using the SWAT model. Results showed that introducing such practices reduced runoff by 30%, CBOD by 64% and sediment, N and P losses by 48%, 43% and 38% respectively. Moreover, the introduction of conservation practices reduced sediment, N and P transported into the reservoir by 5%, 18% and 7% respectively. Despite the model uncertainties, the results could help decision makers in developing land use plans and agricultural conservation practices leading to water quality improvement.

Keywords

Water quality, Agricultural diffuse water pollution, SWAT model, Conservation practices, Vacacai Mirim River Watershed.

Effect of land cover change scenarios on the long-term runoff in the urban watershed, Akaki river, Ethiopia

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Abstract

Analysing the hydrologic response of a basin at multiple spatial and temporal scales can highlight vulnerable subbasins due to the extent of Land Cover (LC) change, and it is one of the essential steps in the water resources management. This paper examines the influence of land cover (LC) changes on the hydrological regimes in the Akaki watershed at the upland of Awash basin. The soil and water assessment tool (SWAT) model was used to evaluate the changes in streamflow under historical, future, and hypothetical LC change scenarios. The Land Change Modeler (LCM) model was used to predict the future LC scenario for the year 2045 based on the historical map of the year 1972, 2000 and 2014. In addition, the hypothetical scenarios, namely, urbanization, deforestation, and afforestation were generated to outline the probable impacts of land management on streamflow. The streamflow was calibrated for the three historical LC data which resulted in a good model predictive efficiency both for Little Akaki and Akaki gauging sites. The Pearson correlation matrix indicated that urban areas are the main contributor to the increase in surface runoff (r= 0.99), whereas, forest areas are highly attributed to total aquifer recharge (r = 0.90). The urbanization scenario is found to increase the peak runoff in larger magnitude, whereas, the afforestation scenario has significantly reduced the runoff mainly on wet seasons. Moreover, the estimated 100-year annual maximum daily flow increases by 52% under future year LC 2045 related to the baseline scenario. The change in past and future LC generally shows considerable alteration in the daily streamflow values than the monthly and annual values. The enduring LC change has a significant impact on runoff, and maintaining forest at the upland areas was found to minimize the peak runoff. Thus, the need for sustainable land use planning for improved watershed health.

Keywords

Land cover change, Surface runoff, Urbanization, SWAT model, Akaki river

Effect of land use and land cover dynamics on streamflow by using SWAT model in Chindwin Basin, Myanmar

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Abstract

Land cover in Myanmar is rapidly changing due to population dynamics, economic developments, and climate change. These changes might affect the hydrologic response and increase the vulnerability to natural disasters such as flooding and landslides. The Chindwin River, which is a major tributary of Ayeyarwady River, experiences severe floods almost every year. Anthropogenic changes to the landscape can negatively affect flood risk. However, these are not accounted for in most hydrological models as land cover maps are often static and outdated. Recently, new land cover maps with a higher temporal and spatial resolution have become available for the whole greater Mekong region.

This study we analyze the sensitivity of the SWAT model to the land use and land cover dynamics on streamflow in Chindwin River Basin. We explore the effects of higher resolution land cover data on stream flow. The simulation and sensitivity analysis uses current free available land use and land cover (LULC) dataset from UNEP in 2000, which is published on Myanmar Information Management Unit (MIMU) website. The comparison of streamflow results from LULC MIMU2000 with both Regional Land Cover Monitoring System (RLCMS), which has been developed by SERVIR-Mekong program lead by the Asian Disaster Preparedness Center (ADPC) and Globcover 2009 from European Space Agency (ESA). The RLCMS provides higher spatial and temporal resolution data for the Lower Mekong countries. Preliminary results of the sensitivity analysis, calibration and validation will be presented. The results provide valuable new insights into how LULC dynamics affect streamflow in Myanmar and will help improve flood Early Warning Systems and flood risk management strategies to save lives and livelihoods.

Keywords

Land use and land cover change, SWAT model, Sensitivity analysis, streamflow, floodrisk, Chindwin River basin, Myanmar

Modeling Streamflow Response to Changes in Land Use and Land Cover in the Upper Ruvu Watershed, Tanzania

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Abstract

Changes in land use and land cover (LULC) as a result of population increase have far reaching consequences on various landscapes and watersheds in Tanzania. LULC directly impacts hydrologic processes leading to changes in streamflow in watersheds affecting ecosystems functioning. In this study, the Soil Water Assessment Tool (SWAT) was used to assess the impacts of LULC change on streamflows in the Upper Ruvu watershed in Tanzania which has endured significant land alterations in the last three decades. Calibration and uncertainty analysis of the model was performed with the Calibration and Uncertainty Programs (SWAT-CUP) using the Sequential Uncertainty Fitting version 2 (SUFI-2). Daily simulation results from 1973 to 1977 were used for model calibration, and evaluation was based on the period from January 1978 to December 1982. Plausible model performance was achieved for simulated daily streamflow through comparison with measured streamflow from two gauging stations with the Nash-Sutcliffe Efficiency (NSE) of 0.69 and 0.84 during calibration and 0.68 and 0.67 during evaluation. Model performance was also evaluated using percent bias (PBIAS), ratio of root mean square error to the standard deviation of measured data (RSR), and the correlation coefficients (R^2) which indicated reasonable predictions. The calibrated model was used to investigate streamflow response to changes in LULC between 1991 and 2015. Long term average annual streamflow simulation between 1991 and 2000 showed a slight decrease (2%) from 47.41 m^3s^{-1} to 46.32 m^3s^{-1}. Average streamflow simulation between 1991 and 2015 showed a 13% decrease (from 47.41 m^3s^{-1} to 41.50 m^3s^{-1}). Average peak flows increased by 5% and 12% for 2000 and 2015, respectively compared to the baseline. Land alterations had significant impacts on surface runoff which increased by 5% in 2000 and by 75% in 2015, and on baseflow with declines of 43% by 2000 and 66% by 2015 from the baseline period (1991). Higher surface runoff was generated in the upstream sub-watersheds and areas in the uplands of the Uluguru Mountains. These results reveal the dominant role land use plays in the hydrology of the Upper Ruvu watershed. Primary areas of significant changes can be identified, providing quantitative information for decision makers and water managers.

Keywords

land use, land cover change, SWAT, streamflow, modeling, Upper Ruvu, watershed management, surface runoff

Investigating the Hydrologic Response to Changes in Land Use and Land Cover in the Kihansi River Watershed, Tanzania

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Abstract

As in most other developing countries particularly in the Sub-Saharan Africa, rural residents directly derive their livelihoods from nature. Population growth is on the rise and consequently inducing pressure on the natural resources and further shrinking the resource base by deforestation or forest conversion for expanding cultivated land pose negative effects on the environment. The Kihansi River which runs through the Kihansi Gorge is the source of the Lower Kihansi Hydropower Project, an important source of electrical power in Tanzania. The Gorge is home to the Kihansi Spray Toad (KST) which have been listed as 'Critically Endangered' species. However, the survival of the KSTs and the hydropower project is under serious threat from anthropogenic activities. This study was aimed at identifying the impacts of land use changes on streamflow in Kihansi using the Soil and Water Assessment Tool (SWAT). The study specifically focuses on understanding the changes of inflows into the reservoir due to modified catchment cover characteristics. To investigate the impacts of changes in land use and land cover on the hydrology of the Kihansi River, thee land use maps for 1990, 2004 and 2016 were classified and used in the model. The impacts of changing land use on the hydrology of the watershed were investigated for streamflow at the inflow gauging station (NC3) of the reservoir. Calibration and uncertainty analysis of the model was performed with the Calibration and Uncertainty Programs (SWAT-CUP) using the Sequential Uncertainty Fitting version 2 (SUFI-2). Daily simulation results from 1997 to 2003 were used for model calibration, and evaluation was based on the period from January 2005 to December 2007. Plausible model performance was achieved for simulated daily streamflow through comparison with measured streamflow from two gauging stations with the Nash-Sutcliffe Efficiency (NSE) of 0.63 and 0.5 at daily and monthly time steps, respectively. NSE at evaluation at the same station was found to be 0.7 and 0.62 at daily and monthly, respectively. Model performance was also evaluated using percent bias (PBIAS), ratio of root mean square error to the standard deviation of measured data (RSR), and the correlation coefficients (R^2) which indicated reasonable predictions. The calibrated model was used to investigate streamflow response to changes in LULC between 1990 and 2016. Results indicate on average streamflow decreased from 1990 to 2016 showing about 14% decrease in the average flow. Minimum flows were also less in 2016 (3.19 m^3/s) from 4.97 m^3/s in 1990. This indicates that the low flows have been affected by the changes in land uses between the two time periods. Other indices of low flows (Q70 and Q90) show the same pattern which show a decrease of up to 38% and 43% for Q70 and Q95, respectively. The results reveal the role played by the land use in influencing the hydrology of the Kihansi River Watershed.

Keywords

Kihansi River, Kihansi Spray Toads, SWAT, modeling, surface runoff, watershed management

Hydrological simulation of the Aliakmonas river under changing land cover conditions

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Abstract

Changes in land cover is a dynamic phenomenon that is mainly influenced both by human interventions and physical processes, which play a significant role in water resources management. The study area was the Aliakmonas river basin in Greece, which is one of the important agricultural and energy provinces of the country. In this study, satellite imagery from USGS Landsat was derived to create extended land cover datasets for three different years (1972, 1986, 2017), that in conjunction with the Corine Land Cover (CLC 1990, 2000, 2006 and 2012), constitutes a 45-years' time series aiming to assess long-term land cover changes. Subsequently, meteorological data and land cover time series were integrated in SWAT model. In this context, the model was split in two simulation periods, from 1970 to 1975 and from 1976 to 1990 in order to assess the impacts of Polyfito's reservoir, which was the most important land cover change. Afterwards, analyses took place in order to calibrate and validate the model. SUFI-2 optimization and uncertainty algorithm has been used to analyze the sensitivity of selected input parameters of the model, which is incorporated in SWAT-CUP application. Observed outflows from four stations were utilized for the calibration and validation stages from 1970 to 1990. The results of hydrological simulation are satisfactory while at the same time the land cover changes do not show significant alterations of the upstream areas.

Keywords

Remote sensing, land cover changes, hydrological modeling, SWAT, SWAT-CUP

Predicting dissolved reactive phosphorus in tile-drained catchments using a modified SWAT model

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Abstract

Phosphorus (P) is mainly leached by subsurface transport pathways in tile-drained landscapes. In this study, we modified the SWAT model (SWAT-P) by incorporating dissolved reactive phosphorus (DRP) losses from drainage water and the deep aquifer. SWAT-P was tested in a tile-drained lowland catchment using a multi-site calibration and validation approach. SWAT reached a good statistical performance regarding streamflow for all subbasins and a daily time step. As discharge was dominated by subsurface flow, we optimized DRP concentrations for the drainage water (SWAT-P), the shallow aquifer (SWAT, SWAT-P), and the deep aquifer (SWAT-P) and left other P-related parameters at their default settings, since they did not influence the model output. DRP losses were simulated at a monthly time step using SWAT and SWAT-P. The predictive power was weaker compared to streamflow for both SWAT and SWAT-P. Nevertheless, SWAT-P performed considerably better than SWAT. Additionally, optimized DRP concentrations were unrealistically high for SWAT, whereas optimized DRP concentrations reflected the prevailing conditions in the region using SWAT-P. The results indicated improved prediction accuracy for DRP losses into streams by using SWAT-P, as well as a roughly realistic estimation of DRP losses from drainage water. Further research is necessary to account for the temporal DRP concentration dynamics in drainage water. SWAT-P is ready to use after defining DRP concentrations in drainage water and the deep aquifer in the SWAT-P input files. In addition, the model output was extended in SWAT-P to visualize DRP losses from drainage water and from the deep aquifer.

Keywords

hydrological modeling; watershed; subsurface flow; DRP; SWAT; tile drainage

The assessment of future ecosystem services related to water availability and water quality in the Lithuanian coastal zone

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Abstract

Lithuanian coastal zone, as the coastal ecosystems around the world, provide essential goods and services to human societies. In the last decades anthropogenic pressure has caused serious threat to ecosystem integrity, functions and processes, potentially leading to habitat degradation, creation of uncertainty related to “novel ecosystems” and increased risk of collapse, with related loss of ecosystem services. Ecosystem degradation and loss of ecosystem services can seriously affect human well-being and climate processes at local and regional scale potentially amplifying the negative effects of global change. The need to address these challenges in the Lithuanian coastal environment calls both for the updated management strategies and qualified human resources capable of further adaptive upgrades. Therefore one of the objectives of “The future ecosystem services of the Lithuanian coastal zone: the global change perspective (EcoServe)” project is to outline how a ‘more adaptive’ management strategy for coastal areas could be facilitated on the basis of ecosystem services thinking. One of the projects’ activities is focused on developing a framework for the application of coastal, riverine, environmental and socio-economic modelling tools in an integrated way that can test indicators for ES through a sensitivity analysis. A detailed hydrological and diffuse pollution load model implemented in SWAT is applied for the study area watershed and will be coupled with the Curonian Lagoon Hydrodynamics and Ecological Simulator based on Shallow Hydrodynamics Finite Element Model (SHYFEM) to assess the state of ecosystem services related to water availability and water quality of the Minija River Watershed and the adjacent coastal area.

The studies are still ongoing, however the SWAT model is already set up by using an own-developed script-based modelling environment for a highly customized watershed configuration that addresses the specific needs of the project objective. The watershed delineation is performed by combining subbasin and hillslope discretization schemes, and the hydrological response units (HRUs) needed to run the SWAT model are defined by the aggregation of the topographic, landuse, soil and administrative unit features of the area. The created model will be used to assess different scenarios, such as climate change, anthropogenic pressures, land-use change and assessing Best Management Practices based on legislative background of the region.

This research is funded by the European Social Fund according to the activity ‘Improvement of researchers’ qualification by implementing world-class R&D projects’ of Measure No. 09.3.3-LMT-K-712.

Keywords

Ecosystem Services, SWAT modeling, Minija River, SHYFEM

Development of a universal calibration platform tool for watershed models using global optimization

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Abstract

Abstract: Calibration is an essential part of watershed models, and a universal calibration tool based on advanced genetic algorithms is needed. In this study, a universal, quick, free and effective platform was constructed for different watershed models by transferring the configuration files of models and incorporating the non-dominated sorted genetic algorithm-II (NSGA-II). This universal platform was tested in two real cases studies by using two commonly used models, including the Hydrological Simulation Program-FORTRAN (HSPF) and the Soil and Water Assessment (SWAT) tool. For the HSPF model, the results showed that the goodness-of-fit indicators, in terms of NSE and R^2, were 0.82, 0.83 and 0.66, 0.67 during the calibration and validation period, respectively. For the SWAT model, NSE ranged from 0.854 to 0.920 and from 0.737 to 0.912 during the calibration and validation period, respectively. These results indicate that this new universal platform provided good model calibrations for both models and that this new universal platform tool could be extended to other watershed models and catchments as an effective and robust method for model calibration.

Keywords

Watershed model; Universal calibration platform; NSGA-II; Global optimization; SWAT; HSPF

Natural hydrological responses due to climate variation based on short-time series of a headwater catchment in Taiwan

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Abstract

Due to the dramatic changes in the global climate, the surface hydrological environment has undergone tremendous changes that have affected the hydrological system of Taiwan. Considering the mountainous area is an important source of groundwater recharge in Taiwan, the study choose Acacia Hill as the research site. The site is with a short time series meteorological and hydrological data. We carried out correlation analysis of the raw data and extended data by statistical methods. SWAT (Soil Water Assessment Tool) model is adopted and conjunctively need MODFLOW to establish a regional hydrological and hydrogeology model. Model is calibrated and verified. Future meteorological data (i.e., rainfall and temperature) based on general circulation model's projections under Coupled Model Intercomprison Project Phase 5 experiment scenarios are used for prediction. The Taiwan Climate Change Projection and Information Platform Project (TCCIP) has adopted the CMIP5 experiment data and applied statistical downscaling technology to derive local rainfall and temperature estimations under climate change scenarios. In this study, we choose RCP8.5 and RCP4.5 which are defined in IPCC AR5 as scenario simulation. The results show that, under the scenario of intensified greenhouse gas emissions, the future rainfall increasingly concentrates in summer and autumn, and the intensity increases. The surface runoff has a quick response to the heavy precipitation. The greenhouse gas emission causes an increase in the average temperature, so evaporation volume increases apparently. The changes in the water cycle have led to a decreasing trend in the amount of groundwater recharge. Therefore, we propose strategies in water resources management and recommendations for downstream water use in the summer and autumn, as well as suggestions on upstream water retention.

Keywords

climate change, Acacia Hill, short time series, SWAT, SWAT-MODFLOW, GCM, prediction, CMIP5, TCCIP, RCP8.5, RCP4.5, IPCC AR5.

Estimation of hourly peak flow by combining SWAT simulation and Sangal's method in the Han River basin, Korea

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Abstract

Since the use of daily flow data rather than peak flow data may cause an underestimated information for flood risk management and hydraulic structure design. However, the results of SWAT simulation are daily based, the exact peak discharge is very difficult to estimate. To overcome this limitation, Sangal's method was used to estimate the instantaneous peak flow from the mean daily flow. Firstly, The overall procedure of SWAT modeling including model setup, calibration, validation were performed at the Paldang Dam, in the Han River basin from 1986 to 2015. Secondly, hourly peak flows were predicted from SWAT simulation using Sangal's method. Finally, the annual maximum series of simulated and observed hourly inflows at the Paldang Dam were compared and showed a good agreement (R^2 = 0.9). This developed approach will be able to improve the applicability of continuous simulation models for the analysis of flood management.

Acknowledgments: This research was supported by a grant from a Strategic Research Project (20180374-001) funded by the Korea Institute of Civil Engineering and Building Technology.

Keywords

SWAT, Sangal's method, peak flow, flood

Redefining water protection measures on an alluvial plain with shallow soil in Slovenia

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Abstract

With the implementation of EU Water Framework Directive, Slovenia is facing the challenge to meet the desired water protection thresholds. In some parts of the country the poor quality of drinking water resulted in closing of pumping stations. Intensive agriculture is considered the main polluter in our study area, the alluvial plain Krško polje in SE Slovenia. The study area shows very shallow soils, and currently the existing soil map of the plain is inadequate as input for integrated river basin modelling. In order to improve the soil map as model input, several soil profiles will be investigated to evaluate the soil conditions and distribution in our region. The improvement of the soil map in combination with compiling the most widespread land management practices will allow us to set-up a SWAT model for the area. In this presentation both the results of the soil survey and the setup of the SWAT model will be presented. Current water protection measures will also be evaluated and compared to actual farming practices in order to define improved scenarios for future simulations. Further work will concentrate on simulating the current processes and several promising alternative measures while comparing them with experimental results from nearby field trials. The final aim is to redefine water protection measures and help farmers implement improved practices to mitigate nitrate leaching in the area.

Keywords

Water protection, nitrate leaching, vulnerable areas, alluvial plains, shallow soil

Modelling management practices to reduce soil erosion in an agricultural watershed in Southern Europe

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Abstract

Soil erosion is the most widespread form of soil degradation in Europe. European policies (PAC 2014-2020) aimed at reducing soil erosion are increasingly directed to the application of Best Management Practices (BMPs). Indeed, European states and, consequently, regions have foreseen in their development policies many funds to counteract this problem. This work aimed at (i) quantifying sediment yield; (ii)identify critical areas where interventions to reduce soil erosion are needed; (iii) identify specific Best Management Practices (BMPs) for reducing erosion. The Soil and Water Assessment Tool (SWAT) was applied in a southern Europe watershed, the Carapelle (Puglia, Southern Italy) to quantify sediment yield at basin and subbasin scale and to simulate BMPs scenarios. The model was calibrated and validated, manually and with SWAT-CUP, both for runoff and sediment load at daily time scale for a five years period (2007-2011). Performances were evaluated using the Nash and Sutcliffe efficiency coefficient (NSE), the Percent Bias (PBIAS) and the coefficient of determination (R2). Statistics showed generally a satisfactory efficiency. In particular, for the runoff calibration NSE, R2 and PBIAS were 0.6, 0.6 and +10.8 respectively, while for validation were 0.5, 0.5 and -17.1. Regarding the sediment load, for the calibration, NSE, R2, and PBIAS were 0.5, 0.5 and -2.8, whilst, for the validation were 0.5, 0.5 and +5.1, respectively. On the basin scale, average annual sediment load was estimated to be 6.8 t ha^{-1} yr^{-1}. At subbasin scale a gradient of sediment yield was found, characterized by a large difference among the upper (from 7 to 13 t ha^{-1} yr^{-1}), central and lower parts (<1 t ha^{-1} yr^{-1}) of the basin. The results show that in the Carapelle the soil erosion is irreversible as soil losses are higher than the soil formation rate. To reduce economic and environmental impacts, specific measures are needed, especially in the upper part of the basin. Subsequently, based on the regional policies, three different scenarios of BMPs were implemented: (i) contour planting, (ii) no-tillage and (iii) reforestation. A threshold of sediment yield greater than 10 t ha^{-1} yr^{-1} was selected to discretize the target areas in which apply the BMPs. Among these, the first scenario was applied in areas with a slope < 20% (risk of the overturning of tractor), the second in areas devoted to the winter wheat production and the third in all the abandoned lands. The comparison of the different scenarios will be useful for the watershed management in order to select and prioritize the interventions in the Carapelle watershed.

Keywords

SWAT, soil erosion, contour farming, reforestation, no tillage

Surface runoff management modelling in dry valleys (Upper Normandy, France)

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Abstract

Soil erosion is one of the major environmental threats that is related to agricultural land use in France, especially in Normandy, where agricultural land occupies 65% of the territory. This region is located on a chalky plateau that is affected by the karst phenomena. One of the characteristics of this karst landscape is the low proportion of surface flows, where many basins do not have perennial streams but have dry valleys instead. Besides, this region is characterised by a continuous or sub-continuous loess cover, which remain significantly unsaturated soils. Additionally, Normandy is nationally recognised as being flood risk sensitive, and the land use and agricultural practices play an important role in this context. In dry valleys, the accumulation of surface runoff leads to the occurrence of muddy floods; this process is associated with the structural degradation of soil as a result of compaction by cropping practices. The muddy floods have several social and environmental impacts as well as cause damage to property and (public) infrastructure. These potential impacts and damages can be prevented and/or minimized through the Best Management Practices (BMP) and land use planning. This work aims to model soil erosion in the Étretat dry valley (Upper Normandy) under the following different land use and cropping practices scenarios: (i) existing conditions of land use; (ii) the land cover of 1992 (Common Agricultural Policy [CAP] adopted an environmental policy with the introduction of agri-environmental measures in 1992); (iii) introduction of punctual elements (e.g. ponds), (iv) introduction of linear elements (e.g. ditches, hedges, and embankments), and (v) reforestation. We use the Soil and Water Assessment Tool (SWAT) to model the surface runoff and analyse the different cropping practices in order to identify BMP. This study is part of the 'Risk and Flood Hazard of Coastline Cities' project (Risque et Aléa Inondation de Villes Côtières – RAIV Cot), which aims to determine the characteristics of the marine and continental floods hazards.

Keywords

surface runoff, land use, Best Management Practices, dry valleys, muddy floods

SWAT.CH21: A high resolution hydrological model for the water-energy-food-ecosystem nexus in Switzerland

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Abstract

Many hydrological models have been developed for Switzerland, especially tailored to its mountainous nature. However, no integrated model accounting for other factors like agriculture practices is available to date. There is also currently no integrated model to understand the effects of climate and land use changes on hydrologic ecosystem services and aquatic biodiversity at country scale.

In this project, we calibrate a high-resolution SWAT model comprising about 15'000 subbasins at 200-ha resolution on a monthly and daily time scale for the period 1980-2015. Parameters are calibrated for river flow, sediment, nutrient and dissolved oxygen concentration using SWAT-CUP Sufi-2 algorithm. Various eco-hydrological indicators are then calculated to predict aquatic species distribution in Swiss rivers and potential effects of future climate and land use changes. Among those indicators, flow regimes are derived and validated for the entire country.

In the second phase of the project, water demand from the main human activities (agriculture, drinking water, energy and industry) will be spatially and temporally assessed. Confronting human needs with aquatic ecosystem requirements and water availability, the main actors implicated in the water-energy-food-ecosystem nexus in Switzerland will be identified.

SWAT.CH21 is an ongoing project founded by the Swiss National Science Foundation (SNSF).

Keywords

ecosystems, water, energy, food, nexus, Switzerland

Assessment of the SWAT model for downscaled future climate scenarios for the Ivaí River Basin

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Abstract

Numerical models are useful tools to support the development of water resources management. Among these models, the ones from the Coupled Model Intercomparison Project Phase 5 (CMIP5) are widely used to assess the climate predictability under climate change scenarios by producing a range of responses in a multi-model context. To elect the best prediction model, over 21 CMIP5 possibilities, and assess future climate scenarios, this work runs historical precipitation data during the period of 1991 and 2005 in a calibrated SWAT model in a southern Brazilian watershed. The Ivaí River basin is one of the most economically productive areas of Paraná state, it is characterized by its agriculture potential and favorable slope to hydroelectric exploitation. The model was previously calibrated with observational data from the Agência Nacional das Águas (ANA; National Water Agency). Each 24 subbasins delineated had a virtual station positioned in the centroid to extract information of rainfall from CMIP5 readings. Runoff response for those input data was carried out to evaluate the resemblance with observational data. The most related CMIP5 scenario is the chosen one to simulate future climate scenarios. Since these models are used for the future climate scenarios projections – proposed by the 5th Report of Intergovernmental Panel on Climate Change (IPCC), and downscaled by the NEX-GDDP program (NASA Earth Exchange Global Daily Downscaled Projections) – these analysis can benefit policy makers and water resource manager to prepare for the challenges to come.

Keywords

Climate Change, Downscale, Runoff Response

Application of the SUPer system for the basins of Pontal and Brígida in the state of Pernambuco, Brazil

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Abstract

The SUPer (*Sistema de Unidades de Reposta Hidrológica para Pernambuco* in portuguese) is a Hydrological Response Units System that is being developed for the state of Pernambuco in Brazil. This system is very similar to the HUMUS (Hydrologic Unit Modeling for the United State), which was developed for the United States, and now is called HAWQS (Hydrologic and Water Quality System). The HAWQS is not anymore restricted for the United States. It is a would system. In Pernambuco, SUPer was launched in October, 2017, although the system has only two basins available, Pontal and Brígida, from a total of 13 basins. This study aims to use the SUPer to evaluate the surface runoff for the years of 1982, 2001, 2002, 2005, 2010, 2011 and 2016 for the Pontal and Brigida basins. The choice of years was due to the occurrence of El Niño and La Niña. Out hypothesis is that there is a strong influence of these phenomena on the surface runoff on these two basins. During the La Niña period, we observed that surface runoff was 50% higher when compared to the the El Niño years. The surface runoff peaks occurred between March and April due to the influence of the Intertropical Zone of Convergence. The influence of El Niño occurs acoording to the month of the year that El Niño is strongest. In general, during the years of El Niño, the basins produced the highest surface runoffs on April, and for the years of La Niña, it was on May.

Keywords

SUPer, HAWQS, semiarid, Brazil

Analysis of climate and soil occupation impacts on surface runoff of the Pontal watershed in Pernambuco, Brazil

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Abstract

The climate and soil occupation are well discussed in literature towards the impact that their changes may cause on surface runoff of basins. The objective of this study is to evaluate climate and land use impacts on surface runoff in the Pontal watershed, Brazil. For that, we used the SWAT model (Soil and Water Assessment Tools) calibrated by Miranda (2017), and simulated the impacts of anthropic actions and climate on surface runoff. The simulation period was set from 1987 to 2014, in which the land use map and rainfall varied through. The watershed is located in a semi-arid region, where many of the years present zero of streamflow in the fluviometric station. Considering those, we evaluated the impacts only for the years that we had some flow in station. We observed that in the year of 1997, there was a considerable increase in the surface runoff due to changes in land use. Also, we could see that the variation of precipitation was not altered during the last 30 years, evidencing that the increase in the surface runoff for 1997 was really due to anthropic actions on land. These changes in the surface area of the basin, especially this one located in a semi-arid, causes problems in the dynamics and management of water resources that are, by nature, scarce.

Keywords

management of water resources , Brazil, Semiarid, land use

Effects of water protection regime on nitrogen leaching in Dravsko polje, Slovenia

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Abstract

Leaching of excess nitrogen (N) from agricultural in to water bodies is a serious environmental problem which is addressed in the Nitrate Directive (91/767/EEC) and in the Water Framework Directive (2000/60/EC). The aim of this paper is with the help of the Soil and Water Assessment Tool (SWAT) model to show the influence of crop fertilisation rates on nitrogen leaching below the bottom of the soil profile in groundwater water protection areas. We prepared three 3 scenarios, the main difference being the preparation of the land use map, to which the cultivation technologies (ring, fertilization) were linked. In view of this, various redistribution of nitrogen fertilization across the aquifer area has been achieved. The three scenarios were: scenario 1 – Basic Farmers Report (BFR) with average management in the reported by farmers; scenario 2 – Precise Production Type (PPT) with spatially defined management, rotations and source of organic fertiliser; scenario 3 – Inverse Groundwater Concentration (IGC) with fertilisation rates estimated by inverse calculation from groundwater concentration of nitrate. The purpose of the scenarios was to show the spatial impact of water protection regime on groundwater quality from the nitrogen perspective. The nitrogen balance is strongly influenced by the soil properties. On shallower soils with a larger shares of sand and skeleton in the central part of the studied area, the balance surplus of N is as much as two times higher than the average for the entire study area. Thus, on the shallow soils in the central part of the area, according to scenario 1, between 91 and 100 kg N/ha is leached from agricultural land and according to scenario 3, with an inverse model, between 101 and 125 kg N/ha of agricultural land. On the periphery of the studied area, where there is a greater proportion of deeper and more silty clayey soils, the N loses are notably lower (up to 50 kg /ha). These differences arise as a result of the type of soil and their properties and the parent material. They have a notable effect on the binding of nutrients to the soil particles as well as on water retention and plant growth. Scenario 2 showed that the impact of crop production is not negligible, as the balance varies between individual land parcels.

Keywords

N leaching, SWAT, fertilisers, water proetection zone, groudwater

SWAT Simulated Hydrological Response to Climate Change Impacts in Upper Awash Sub-basin, Awash Basin, Ethiopia

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Abstract

Climate change alters regional hydrologic conditions and results in a variety of impacts on water resource systems. Such hydrologic changes will affect almost every aspect of human well-being. The economy of Ethiopia mainly depends on agriculture; and this in turn largely depends on available water resources. The aim of this study is to assess the impacts of climate change on surface water availability of Upper Awash River Basin by using Soil and Water Assessment Tool (SWAT) hydrological model and Regional Climate Model (RCM). Regional climate model (ECHAM5 with A1B emission scenario) and meteorological variables at local scale was applied for three time periods (2020s, 2050s and 2080s). Bias-correction methods have been developed to adjust RCM climate variables. The results showed that average annual maximum temperature changes for the basin were, for 2020s, 0.53°C; for 2050s, 1.18°C and for 2080s, 1.87°C, relatively to the historical climate (1980-2010). Average annual minimum temperature changes were 0.58°C, 0.82°C and 2.14°C in 2020s, 2050s and 2080s, respectively. The percentages of basin average annual rainfall, based on the ECHAM5 downscaling, were 2.40%, -2.14% and -10.11% for future periods of 2020s, 2050s and 2080s, respectively. The annual stream flow of Upper Awash Sub-Basin was reduced by 2.46% and 18.14% in 2050s and 2080s, respectively, while the stream flow increased in 2020s by 4.90% for A1B scenario. The simulated flow at 2050s and 2080s, with A1B scenario from RCM, showed reduction of runoff by 1.52% and 3.50% respectively in the Sub-Basin and it was directly related to the reduction in precipitation, while the annual runoff increases in 2020s by 8%. Model result showed that about 44.36% of annual rainfall contributes to stream flow as surface runoff. Generally, the results revealed that changes in climatic variables, such as reduction in rainfall and change in both minimum and maximum temperature would have a significant impact on the stream flow and surface runoff, causing a possible reduction on the total water availability in the Sub-Basin.

Keywords

A1B Emission Scenario; Climate Change; Regional Climate Model; SWAT Model; Surface Water

Monitoring and Modelling Set up to assess the impacts of Short rotation coppices on the site water balance

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Abstract

The Dendromass4Europe project (grant agreement 745874) aims at establishing sustainable, Short Rotation Coppice (SRC) based, regional cropping systems for agricultural dendromass production on marginal land. The water availability for and consumption of SRC plantations is a central factor when considering a sustainable system. In order to evaluate water supply and blue and green fluxes of the plantations, three monitoring sites have been established with continuously measuring soil water moisture, matrix potential, groundwater table, transpiration and throughfall. The sites have comparable conditions regarding soil characteristics, topography and climate, but differ in the connection to the groundwater table with close, medium and far to surface table depth. To support the site monitoring and extend the observations to other climatic situations, APEX will be used. Model calibration and key parameter finding was primarily conducted to simulate groundwater recharge and water use by the trees. Aim of the simulation is to simulate and assess the blue and green water fluxes from the SRC under different climatic conditions like wet extremely wet periods or long drought periods as well. In this poster the monitoring set up is illustrated, first measurements and applications of APEX are shown.

Keywords

APEX, Short Rotation Coppices, Blue and Green Water Fluxes

Future prospect of dam inflow based on user-centered multiple GCMs and downscaling techniques

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Abstract

In this study, the influence of user-centered climate change information on the reproducibility of dam inflow was analyzed. For this, uncertainty evaluation was conducted in the selection process of appropriate GCM and downscaling method for climate change impact assessment in the Chungju Dam watershed in Korea. The SWAT model was applied to estimate the dam inflow, and the model efficiency of 0.92 was obtained for the monthly data of the past 30 years. It was found that selection of downscaling method is more crucial to overall uncertainties rather than GCM selection. Also we analyzed the changes of the dam inflow by the RCP scenarios based on the selected climate information. The average inflow for the future period increased in all RCP scenarios, and it was predicted that the inflow volume will be higher in the RCP 8.5 scenario than in the RCP 4.5 scenario in all future periods.

Acknowledgement
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Keywords

SWAT, dam inflow, climate change, GCM, downscaling

Using SWAT watershed modeling to analyze the relationship between water balance components in Jeju Island of Korea

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Abstract

In Jeju Island, due to the intermittent flow characteristics of rivers, high permeability, and irregularities in the cross section of the river bed, there are many limitations in securing the accurate observation flow. According to the previous studies, it is very difficult to analyze the runoff and water balance depending on the observed data because it shows a very low discharge rate even in case of over 100 mm of heavy rainfall. Therefore, we analyzed the interrelationship between water balance factors such as precipitation, evapotranspiration, runoff, and groundwater recharge using long-term simulation data derived from the SWAT model. As a result of analyzing the major river basins and Jeju Island as a whole, the regression equation of the proportional relation between the runoff and the groundwater recharge was derived for the annual precipitation, while the inverse relation between the precipitation and the evapotranspiration rate was derived. In addition, the estimated data with the regression equation for the future period (2010-2099) and SWAT simulations (runoff, evapotranspiration, recharge) showed a good agreement, indicating that there is sufficient applicability for the future periods. Therefore, by using the regression equation derived from the relationship between water balance components, assuming that the modeling result guarantees sufficient reliability, it is possible to understand the annual runoff and groundwater recharge without complicated modeling.

Acknowledgments
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Keywords

SWAT, water balance, groundwater recharge, regression equation

Hydrological analysis of environmental changes in the reservoir using SWAT model

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Abstract

To analyze the environmental change of the upper stream of the reservoir, a SWAT model was applied to analyze the environmental change scenarios. The model was verified and calibrated from 2015 to 2016 with runoff data from the Songsan Observatory including the Suyang reservoir in Korea. Suyang reservoir was increased from 13.5m to 15.1m by enhancing embankment project and the total storage capacity increased from 7,472,000 ㎥ to 11,926,000 ㎥. As a result of the model verification, the model efficiency was confirmed to be 0.9 and the simulation model was simulated before the project (2001-2010) and after the project (2015-2016). Hydrological elements (precipitation, runoff, infiltration, evapotranspiration, infiltration, soil moisture, groundwater evaporation, groundwater recharge) were summarized. Simulation results before the enhancing embankment project were simulated as mean precipitation of 1549.8 ㎜, runoff of 907.9 ㎜, infiltration of 615.4 ㎜, evapotranspiration of 624.2 ㎜, infiltration of 241.1 ㎜, soil moisture of 355.7 ㎜ and groundwater recharge of 222.5 ㎜. The results of the simulation after the enhancing embankment project showed an extreme drought with an average precipitation of 1100.1 ㎜ and an runoff of 370.4 ㎜. The amount of groundwater recharge was 186.9 ㎜ in 2006 and 222.9 ㎜ in 2006, which showed similar rainfall before the project.

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Keywords

SWAT model, Reservoir, Hydrological, Dam

A conceptual framework to analyze ecosystem services with a physically based eco-hydrological model SWAT

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Abstract

The concept of ecosystem services (ES) has gained prominence in the last decade within many communities of researchers. There is also a great demand for reliable research tools and models when it comes to ES. Here we aim to present a conceptual framework to be used with the physically based Soil and Water Assessment Tool (SWAT), a well-known research model to assess the effects of management decisions on water, sediment, nutrient and pesticide yields on a basin/catchment scale. However, investigating the ES using the SWAT model has mostly been limited to water quantity and quality applications, although it has great potential in quantifying other ES as well. In this poster, a conceptual modeling approach is introduced from the scenarios to input parameters and model outputs as indicators for different ES. This study focusses both on water quantity and quality, as well as sediment yield, nutrient yields, flood hazard, water stress, carbon sequestration and biomass/crop production. For this, a correlation is hypothesized between a set of causal factors and ES. The causal factors determined by the scenarios are grouped into three categories: management factors, abiotic factors and biotic factors. Management factors are relatively easily changed by human decision making; such as water use volume, land cover etc. In contrast, abiotic factors are more difficult to change such as soil physical properties, temperature, precipitation, slope and others. The causal factors are modeled as input parameters and the model outputs are used as indicators for the different ES. For example, a change in irrigation efficiency or establishment of a flood control reservoir are causal management factors, these are then modeled through the input parameters in SWAT and outputs indicate the impact on water balance in the catchment, providing quantification for the ES of water regulation.

Keywords

Soil and Water Assessment Tool, SWAT, Ecosystem services, Quantification

Assessment of effects of agricultural reservoirs on the flow regime in a small rural catchment

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Abstract

Diversion of water from agricultural reservoirs to irrigation districts has changed the natural streamflow regimes. The objective of this study is to analyze the effects of agricultural reservoirs on water balance and streamflow regimes for a small rural catchment. The SWAT model was modified to simulate irrigation return flow as well as water transfer from a reservoir to paddy fields. The simulated results showed that more than 30% reduction of streamflow in the low flow season was found downstream of the agricultural reservoir, but the flow reduction was significantly reduced as the distance from the reservoir increases due to the return flow. The water supplied to the paddy also greatly increased surface flow and evapotranspiration during the irrigation period.

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Keywords

agricultural reservoirs, natural streamflow, SWAT, return flow

Impacts of water withdrawal and release on streamflow in the Anseongcheon watershed, Korea

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Abstract

Water withdrawal and release have changed the natural flow regimes. Understanding their impacts on streamflow is important for effective water resources planning and management. A SWAT model has been set up using digital elevation model, land cover map, soil class map, weather data, water use data and wastewater treatment release data of the Anseongcheon watershed in South Korea. The model is first calibrated and validated by using streamflow data observed at two gauging stations over the period 2012-2015. Long-term continuous natural flow series are then reconstructed during 2001–2015 in the absence of water withdrawals and wastewater discharge. From the comparison between altered and natural low flow regimes, a large amount of treated wastewater discharge highly contributes to increases in instream flow and water availability, even though water withdrawals have caused a significant reduction in low flow.

Acknowledgments: This research was supported by a grant from a Strategic Research Project (20180101-001) funded by the Korea Institute of Civil Engineering and Building Technology.

Keywords

water withdrawal and release, natural flow regimes, SWAT

Assessment of flood alterations by dam using SWAT simulation in the Han River basin, Korea

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Abstract

Instantaneous peak flows is often required to estimate or assess the design flood for hydraulic structures, such as dams and levees, because there may be significant streamflow variations within hours. Also, dams have major impacts on river hydrology, primarily through changes in the timing, magnitude, and frequency of flows. In this study, SWAT was used to evaluate the effects of flood regulation by upstream Soyanggang and Chungju multipurpose dams on downstream flood at the Paldang Dam, in the Han River basin of South Korea, for the period 1986–2015. The daily flow peaks simulated by SWAT were converted to hourly flow peaks using Sangal's method. The effects of dams on the peak inflows and flood frequencies at the Paldang Dam were determined by simulating the annual peak flows with and without dams. The developed approach allowed for better understanding of flood frequency, which was influenced by dam regulation on a relatively large watershed scale.

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Keywords

SWAT, sangal's method, flood frequency, flood regulation

Evaluation of the modified SWAT with variable time of concentration

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Abstract

The objective of this study is to improve the SWAT model performance by incorporating the variable time of concentration method in which overland flow time of concentration is calculated using the amount of surface runoff generated in the subbasin. The modified SWAT was applied to the Chungju Dam watershed, Korea and the model performance was evaluated by comparing the simulated and the measured peak flows. The results showed that the modified SWAT with variable time of concentration can reproduce more accurate hydrographs than the original SWAT. In particular, the number of peaks increased by more than 5% in many flood years. This study also emphasized the combined effects of the variable time of concentration method and other methods such as the temporally weighted average runoff curve number method, the excessive infiltration estimation method with variable travel time that were developed for better simulation of surface runoff response.

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Keywords

SWAT, peak flows, variable time of concentration

Uncertainty analysis of SWAT model based on land use change in Xiangxi River Watershed, China

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Abstract

Nowadays, models have been widely used to simulate the NPS pollution. The spatial distribution and temporal change of the input data of these model have great effects on the model results. In most of the studies, the spatial variation of the input data was considered, while the temporal change of these data were lack of consideration, particularly the land use data. In our study, the impacts of different land use input conditions on the model performance were studied based on the SWAT model in Xiangxi river watershed. The simulation period was from 2000 to 2015. Four years of land use data within the simulation period were obtained (2000, 2005, 2010 and 2015). Seven SWAT projects were built based on seven different land use input conditions. Among these seven land use input conditions, four of them were static land use input (JY2000, JY2005, JY2010 and JY2015), which meant only one year of land use data was used. Another three were dynamic land use input (CE5Y, CE10Y and CE15Y), which meant land use data was changed every 5 years, 10 years and 15 years. The calibrations of the seven SWAT projects were carried out independently to reach the best performance for each SWAT project. Then the calibration results of the seven SWAT projects were compared to find out the best one with the best model performance. The impacts of the land use input conditions on the model outputs were also analyzed.

The results showed that land use pattern in the study area changed significantly during the simulation period due to climate change and human activities, leading to inconsistencies between different land use patterns. The calibrated results indicated that dynamic land use input conditions could apparently improve the simulation accuracy of total nitrogen (TN) and total phosphorus (TP). CE5Y condition had the best calibrated result. However, for flow simulation, the land use input conditions had no apparent effect on the model calibration and validation results. The deviation analysis of the model outputs indicated that monthly outputs were more affected by the land use input conditions than annual outputs and that deviations in wet seasons were larger than those in normal and dry seasons.

Acknowledgement

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Keywords

non-point source pollution; SWAT model; climate change and human activity; static and dynamic land use input; uncertainty analysis

Impacts of Land-Use and Climate Changes on Hydrologic Processes in the Piracicaba River Basin, Brazil

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Abstract

Climate and land use changes are two factors affecting the hydrology of watersheds. The greatest effect of climate change is probably the change in the hydrological cycle, thus water availability for human consumption, industry, and power generation. While the change in land use can cause changes in the hydrological components of the basin, such as evapotranspiration, runoff and groundwater recharge. From these projections, it is necessary to understand the processes involved in climate change and land use and its impact on water systems. In this context, the objective of this study is to simulate climate change scenarios combined with the change of land use and to analyze the impacts on the hydrology of the basin. Two periods were selected based on the preliminary result of detection of the abrupt change point of the annual flow series. The first period selected prior to the occurrence of the point of the change was from 1985 to 2000. The other period after the point of the change was 2001 to 2015. Land use maps of the years 1990 and 2010 were used to represent the two periods. Preliminary results showed a good performance of the SWAT model. The NS (Nash-Sutcliffe coefficient) was 0.88 in calibration for both periods. In the validation, the NS was 0.92 and 0.94 for the first and second periods respectively.

Keywords

Climate change, hydrology, land use change, watersheds

Effect on Water Quantity and Quality Under Land Use Scenarios in South Central Chile

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Abstract

The growing production of exotic plantations in Chile has sparked an interest in land use change and associated environmental impacts that may occur due to the increased demand for raw materials. In the present study, the Soil and Water Assessment Tool (SWAT) was used to evaluate the impacts over water quantity and quality, under different land use scenarios such as native forest, agricultural and exotic plantations, in two sub-basins of the Vergara River in South Center Zone of Chile. Water quantity indicators include daily and monthly flows, while water quality indicators include the increase in total nitrogen (TN) and total phosphorus (TP) loads compared to baseline conditions. The main results showed that SWAT model is an useful and reliable tool for modeling hydrological flows mainly at monthly level, where the statistical parameters for the calibration stage were EF = 0.91, R^2 = 0.89, PBIAS = 0.57 for Mininco basin and EF = 0.69, R^2 = 0.76, PBIAS = -17.4 for Malleco basin. Regarding export of nutrients within the sub-basins, it is verified that the highest exported TN load occurs during periods of surface runoff and on land with agricultural activity. Results are related to the mobility of these elements in the environment, which improves its transport and the deposit in the soil, product of the fertilization in the crops. On the other hand, exported loads of TP are mostly obtained in soils with exotic plantations, a phenomenon attributed to land erosion resulting from the exploitation of trees for commercialization, erosion generated by rainfalls and the geographical location of the activities in areas with sudden slopes and hills.

Nutrient modelling and land use assessment using the Soil and Water Assessment Tool (SWAT), case study: Coca River Basin

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Abstract

Globally, livestock activities are in 80% of all agricultural lands, which represents 26% of the land surface that lacks water (FAO, 2012). Therefore, the integration of tools that include hydrological aspects and nutrient dynamics have become essential for a more comprehensive assessment of land use change scenarios. The main objective of this study is to evaluate the nitrogen and phosphorus dynamics in the Coca River Basin and how they vary for two different land use change scenarios using the SWAT model. The first scenario called degradation, where no good practices are applied, and deforestation increases due to livestock activities. The second one called best management practices, where activities are improved e.g. from livestock to forest pasture activities and from degradation zones to forest restoration areas that could be preserved. The main input data such as climatic time series until 2030, type of management using beef manure and application frequency were taken from The Economics of Ecosystems and Biodiversity (TEEB) – Coca River Basin project. The two land use change scenarios were simulated using the Terrset software and the Land Change Modeler module. The calibration results show an NSE = 0.74, PBIAS = -5.11 and RSR = 0.51. The sensitivity analysis to assess the nutrient dynamic parameters showed that the amount of beef manure and the frequency of application were the most sensitive. Our results for nitrates (0.4 mg/L) and for phosphates (0.006 mg/L) are comparable with those obtained in the field by SENAGUA (National Secretary of Water). The difference between the simulated annual average and the observed point data ranges around 0.1 mg/L. The scenario simulations showed an increase of 96% for nitrate concentrations and 200% for phosphorus concentrations in the degradation scenario (increase of livestock areas). In conclusion, the degradation scenarios in the Coca River basin will increase the nutrient pollution in the rivers up to 90% compared to the scenarios where best management practices are applied.

Keywords

nutrients, hydrological modelling, nitrogen, phosphorus, Coca River, SWAT.

Water balance of the Northern Axis Basins of the São Francisco River Transposition area using the SWAT model

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Abstract

The nature and intensity of the problems caused by the droughts in the Brazilian Northeast (NEB) are the fruit of the combination between the absence or irregularity of rainfall, with the lack of management of water resources. In recent years, the integration of the Northeastern Semiarid Basins with the São Francisco Basin (one of the most important Brazilian Basins) has resulted in a new hydrological dynamics and the contribution of sediments that reach the catchment basins. With that in mind, the objective of this work is to make the water balance, using the SWAT model of three sub-basins belonging to the state of Pernambuco, included in the north axis of the São Francisco River Transposition: Brígida, Terra Nova and Pajeú. Data from 1961 to 2016 was used in this study, covering a total of 56 years, and 5 years for the model's warm up. The water balance modeling showed results for the three sub-basins studied that took into account the total amount of rainfall precipitated during the simulation time (PREC), the real evapotranspiration of the basin (ET), and the volume of water passing through the channels of the drainage network to the water yield (WY). For the quantification of water production, the contributions of surface runoff (SURQ), sub-surface flow (LAQT) and baseflow (water returning from the shallow aquifer into the GWQ channel) are included in this process, subtracting from the calculation the losses related to the water stored or percolated in the soil at the HRU's (SW), that becomes groundwater recharge (PERCO). The work is expected to serve as a basis of comparative studies between the natural dynamics of the basins that are part the Northern Axis of the transposition and the scenario of modifications caused by the transposition of the waters of the São Francisco Basin to the three sub-basins studied. The data worked will be able to supply SUPer (*Sistema de Unidades de Resposta Hidrológica para Pernambuco,* in portuguese), developed in the State of Pernambuco, which is a similar system to HAWQS (Hydrologic and Water Quality System), which is used for analysis of the resulting impacts of a transposition work of basins (such as the São Francisco River) for the hydrological dynamics of basins of semiarid regions.

Keywords

Transposition; Semiarid Basins; SUPer

SWAT2lake: A QGIS tool to tailor SWAT watershed delineations to waterbodies

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Abstract

The SWAT (Soil and Water Assessment Tool) model is often coupled with lake or reservoir models to provide inputs to these and to simulate a variety of scenarios. However, outlets for watershed delineation in SWAT are required to be in the river network, which may yield modellers to make choices leading to imprecise results (e.g. targeting only the major streams flowing into the waterbody or including the waterbody area within the delineated watershed). The impact of these choices when modelling the inputs to a waterbody can be highly relevant. To remedy this imprecise delineation of watershed to lakes and reservoirs, we have developed SWAT2lake. Here we present it, together with a practical application for a Danish lake as illustration. SWAT2lake, available through wet.au.dk, is a plugin for the QGIS software that works in parallel with QSWAT.

Keywords

Lake; QGIS plugin; Reservoir; SWAT; SWAT2lake; waterbody; watershed delineation

Evaluation of TRMM Products and Their Use in Hydrological Modelling Over Pirapama River Basin, Pernambuco, Brazil

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Abstract

Satellite precipitation products are unique sources of rainfall measurement that overcome data failures and temporal limitations, but their precision differs in specific watersheds and climate zones. The hydrological models have searched to predict in a realistic way the hydrological processes that occur in hydrographic basins, having precipitation as their main input data. In view of this, the present study aims to analyze TRMM precipitation data (3B42) in comparison with rainfall data in the estimation of flows with the SWAT model, in the Pirapama River basin, located in Northeastern Brazil. To verify the homogeneity of the observed and estimated rainfall data, a consistency analysis was performed applying the double mass method and analyzed the historical series (2000-2010). For the calibration monthly flow data from 2000 to 2006 and for validation monthly flow data from 2007 to 2010 were used. The results of the consistency analysis showed that the rainfall data from the TRMM are proportional to the average values of the stations of the region (measured rainfall). However, the results of the historical analysis between the precipitation series revealed that the TRMM data tended to underestimate precipitation in the region, with Pbias values of -21.97% (calibration) and -7.56% (validation). For the discharge, the results obtained with measured rainfall data presented an excellent calibration, with a R^2 = 0.83, NS = 0.82 and Pbias = -9.9%. The calibration of the flow obtained with rain data estimated by the TRMM presented little adjustment in relation to the initial simulation and in comparison with the calibration with measured rainfall data, although it presented good statistical results, except for the value of Pbias (R^2 = 0.79, NS = 0.72 and Pbias = 29.6). In the validation process, the data presented a good adjustment in relation to the observed flow, both with measured (R^2 = 0.72, NS = 0.78 and Pbias = -12.55%) and estimated satellite data (R^2 = 0.87, NS = 0.63 and Pbias = 18.60%), with better adjustments of the peak and base discharge to the estimated flow with measured rainfall data. Thus, it is concluded that the rainfall estimates obtained through the TRMM represented well the rainfall and discharge behavior in the study area and produced relatively satisfactory results, but presented less accurate estimates in relation to the discharge forecasts obtained by the measured data of rain.

Keywords

Keywords: data scarcity, discharge, precipitation, SWAT, TRMM

Identification of Critical Erosion Watersheds for Control Management Using the SWAT Model for Pirapama River Basin, Brazil

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Abstract

In this study, identification of critical watersheds prone to soil erosion has been performed by using a hydrological model in data scarce Pirapama River basin, located in Pernambuco state of Northeastern Brazil. Runoff-erosion models are useful tools to help in the understanding of processes that occur in basin scale, allowing a more realistic forecast of the transformation of rainfall in runoff and sediment yield, or in other components of the water cycle. Model was calibrated for streamflow gauge Destilaria Inexport (located in sub-basin 19) for the period from 2000 to 2006. In this study, geospatial data from the region were used, such as the digital elevation model, soil types map and soil use and occupation, daily precipitation and flow data, and meteorological variables acquired at the Global Weather Data for SWAT website. The achieved R^2 and Nash-Sutcliffe values of predicted monthly runoff were 0.84 and 0.81, respectively, for the streamflow gauge during calibration period. The estimated average sediment yield in the Pirapama River basin varied from 2.94 to 14.80 ton/ha/year, with an annual average for the period 2000 to 2006 of 6.36 ton/ha. The relationship between monthly precipitation and sediment yields showed low correlation, with R^2 of 0.50. The highest values of sediment yield are located in sub-basins 6 (14.39 ton/ha/year), 7 (12.79 tons/ha/ year), 10 (13.45 tons/ ha/year), 14 (51.56 ton/ha/year), 18 (13.10 ton/ha/year) and 24 (15.63 ton/ha/year). Subbasin 14 is located in the eastern part of the basin (in the outlet) and the others are more concentrated in the west. The spatial distribution of the results showed higher values of sediment production in the sub-basins that have a higher concentration of surface runoff and high values of precipitation, with the exception of sub-basin 14, which presented higher sediment yield and lower runoff value between these sub-basins, possibly because it is less extensive and because its location. Subdacia 21, despite having a surface runoff high value, showed a reasonable sediment yield, ranging from 5.27 to 9.76 tons/ha/year. The areas of these sub-basins have a predominant coverage of sugarcane, except sub-basin 14 that is covered by grass vegetation and dense, with the presence of indiscriminate mangrove soils. The methodology allowed identification of the most susceptible areas to soil erosion, constituting an important predictive tool for soil and environmental management in the watershed, therefore, this approach can be applied to other areas for simple, reliable identification of critical areas of soil erosion in watersheds.

Keywords

Sediment yield, SWAT model, scarce data.

Effects of Scenarios of Land Use and Cover on Streamflow and Sediment Yield: A Case Study of Peixe River Basin, Brazil

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Abstract

The objective of this work was to simulate different scenarios of land use in the Peixe river basin, located in semi-arid of Paraíba State, Brazil, and to analyze the effects of changes in stream flow and sediment yield, making comparisons with the present land use classification. In this study, the Soil and Water Assessment Tool (SWAT) was used to perform the hydrological simulation. For this purpose, daily data of temperature, humidity and wind speed of the São Gonçalo meteorological station and precipitation data from 2002-2014 were used. In addition, maps of land use and occupation, soil types and digital elevation model were used. The calibration period was from 2005 to 2007 and the validation period from 2009 to 2014 for Aparecida streamflow gauge. The calibration period was from 2005 to 2008 and the validation period from 2009 to 2013 for Antenor Navarro streamflow gauge. The results showed that the observed and calculated flows were 13.01 m^3/s and 2.82 m^3/s, respectively. The calibration performance values were considered very good (R^2 = 0.90 and NS = 0.87), showing a good fit between the observed and estimated data, while for the validation the results of R^2 and NS were 0.75 and 0.73, respectively. Agriculture produced the highest sediment loads, approximately 3 times larger than the present scenario. It was observed that changes in land use can impact the regime and water availability in the basin.

Keywords

SWAT model, land use change, sediment yield.

Assessment of Water Availability and Uses in Kilombero Basin, Tanzania

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Abstract

Water availability is threatened by the expansion of agricultural activities and rapid population growth. This study assesses the available water resources in a data scarce, Kilombero Basin and associated uses. Specifically, the study quantifies water availability and assessed the consumption patterns while embarking on water allocation scenarios.

SWAT model was used in this study to model the basin hydrology while Water Evaluation and Planning model (WEAP) were used to assess water allocation scenarios. Streamflow data were reconstructed and extended was to obtain the required time series data necessary for model set-up. Use was made of global datasets to supplement the data scarcity issues. A Land use from Global Land Cover Facility (GLCF) and soil database from World Soil Database was used. The basin topography (DEM) was derived from the Shuttle Radar Topographic Mission (SRTM) with a 90m resolution. Rainfall data were collected from the Rufiji Basin Water Office, Kilombero Teak Company, ARI-Katrin Ifakara and Tanzania Meteorological Agency, TMA. SWAT model was successfully calibrated with the Nash efficiency of 0.64 and 0.75 coefficient of determination.

The study identified five groups of water users as domestic, industrial, environmental, livestock and agricultural users. The current water available in the basin was estimated to be 1314.14 MCM (Million cubic meters) in which total demand was 573.7 MCM. Agriculture, domestic, Livestock, Environment and industrial water demands comprise 84.53%, 3.06%, 0.61%, and 11.80%respectively of the total water demand. Further, the study shows that the expansion of irrigation schemes and population growth by 2035 will increase the average annual demand by 81.85% and 41.54 % respectively. The study findings generally point out to the fact that, the currently available water resources suffice the existing water uses in the basin but will not be able to cater for future basin plans like irrigation expansion and the expected population growth.

Keywords

Water allocation scenarios, water availability, water demand, water uses

Flood Routing in the Soil and Water Assessment Tool: A Review

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Abstract

The Soil and Water Assessment Tool (SWAT) is one of the most widely used hydrologic models. SWAT has been undergoing constant changes since its development. However, compartment review and testing of SWAT are very limited, especially the flood routing function. In this study, the daily flood routing subroutines of SWAT were reviewed and tested. Results show that there are several issues in the flood routing subroutines of SWAT. For example, in the daily Muskingum routing subroutine of SWAT revisions 664 and 528, the amount of daily evaporation was mistakenly taken as sub-daily evaporation. In semi-arid regions, up to about 91% of the generated runoff from hydrologic response units are lost due to this issue. In the daily variable storage routing subroutine of SWAT revision 664, inflow is simply assigned as outflow. In addition, SWAT estimates the parameters in the Muskingum method and the storage coefficient in the variable storage method differently compared to the Muskingum and variable storage coefficient explained in the literature. This raises questions about the validity of the Muskingum and variable storage used in SWAT. The findings of this study are useful for SWAT users and SWAT developers in their future studies.

Keywords

SWAT, Muskingum, variable storage coefficient, review

The concurrent effects on land use conversions and local geomorphological features on Nitrate level to the regulation of fresh water quality.

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Abstract

Water and nutrients are building blocks of life and limiting in crop growth, so providing enough of these removes bottlenecks for the plant growth. Exercising excessive fertilization to meetup the ever-growing global food demands in the modern agricultural system is the main reasons behind fresh water quality pollution through runoff after rain events and leaching of nutrients from soils primarily. Different forms of agricultural lands require different fertilization methods and responses differently along with slopes and soils types resulting different contributions to water and nutrient cycles within a watershed. This study attempts to determines the effect of land use conversions from pasture to arable land along with geomorphological features in two distinct watersheds from Germany on nutrient flows to freshwater sources with Soil and Water Assessment Tools (SWAT). One watershed has moderate flat land with high land conversion rates; and other watershed has more variable slope with low land conversion rate. The models from both watersheds was calibrate and validate against discharge and nitrate data and compared with two different scenarios for 2004-2006 and 2013-2015. The models from both watersheds showed an increase on Nitrate (NO_3) level of 12-15% in river stream in higher slope areas and Nitrate concentration approximately 0.6 mg/L in groundwater sources through infiltration in silt-loamy or clay-sandy soils. Both watersheds showed that the concurrent effect on land use conversions and changing fertilizer managements with site specific features of slope and soil types can either enhance or buffer the nutrient pollution effect upon water sources. This information will help to take right decision to the policy makers for land conversion with appropriate slope and soil types for the regulation of fresh water quality.

Keywords

SWAT, Nitrate, Slope, Soil types, land conversion

Assessment of climate change impact on water temperature of rivers in Poland

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Abstract

Despite the increase of interest in researching water temperature, knowledge about the spatial and temporal variability of the relationship between air and water temperature is still poorly understood, in particular on a large scale. This research focuses on developing a method for a systematic analysis of the dynamic relationship between water and air temperature and investigates the spatial sensitivity of rivers in terms of changes in water temperature. The main goal of this research was to identify a regression model for calculating the temperature of water in rivers in Poland and its application to assess the impact of climate change on habitats. Data on historical water temperature measurements was obtained from the Institute of Meteorology and Water Management. The relationship between water and air temperature was examined and was related to the projections of changes in air temperature in the future to study the impact of climate change on the river water temperature. It was carried out with the use of built models. The projections include two scenarios of changes in greenhouse gas concentrations in the atmosphere prepared by the Intergovernmental Panel on Climate Change (IPCC): an intermediate scenario - RCP4.5 and containing no greenhouse gas reductions - RCP8.5. For each scenario, air temperature projections up to year 2100 were obtained from the public repository: CHASE-PL Forcing Data: Gridded Daily Precipitation & Temperature Dataset 5 km (CPLFD-GDPT5). Hydrological modelling with the use of SWAT was driven by a set of nine EURO-CORDEX Regional Climate Models in two time horizons of the near (2021-2050) and far (2071-2100) future. The baseline period was 1971-2000. On the basis of the above data, changes in water temperature of rivers in the conditions of climate change were projected. Calibration and verification was performed. An assessment of the consequences of these changes for habitats dependent on rivers was carried out. This work feeds into existing challenges in the field of water temperature research concerning a better understanding of thermal heterogeneity in various spatial and temporal scales.

Keywords

regression, model, rivers

The Desna river daily multi-site streamflow modeling using SWAT with detail snowmelt adjustment

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Abstract

The Ukrainian Government started the process of EU water Directives implementation aimed at developing of the River Basin Management Plan for 9 main river catchments. The program SWAT was tested to simulate the water flow of the large plain Desna river (89 000 km^2) with predominant snow supply.
This study using SWAT model provides significant insight into calibration process of a plain snowmelt-driven watershed with a daily time step. The calibration was based on snow cover depth (13 stations), river discharge (12 stations) along with soft data constraints on surface flow and evapotranspiration. The calibration flowchart along with detailed source data description is proposed to aid with streamflow simulation for the snowmelt-driven watersheds and fill the existing gap of distributed hydrological modeling in the region. The date of snow cover loss was identified as a key factor of successful calibration because of its linkage with the peak discharge timing of spring flood hydrograph. This date may not be captured by regression-based calibration approach, therefore, the manual visual inspection of snow cover time-series plots is more reliable. Furthermore, the forest snow cover dynamics differs from uncovered lands which is reflected in the subbasin-scale snow pack temperature lag factor (TIMP) optimization during calibration.
The program SUFI-2 in SWAT-CUP package was used for calibration/validation and uncertainty analysis. The statistics (R^2, NSE, PBIAS) showed good agreement (NS > 0.7, R^2 > 0.75, PBIAS < ±10%) for a major part of the gauges and satisfactory almost for all (NS > 0.5, R^2 > 0.6, PBIAS < ±15%), except two linked upstream outlets.
The SWAT model for the Desna watershed could be used to calculate cross-boundary water transfers, flood risk assessment, further research on water resources, the impacts of climate change, and water quality issues. The study provides a detail source data information that will facilitate data collection and assembling for the transboundary Ukrainian-Russian watershed-scale models.

Keywords

SWAT, streamflow, snowmelt, calibration

Modeling the impact of climate change on water resources in the headwaters of the Tagus river basin

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Abstract

Water resources availability in semi-arid regions is highly affected by climate change, especially in the Segura River Basin. This basin is one of the most water-stressed basins in Mediterranean Europe. One of the major source of water in this basin is the Tagus-Segura water transfer (TSWT), whereby water is transported from the headwaters of the Tagus river basin in central Spain along a 300 km channel. TSWT has enabled the socio-economic development of the south-east of Spain. This study assessed the impact of climate change in the headwaters of the Tagus River Basin using the Soil and Water Assessment Tool (SWAT) and the Climate Change Toolkit (CCT). The predicted future climate change by two climate change scenarios (RCP 4.5 and RCP 8.5) and five general circulation models (GFDL-ESM2M, HadGEM2-ES, IPSL-CM5A-LR, MIROC and NoerESM1-M) were applied. The results of calibration and validation at seven stations show that the SWAT model performed satisfactorily in modeling hydrological processes in this basin. Comparing the long-term (2070-2099) to baseline (1970–1999) periods, precipitation showed a decreasing trend of between 12% and 26%, whereas projected annual mean temperatures demonstrated a forecasted increase of 3–5.3°C. The results of this study show that the discharges at the inlets of Entrepeñas and Buendía reservoirs are decreasing under both RCPs in both future periods. In RCP 8.5 and by the end of the century, water resources were predicted to experience a decrease of 57%. These findings provide very useful information not only for water management authorities in the Tagus river basin, but also for the Segura river basin authority in the face of climate change.

Keywords

SWAT model; climate change; Tagus Basin; interbasin water transfer; RCPs

Impacts of land use change and climate variability on water resources in the headwaters of the Segura River Basin (SE Spain)

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Abstract

The climate change and land use/land cover changes (LULC) as a result of the anthropic activity are factors of big importance both in degradation of an ecosystem and in the availability of water resources of a basin. To know how affect these activities on the quantity of water resources of basins like the Segura river basin, which are submitted to a big water stress is of vital importance. In this work, SWAT model has been used for the study of the above mentioned impacts. First of all, the model has been validated obtaining a Nash-Sutcliffe Efficiency (NSE) of 0.89, a coefficient of determination (RSR) of 0.49 and a percent bias (PBIAS) of 7.28%, indicating that SWAT accurately replicated monthly streamflow. Next, land use maps relative to the year 1956 and 2007 have been used to establish a series of scenarios that have allowed us to evaluate the effects of these activities on the water resources both of individual and joint form. The reforestation plan applied in the basin during the 70s have supposed that the forest area has doubled, while the agricultural areas and shrubland has decreased 28%. These modifications, together with the effect of the climate change, have supposed an annual decrease of 95.7 mm in the quantity of generated water resources, and an annual increase of 31.8 mm in the evapotranspiration. The results showed that the climate change had higher impact than reforestation on hydrological processes in the study basin.

Keywords

climate change, LULC, SWAT, Segura River basin

Predicting particulate and dissolved organic carbon exports in watersheds at global scale

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Abstract

Organic carbon is a main driver of greenhouse gas emissions in hydrosystems by respiration or denitrification. Organic carbon is exported from rivers to oceans in two forms, the dissolved organic carbon (DOC) and the particulate organic carbon (POC). Carbon fluxes going from soils to rivers represent 1.7 $PgC.yr^{-1}$. Climate change could have an impact on these fluxes which could have a feedback effect on climate evolution at a global scale. This study tries to understand the complex processes involved in organic carbon exports in watersheds presenting different soil and meteorological conditions, 60 rivers. The POC export equation from Boithias et al. (2014) has been adapted to the study cases. The DOC export equation has been adapted from the Michaelis-Menten equation. The results reveal that the models for DOC and POC can represent fluxes of organic carbon at a daily time step and could be used for further research on denitrification processes. We have identified that the rivers have different behaviors regarding DOC concentrations based on the Köppen climate regions. The averages of the potential maximum concentrations of DOC found in the rivers are 7.8±1.2, 8.4±1.4, 4.5±0.3 and 13.3±2.1 $mg.L^{-1}$ respectively for tropical, arid, temperate and arctic rivers. In the same way, the POC percent found in the sediments which is linked to organic carbon in the soil and to autochthonous organic carbon of the river is dependent on the climate. This approach could be then introduced in the Soil and Water Assessment Tool (SWAT) to study DOC and POC flows in a context of climate change.

Keywords

Organic carbon - Global scale - Modeling

An integration of landscape units in the SWAT-LUD model to better predict water discharge in the Amazon River

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Abstract

Hydrological models should integrate overflowing waters, as they are drivers of many biogeochemical reactions in alluvial floodplains, such as denitrification. The SWAT model has already shown issues to predict flooding conditions, especially over large watershed like the Amazon basin. It has resulted in a prematurely detection of discharge peaks. We have adapted the Soil and Water Assessment Tool - Landscape Unit Darcy (SWAT-LUD) version of Sun et al. (2016) which presents a modified conceptualization of the SWAT model developed to face challenges of modelling floods. Darcy's equation is the main concept of the SWAT-LUD functioning: it restructures the river's closest watersheds with selected land use and soils conditions by creating landscape units around channels to represent alluvial floodplains. Water infiltration to the shallow aquifer, water exchanges between the different landscape units and the river were reconsidered regarding Darcy's law. It is expected to better represent water routing through alluvial floodplain systems and to better assess spatial and temporal variability of hydrological and biogeochemical processes within watersheds. This new module is a key factor in order to better predict water distribution and biogeochemical functions for large watersheds. The SWAT-LUD model has been tested on the Amazon River. We will present here the methodology and the first results by comparing the SWAT-LUD and the current SWAT model.

Keywords

Overflood - Amazon River - Landscape Unit - Darcy

Modeling of Suspended Sediment Load combining the SWAT model and Suspended Particulate Matter using Landsat-8 OLI data: The case of the Orinoco River - Venezuela

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Abstract

The Orinoco River is considered the third most important river in the world in discharge (37,600 $m^3.s^{-1}$) with a surface of $1x10^6$ km^2. The river originates from southwestern part of Guiana Shield, on the western slopes of Sierra Parima Mountains with maximum elevation of 1047 m. As a result of precipitation regime and distribution, the annual hydrograph of the Orinoco River shows a distinctive seasonal cycle in its middle and lower reaches. Suspended Sediment Load (SSL) represents the major part of fluvial sediment transport, its prediction and simulation are important for the management of water resources and environments. Due to the lack of water quality data in the main tributaries of the Orinoco River, an inversion model using the spectral relationship between Reflectance and *in-situ* samples, *i.e.* Suspended Particulate Matter (SPM) spectral retrieval model, was applied to estimate SPM. This study used a time series of Landsat-8 OLI satellite imagery acquired between 2013 and 2016 to estimate SPM at the main hydrological station at Ciudad Bolivar, which controls ~90% of the river catchment. During these three years, a total of 42 water samples were collected during Landsat-8 acquisition day or ± 4 days (in the middle of the channel cross-section). Surface Reflectance was compared with observed SPM samples to calibrate a SPM spectral retrieval model. A regression model based on surface reflectance at Near Infrared wavelengths showed the best performance. Results of the retrieval model were used as observations to calibrate and validate the SWAT model. The SWAT model was used for long-term SSL simulation and prediction. The total SSL for period from 2000 to 2017 was ~$94x10^6$ $ton.yr^{-1}$. The results of this study show that SWAT SSL estimation model can be effectively used combined to the best data available from spectral inversion model, especially in areas with scarce observed data. This could ultimately be used for water resources management.

Keywords

SWAT, Landsat-8 OLI, Orinoco, Reflectance, SPM

Analysis of Sediment and Carbon Fluxes: A study of Ganga-Brahmaputra Basin

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Abstract

The Ganga and Brahmaputra rivers originating from the Himalayas and emptying into the Bay of Bengal together form the 3rd largest basin in the world spreading across China, India and Bangladesh. With heavy downstream sedimentation and nutrient transport critically impacting the lives of more than 500 million people which depend directly or indirectly on the water from the two rivers, it is important for the policy makers and stakeholders to have a better understanding of the hydrology of the basin.

This understanding can be accomplished by using tools based on modelling approaches that closely replicate the in-situ hydrology thus allowing the evaluation and quantification of sediment load and nutrient fluxes. The heterogeneity arising from pasture dominated steep topographies and mountainous climate in the north to agriculture dominated tropical monsoon climate in the south, coupled with unavailability of data pose as serious challenges in modelling.

The current research attempts to use the physically based semi-distributed hydrological model namely SWAT (Soil and Water Assessment Tool) for spatio-temporal analysis of sediment and carbon fluxes at daily and monthly scales across the basin. The study envisages to identify key factors controlling sedimentation and carbon transport. This model will be used to study the contrast between the two diverse basins.

The model has already been setup for streamflow for the baseline period of 1985 – 1992. The periods for calibration and validation are 1985-1988 and 1989-1992 respectively for the two rivers. Performance of the model was evaluated by R^2 and NSE. Comparison between simulated and measured streamflow showed a strong agreement, yielding a value greater than 0.90 for both rivers in calibration as well as validation at monthly scale.

Concluding satisfactory calibration and validation for streamflow, the group aims to work towards suspended sediment, particulate organic carbon and dissolved organic carbon.

Keywords

Sediment, Carbon Fluxes, SWAT, Ganga-Brahmaputra Basin, Hydrologic Modelling

Quantifying the role of Amazonian wetlands in denitrification process and greenhouse gases outgassing patterns by using L-band remote sensing earth observations and SWAT modelling.

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Abstract

The amount of greenhouse gases released to the atmosphere by human industries and agriculture, such as carbon dioxide (CO_2) and nitrous oxide (N_2O), has been constantly increasing for the last decades. Nevertheless, wetlands ecosystems provide an optimum natural environment for carbon sequestration and nitrogen uptake processing. Wetlands are ecotones, transition areas between land and aquatic environment, which supply various ecosystem services: water purification, flood control, shoreline stability, etc. Amazonian wetlands are subjected to seasonally flooding events due to water level changes of the river which trigger off denitrification processes under anaerobic conditions. The main objective of this study is to identify and quantify the peculiar role of riparian wetlands to carbon and nitrogen regulation by both satellite observations and in-situ measurements of the Amazon basin. In this study, authors focus on the role of Amazonian wetlands in carbon and nitrogen cycles and more particularly on the part of denitrification in CO_2/N_2O emissions during flooding events. The spatial and temporal distribution of water surface extent was determined with the Soil Moisture and Ocean Salinity (SMOS) mission within the watershed. Denitrification and outgassing processes were implemented considering the first 30 cm of soil saturated areas as active layers. Those biogeochemical processes turn out to be highly influenced by the seasonality of rivers and are mainly located in floodplains. Denitrification over the entire watershed accounts for 17.8 kgN/ha/yr whereas CO_2 outgassing participates up to 0.001% of the global Amazon Carbon budget and N_2O emissions (0.14 $gN/m^2/yr$) are in accordance to the current global Nitrogen models. The methodology described in this study can be transposed to other large watersheds. We later aim to model the biogeochemical inputs of denitrification with SWAT over the Amazon floodplain to better assess and predict the spatial and temporal patterns of the processes in regard of the current climate change conditions.

Keywords

SWAT, SMOS, denitrification, large-scale, wetlands

Investigating the Role of Wetlands in the Hydrology of the Congo River Basin Using the SWAT Model

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Abstract

Wetlands play an important role in regulating the movement of water within watersheds as well as in the global water cycle. They also help maintain the level of the water table as well as serving as sources or sinks for nutrients. Thus the role of wetlands in the hydrological and biogeochemical cycles has to be quantified in time and space both by observation and modelling.The objective of this study is to analyze the effect of the central cuvette on downstream processes in the Congo basin as well as to estimate wetland storage and its water flux by modeling. In particular, the study was conducted to assess the performance and suitability of the SWAT in modeling the upper part of the basin compared with the lower part impacted by the cuvette.TRMM precipitation data was obtained from the NASA Earth Data website for the period 1998 to 2014. Other Input data used was a SRTM digital elevation model of 90 m resolution available from the Consortium for Spatial Information (CGIAR-CSI) and a global soil and land cover map provided by the food and agricultural organization (FAO). The source of stream flow data is from the Global Discharge Data Center from 1934 to 2007 for Bangui station and SO-HYBAM from 1990 to 2018 at the Outlet (Kinshasa).The major components of the model were calibrated to achieve an acceptable agreement between the simulated and observed flows. Performance evaluation criteria gave the following results $R^2$of 0.73 for the Bangui station and a R^2 value of 0.75 for Kinshasa station. At the outlet of the catchment we simulate a total inter-annual discharge of 539 mm y^{-1} compared with 439 mm y^{-1} of observed discharge. The difference is over 100 mm more than the actual observed annual yield representing about 20 % of waters; implying that the wetlands of the cuvette are impacting on the hydrodynamics. Therefore, further work is needed to quantify the fluxes that directly impact the cuvette in order to account for all waters that supply the cuvette and adjoining wetlands.

Keywords

Congo basin , Cuvette wetlands, hydology

Identification key sensitive parameters for Soil and Water Assessment Tool at multiple temporal scales

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Abstract

Abstract: Sensitivity analysis (SA) represents an important step for the construction of watershed models and sensitive parameters may vary according to the choice of simulation scales. In this study, the sliding window method was utilized to sample and combine parameters randomly and set up different time steps, and then sensitivity analysis of 20000 sampling results was carried out by Fourier Amplitude Sensitivity Test (FAST) based on the simulation of Soil and Water Assessment Tool (SWAT) model. Sensitive parameters at different temporal simulation scales (10, 30, 60, 90, 120, 180, 200, 240, 300 days) were obtained and compared in a real case study (the Daning river basin in the Three Gorges Reservoir, China). The results indicated that the key sensitive parameters varied at different temporal scales. For hydrological simulation, the ranking of soil properties, such as soil erosion factor (USLE_K) and soil wet bulk density (SOL_BD), gradually decreased from daily scale to yearly scale, while the impacts of channel-related parameters, in terms of basic flow factor (ALPHA_BF), river alluvial factor (CH_K), and river Manning coefficient (CH_N), acted conversely. For sediment simulating, Manning coefficient (CH_N) was identified as key sensitive parameter for all simulation scales. For phosphorus simulation, slope factors and physical soil properties were identified as sensitive parameters. These results provided important information for the construction of the SWAT at different temporal scales.

Keywords

SWAT; Parameters sensitivity; Non-point source pollution; Multiple scales; Soil properties.

Groundwater Recharge Estimation in Little Akaki Watershed using SWAT Model

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Abstract

Estimation of the groundwater recharge is an essential component of water balance evaluation for sustainable use and management of the groundwater resources. Groundwater from the Little Akaki watershed is part of the Akaki well field which contributes for more than 25% of the water supply to the capital city of Ethiopia, Addis Ababa (Finfinnee). Due to the increase in water demand by the city, the groundwater abstraction is significantly increasing without the basic understanding of the groundwater recharge, aquifer characteristics and the groundwater extent available for extraction. As part of the groundwater modeling activity in the area, this study estimates the catchment scale groundwater recharge of the Little Akaki watershed using the physically based Soil and Water Assessment Tool (SWAT) model. The model was calibrated based on five years of monthly stream flow data using SUFI2 algorithm. Recharge in the basin mostly occurs in the months of July to October with maximum values in August. In average, the estimated annual catchment recharge was 177 mm. In general, the groundwater recharge estimated were lower for sub basins dominated by urban land covers which could be an alarming for the sustainability of the increasing groundwater exploitation in the area as a result of fast urban expansion.

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Keywords

SWAT, Groundwater Recharge, Little Akaki watershed

SWAT nutrient calibration and validation with a 6-year data set of continuous data in a Finnish catchment

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Abstract

One of the important limitations of numerous applications of water quality models such as SWAT is calibration and validation against temporally scarce observational data (with typical monthly grab sampling frequency). In this study, carried out within the BONUS RETURN project (http://www.bonusreturn.com), a unique dataset of continuous measurements of water height, turbidity and nitrate-nitrogen (NO_3-N) concentrations collected at the Pitkäkoski automatic monitoring station in the Vantaanjoki river basin in southern Finland during 2011–2016 was utilized in calibration and validation of the SWAT model. The catchment is characterized by a high fraction of clayey soils, and in consequence, flashy runoff, with very large and short flood episodes with high nutrient concentrations. Data was recorded at 1-h intervals with a s::can nitro::lyser (www.s-can.at/products/spectrometer-probes#) sensor. Sensor-measured turbidity (raw data) was calibrated against simultaneous water-sampled turbidity and converted to total phosphorus (TP) concentrations by linear regression equations derived from water-sampled turbidity and TP. For the sake of calibration and validation in SWAT-CUP Sufi-2 programme, concentration and flow data were aggregated into daily loads of NO_3-N and TP. Preliminary results show good model calibration results, with the Kling-Gupta Efficiency values above 0.8 for flow and above 0.7 for NO_3-N and TP. In the next step, the added value of using such a unique, continuous data set for SWAT calibration will be more formally analysed by creating 'calibration scenarios' using discrete sub-samples of the continuous data set trying to mimic most typical grab sampling approaches (measurements with a monthly interval, flow-weighted sampling, etc.).

Keywords

automatic monitoring station, continuous data, sampling frequency

Simulation of sedimentation rates using the SWAT model: A case study of the Tarbela Dam, Upper Indus Basin.

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Abstract

Sedimentation in reservoirs is a worldwide problem. It reduces the storage volume and life span of reservoirs, affecting the ability to store water for (multiple) uses. Tarbela Dam is a major multipurpose reservoir of Pakistan, which was put in operation in 1974 for irrigation and hydropower generation. It is situated on the Indus River and is important for the water resources of Pakistan, especially for sustainability of irrigated agriculture and providing hydroelectricity. Over time, sedimentation has reduced the storage capacity of the reservoir, which has adversely effected the power generation potential. There are lack of process-based studies to quantify the sediment inputs to this reservoir and assess the effects of future land use changes. At present, an important project of reforestation called “Billion Tree Tsunami” is being carried out to reduce climate change as well as sediment production in parts of the Indus basin. It is important to optimize reforestation practices by assessing priorities, for instance by starting from the most vulnerable sub-basins. In this study, the SWAT model is used to simulate sediment production in the basin under current and land use change scenarios. The SWAT model was calibrated and validated using the local and global data sets such as precipitation data from PERSIANN-CDR.
This study focuses on the effects of land use changes on water and sediment yield in the Upper Indus Basin on Tarbela Reservoir. Considering the present situation as the “base-case scenario”, two additional scenarios are introduced in which 20% and 40% of savanna deciduous alpine is replaced by forest deciduous, respectively. The results obtained from the comparison of the scenarios indicate that land use changes in the Upper Indus Basin do not have significant impact on sediment yield. For instance, replacing 40% of Savana by forest reduces the sediment input to Tarbela Reservoir by only 4000 tons in ten years. The highest sediment amounts are produced in the middle part of the Upper Indus Basin, which should be the main focus of sediment reduction efforts. The results show that sediment production in the catchment is governed by the processes occurring at steep slopes (landslides, debris flows) in areas in which forests would not survive. However, these processes could not be adequately modelled in the current SWAT version, thus indicating an area of further model development.
The sedimentation rate is estimated at 96 x 106 m3 (bulk sediment volume including voids) by this modelling exercise, which is smaller than previous estimates, but close to the results of a study done by the World Commission on Dams. The study shows that the reservoir capacity is likely to further reduce in future due to sedimentation, which could be off-set to some extent through targeted catchment management interventions.

Keywords

Sedimentation, land use change, SWAT model, Indus Basin, Tarbela Dam.

Analysis of factors affecting sediment yield in catchments draining to the Cantabrian Sea (West Europe)

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Abstract

Erosion is one of the most important environmental problems worldwide. In Europe, the principal consequence of erosion is not soil loss, but downstream sedimentation and pollution. Therefore, stakeholders and policy makers need a better understanding of sources and sinks of sediments in their areas in order to take management decisions. This understanding might be accomplished using modelling approaches assessing the spatial and temporal evolution of erosion. In this study, we apply SWAT model (Soil and Water Assessment Tool) to obtain temporal and spatial estimates of sediment yields in several catchments with climatology and land uses. In addition, results obtained from SWAT are deeper explored through statistical methods to identify factors related to environmental and anthropogenic drivers governing erosion in the selected area. Several catchments draining to the Cantabrian Sea (west of France and north of Spain) are selected for this. Some challenges for SWAT calibration and validation, like data scarcity and heterogeneity in time and space, are addressed using regression methods to fill gaps when possible. Some of the main factors governing soil erosion are precipitation, surface runoff and land cover. These results are useful for stakeholders and policy makers to take management decisions, so they can target practices that influence the sediment transport evolution and prepare plans on their areas.

Keywords

Sediments; Factor analysis; Calibration

Evaluation of the precipitation time-step influence in streamflow and suspended sediment yield using SWAT in a small forested headwater catchment

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Abstract

Headwater catchments have a significant influence in the water quality and quantity that eventually is used downstream for human activities. In catchment modelling, the used precipitation time-step is usually performed on a monthly or dailybasis. Therefore, in some headwater catchments which usually are small, with steep slopes and quick response to precipitation these time-steps are not enough to capture the intensity and the temporal distribution of the precipitation. Soil and Water Assessment Tool (SWAT) was used to model streamflow and sediment yield in a small and forested catchment of the Cantabrian Watershed in the Iberian Peninsula.
The modelling was done with hourly precipitation data (2005-2014) and the obtained results for streamflow and sediment yield were good. Nevertheless, in most of the storm events the simulated sediment yield showed a delay with respect to the observed data. To evaluate the modelling time-step influence, the precipitation input was changed from hourly to 2, 3 and 4 hours. The results show that when the precipitation time-step is increased, the simulation performance downgrades; specially for sediment yield. The results could help in the decision of the precipitation time-step in the modelling of other headwater catchments. Modelling is used by scientists and policy makers to understand hidro-sedimentary processes and this research could help to better understand these processes and perform more reliable simulations.

Keywords

headwater catchment, time-step, sediment yield, storm event, streamflow

SWAT vs. SWAT-MODFLOW in lowland catchments: Comparison of performance and simulation of groundwater abstraction scenarios.

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Abstract

In catchments wherein streams are groundwater-fed, groundwater abstraction can lead to stream depletion, which can conflict with surface water rights and have adverse ecological effects for stream-riparian areas. Thus, an accurate representation of groundwater processes and their interaction with surface water is desirable. In this work, both the Soil and Water Assessment Tool (SWAT) and SWAT-MODFLOW (coupling SWAT with the fully-distributed Modular Groundwater Flow model, MODFLOW) were applied to a Danish catchment. SWAT is one of the most widely used hydrological models, but uses a simple approach to simulate groundwater processes. SWAT-MODFLOW has been recently developed to overcome this issue, but studies assessing its applicability are still scarce.

Both models demonstrated good performance and were able to simulate the discharge in the Odderbæk catchment. However, SWAT-MODFLOW performed better during periods of hydrograph recession, which might reflect a better simulation of the groundwater-surface water interaction. Regarding abstraction scenarios, SWAT-MODFLOW provided more realistic outputs. The coupled model showed a decrease in stream flow approximately equal to the abstracted water volume and close to the location of wells, while in SWAT the impact on stream flow was negligible. SWAT also showed impacts on stream flow only when abstractions were taken from the shallow aquifer, and not from the deep aquifer.

Overall, SWAT-MODFLOW demonstrated wider possibilities for groundwater analysis, which makes it more valuable than SWAT in supporting management and decision making in relation to environmental assessment and potential approval of proposed abstraction wells.

Keywords

Abstraction; catchment; groundwater; hydrology; modelling; SWAT-MODFLOW.

Simulating stream flow using an eco-hydrological model calibrated with global land surface evapotranspiration from remote sensing data

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Abstract

The estimation of stream flow in ungauged basins is a key task in surface water hydrology. Many tropical river basins are either ungauged or sparsely gauged mainly because of terrain complexity, lack of financial resources and technical support with an improper management of the existing hydrological stations. Due to this fact, hydrologists are faced with challenges of accessing and obtaining measured stream flow data in many tropical catchments, even in catchment areas that are of high strategic importance for state and national water development plans. This general lack and scarcity of up-to-date stream flow information has made water resources management challenging and difficult in most of the river basins located in Nigeria. Recent advancements in remote sensing have enabled the calibration of hydrological models with satellite based products. In this context, this study presents an innovative approach to simulate stream flow for individual sub-basins using satellite based evapotranspiration data. Three different structures of the Soil and Water Assessment Tool (SWAT) model were used in which each model structure was a set-up of SWAT with a different potential evapotranspiration (PET) equation. Global Land Evaporation Amsterdam Model actual evapotranspiration (GLEAM_v3.0a) and Moderate Resolution Imaging Spectroradiometer Global Evaporation (MOD16) were subsequently used to calibrate the SWAT simulated actual evapotranspiration (AET) outputs from each model structure resulting in six calibration/validation procedures at a monthly time scale for the Ogun River Basin (20,292 km^2) located in southwestern Nigeria. The parameter sensitivity analysis and the model calibration/validation and uncertainty analysis were performed using the Sequential Uncertainty Fitting technique (SUFI-2). Overall, the SWAT model structure composed of Hargreaves PET equation and calibrated using the GLEAM_v3.0a data performed well for the simulation of AET and provided a good level of confidence for using the SWAT model as a decision support tool for management policies. Beyond the estimated AET simulations, the stream flow estimates were also obtained. The 95% uncertainty of the SWAT simulated AET bracketed most of the satellite based AET data in each subbasin. Due to non-unique parameter sets, more than one well-performing solutions of stream flow estimates bracketed by their 95% prediction uncertainty were obtained when an NSE was selected as the main objective function with a threshold value of 0.59. This study demonstrated the potential to use remotely sensed evapotranspiration data for hydrological model calibration and validation for stream flow simulation in a sparsely gauged large river basin with reasonable accuracy.

Keywords

SWAT model; stream flow; MOD16; GLEAM; monthly calibration; predictive uncertainty; Ogun River Basin; data scarce

Integrating SWAT and HEC-RAS Models for Flood Forecasting in Vu Gia- Thu Bon River Basin, Vietnam

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Abstract

This study are the part of "**Decision Support System (DSS) for Real –time Flood Warning in Vu Gia Thu Bon River Basin, Quang Nam province"** project code **KC.01.24/11-15** under The National Program for Key Science & Technology "Research, Application and Development of Information and Communication Technologies" – Ministry of Science and Technology, Vietnam.

Precise and reliable simulation of hydrologic and hydraulic processes is important for efficient flood forecasting and warning. In recent years, natural disasters associated with unpredictable weather conditions have become increasingly complex and frequent in central Vietnam. We propose a real-time flood forecasting system which integrates a coupled hydrologic/hydraulic modeling system, weather station network, and stream gauges in a web-based visualization environment. An automated procedure is developed to dynamically link terrestrial rainfall-runoff processes and river hydraulics by coupling the SWAT hydrological model and the HEC–RAS hydraulic model. There are five subroutines of the program including Model setup, Auto SWAT, Auto HEC–RAS, Auto RAS mapper and View online flood map. In the first subroutine, Model setup, users declare initial parameters including start time, end time, time step and running mode. The second subroutine, Auto SWAT controls the process of streamflow simulation. Similar to Auto SWAT, the Auto HEC–RAS subroutine also starts with the preparation of input files and ends with the model run. Auto RAS Mapper and View online flood map subroutines were used to produce and visualize flood depth map. Finally, View online flood map routine copied the flood depth file in the RAS Mapper folder to the WebGIS directory and extracted the flood time in this file name to a separate file (Time.txt) before displaying flood depth map online by using GeoServer. The proposed flood forecasting system is demonstrated in a case study on the Vu Gia – Thu Bon River basin, located in Quang Nam Province. The study area experienced major flood damages in the past few decades because floods usually occur in short duration with high magnitude flood waves in the upper and middle of the basin. Results show excellent statistical correlation between predicted and measured flow for a 10-year calibration period (R^2=0.95, PBIAS=-1.54%) and during the following 10-year validation period as well (R^2=0.93, PBIAS=6.18%). A close-up analysis on individual storm events indicates that the magnitude and timing of peak floods are accurately predicted in the Bon River basin. In addition, the automated procedure is demonstrated to be reliable with dependable computational efficiency with less than 5 minutes of processing time.

Keywords

Flood forcasting, Flood warning system, SWAT, HEC-RAS, Vu Gia- Thu Bon river basin.

Analyzing spatial and temporal variation of water balance components in La Vi catchment, Binh Dinh province, Vietnam

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Abstract

Topography, land use, soil and climate are the main factors affecting water resources (both quantity and quality) in a basin. For purely agricultural basins, water resource assessment and management plays a very important role in the region's agricultural development. This study aimed to analyze the variation of water balance components at different spatial scales (catchment, sub-catchment, Hydrologic Response Unit) in La Vi catchment, Binh Dinh province, Vietnam from 2000 to 2015 using Soil and Water Assessment Tool (SWAT) model. The results showed that actual evapotranspiration mainly depended on land use with high values (600-1,110 mm) in residential land, low values (520-600 mm) in perennial industrial crop areas. Soil moisture has been altered by soil texture with high values (131-178 mm) on Haplic Acrisols, low values (95- 130 mm) on Rhodic Acrisols. Percolation to shallow aquifer varied inversely with the impervious surface (high value in perennial industrial crop areas, low value in residential land) and directly with rainfall (e.g., in the wet year 2005, the value reached 1,461 mm while in the warm year 2001, the value fell to 94 mm). Surface flow positively correlated with both the impervious surface (high value in residential land, low value in perennial industrial crop areas) and rainfall (high value in rainy season, insignificant value in dry season). For base flow, high values occurred in perennial industrial crop areas while small values occurred in residential land with a time lag of more than one month compared to the rainy season. These findings were expected to provide a reference for water resource management and planning in La Vi catchment as well as other similar basins in Vietnam.

Keywords

Water balance component, Hydrologic Response Unit, La Vi catchment, Soil and Water Assessment Tool

Assessment of Impact of Climate Change on Water Resources in Sungai Muda Watershed using Soil and Water Assessment Tools (SWAT)

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Abstract

Sungai Muda watershed is one of the most important river basins which serve as a water supply source for the agriculture, domestic sectors, fishery, and hydropower over the northern Peninsular Malaysia. Climate change projections of the streamflow for Sungai Muda watershed was conducted using the Soil and Water Assessment Tools (SWAT) Model. The SWAT model was calibrated for a ten years (1981-1990) period with value of the coefficient of determination, R^2=0.76, Nash-Sutcliffe efficiency, NSE=0.76 and percentage bias, PBIAS= -3.6. Then, the model was validated for another ten years (1997-2006) period which gives R^2=0.71, NSE=0.70 and PBIAS= -8.6. The calibrated SWAT model was used to simulate the future streamflow rate for Sungai Muda watershed at Jambatan Syed Omar station using NASA Bias Corrected Statistical Downscaling (BCSD) rainfall from three Global Climate Models (GCMs) based on two climate scenarios i.e. Representative Concentrations Pathways (RCP) 4.5 and 8.5. The results from simulations were ensemble average according to the respective scenarios. Analysis regarding the average of the monthly streamflow rate was conducted. Based on RCP 4.5 scenario, during mid-century, an average flow for each month is projected to be about 1.84% higher than the baseline. However, toward the end of the century, it showed different projection which indicates an average of 1.89% reduction compared to the baseline. On the other hand, for RCP 8.5 scenario, during mid-century, an average flow for each month is projected 0.57% higher than the baseline. Moreover, during the end of the century, it is projected to be 9.32 percent higher than the baseline. In general, during drought season, the streamflow is not expected to have significant changes driven by RCP 4.5 and 8.5 scenario. However profound changes were projected in minimum flow throughout at the beginning of the first 50 years. Essentially, during flood season there appear to be significant projected changes for both RCP scenarios. Toward the end of the century, both RCP4.5 and RCP8.5 is projected to drives significant changes to the streamflow during February to May periods.

Keywords

Climate Change, Water Resources, Sungai Muda Watershed, SWAT

Climate change impacts on glaciers and runoff in Alpine catchments

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Abstract

Climate change impacts on water availability and glacier retreat are major concerns in Alpine catchments. Impacts on hydrological cycle are normally assessed in climate-impact modeling chain. Hydrological cycle of mountainous catchments is challenging in modeling due to complex climatic and topographic conditions. In our study, we used a newly developed SWAT-GREM framework to assess the impact of climate change on glacier retreat in Aletschgletscher, a glacierized catchment, in the Swiss Alps. We calibrated and validated the model using ice volume changes from three digital elevation models from 1957-2009 and monthly discharges at the outlet of the basin from 1980-2015. We used 10 climate projections consists of five GCMs from the CMIP5 archive and two different RCPs from ISI-MIP to assess ice volume, glacier outline and runoff changes in 2025-2050 time horizon. We downscaled and bias-corrected the future climate projections using Climate Change Toolkit (CCT) and historical climate data from MeteoSwiss for 1980-2015. Our results showed a significant shrinkage in glacier area for all climate projections. We found an initial increase in annual runoff, followed by a stabilization period in the mid-century and finally dropping below the current level at the end of the century.

Keywords

SWAT-GERM, climate change, glacier retreat

Using big data sets to combat climate change impacts

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Abstract

Although there is enough evidence that climate change is one of the major 21st-century environmental problems, there is still a need to make scientific researches' results accessible to the public and bridge the gap between scientific community's achievements and social awareness. We developed a software "Climate Change Toolkit (CCT)" to handle the repetitive tasks involved in a climate change study. The user can select a dataset from an inventory of global climate models (GCMs), extract data for a desired spatial and temporal extent, perform extreme weather analysis, and visualize the results in one package. CCT is linked to an archive of 0.5° historical and future global daily climate dataset. The format of climate data is exactly the same as SWAT climate data. 1,752,920 files ((5 GCMs * 5 representative concentration pathways + observational local climate data = 26 scenarios) * 67,420 global grids)) are prepared and accessible from www.2w2e.com website. Each of these 1,752,920 records consists of 7 dependent variables (latitude, longitude, elevation, precipitation, maximum temperature, minimum temperature and file name) from 1950-2100. To demonstrate an application of CCT we implemented the extreme frequency analysis in California. Our results showed that every county in northern California may experience flooding conditions of 1986 in Sacramento at least once between 2020 and 2050. Although the CCT and 2w2e website facilitates many tasks, there is a need to inform people of extreme weather conditions as early as possible. One of our ongoing projects at Eawag and the University of Geneva is to investigate how extreme weather patterns and frequencies in Switzerland have changed spatially and temporarily. With this project, we aim to show real-time any occurrences of extreme conditions in the weather in the next two weeks.

Keywords

CMIP5, ISI-MIP, Climate Change toolkit, SWAT

Simulation of hydrological processes of Sot river watershed in western Uttar Pradesh- a case study of sambhal district

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Abstract

Wetlands in the preserve play a key role in maintaining regional ecosystem function and integrity. Global climate change and intensified anthropogenic activities in the region have raised great concerns over the change of natural flow regime, wetland degradation and loss. With the recent advancement in Remote sensing technique, the feature extraction of wetland with the help of different satellite derived band algebras including Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Modified NDWI (MNDWI), and Normalized Difference Moisture Index (NDMI) is being used by experts. The common diagnostic features of wetlands are surface water, swamps and aquatic vegetation. The present study is based on a comparison between these four indices. Some wetlands of sambhal district is selected as a site for the study because the surface water of the wetland has decreased rapidly in last half decade which is alarming for the related ecology and biodiversity. In this study, two key hydrologic components in the preserve, water surface area and water volume, as well as their variations during the period 1979– 2017, were investigated with a spatially-distributed hydrologic modeling system (SWAT). A wetland module was incorporated into the SWAT model to represent hydrological linkages between the wetland and adjacent upland areas. Overall, the modeling yielded plausible estimates of hydrologic changes in this large wetland reserve, building a foundation for assessing ecological water requirements and developing strategies and plans for future water resources management within the river basin.

Keywords

Wetlands, Remote Sensing, NDVI, NDWI, MNDWI, NDMI and SWAT

A web platform to activate an operational forecast mode for existing SWAT setups

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Abstract

SWAT is widely applied for assessing water resources dynamics, and for understanding how weather forcing influence water resources. We present a new web-based platform that features a 16-day forecast service for SWAT applications, which has potential to become a key decision-support tool within the water management and agricultural sectors. The service is based on globally available weather forecasts, and allows a "plug-and-play" solution for already existing SWAT applications. This new web-based platform can bring SWAT applications to life and provide operational 16-day forecasts on, for example, river discharge, soil water content and reservoir dynamics. Users of the web-platform can customize their own warning levels for individual model outputs of the forecast time window – for example, for generating a warning if discharge exceed a certain threshold for a certain river location. The forecasts, combined with the customizable warning levels, can aid decision-making relating to flood protection, droughts (from soil water content) and drinking water availability. We illustrate the concept of the forecast service and hope to get ample input from the audience on the concept and relevant of the forecast service.

Keywords

SWAT model, forecasting, water resource management, web-platform

Evaluation of water resources of the Mundaú basin using the SWAT model

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Abstract

The world population is constantly growing, and at the same time, basic inputs are becoming increasingly scarce. The Soil and Water Assessment Tool (SWAT) model is an instrument for the hydrologic and water quality simulation. In this study, it is used to estimate the surface runoff of the Mundaú basin. The input data were previously analyzed, the land use map showed 72% of agricultural areas with forest remnants; the most predominant type of soil is Argisol, which has a direct relation to the morphology of the landscape, with predominant relief and slopes between 8 and 20%. The comparison between estimated and observed runoff obtained a Nash Sultcliff (NSE) of 0.67, that is, this initial modeling shows satisfactory results. The surface runoff showed high sensitivity to soil parameters, i.e. depth, porosity and density, which contributed with more than 20% of the estimated surface runoff. We concluded that any change in the river basin that changes soil characteristics may cause major impacts on surface runoff of the Mundaú basin.

Keywords

Hydrologic model, Mundaú, SWAT

Uncertainty Analysis in Real-Time Flood Forecasting; a Case Study of Dender River flooding, November – 2010, Belgium.

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Abstract

Flood is the most devastating natural hazard in the world. It causes human sufferings and losses of properties. Due to the fact that, flood is an uncertain phenomenon; it raises issues about the reliability and credibility of flood forecasting and warning systems. As flood simulation models are necessary to forecast flood, analysis of uncertainty and sources of uncertainty are two major issues for accurate prediction. In flood forecasting models, different types of uncertainties are involved. The uncertainties are commonly related to model input, model parameters and model structures. Among them, Uncertainty due to forecasted rainfall is the major part of the total uncertainty. In this study, uncertainty analysis has been carried out for flood simulation model of the Dender river basin, Belgium for the flood of November, 2010. Moreover, part of uncertainty due to rainfall forecasting has also been analyzed. This flood occurred due to heavy rainfall and four deaths have been attributed to this flooding. To analyze the total uncertainty and rainfall uncertainty, evaluation has been performed by comparing simulated results with forecasted rainfall and simulated results with observed rainfall in a hydrodynamic model, MIKE 11. The uncertainty analysis of the model output has been done by means of statistical indices and graphical interpretation. Statistical indices include residuals analysis, different percentile value of residuals, 95% confidence intervals, cumulative catchment rainfall etc. Also 95% percentile and bias correction have been set for the water level of January 2011. Also, water managers are informed about the uncertainty and part of uncertainty due to the forecasted rainfall. This study deals with the real time flood forecasting and it can be said that the flood forecasting model had the total uncertainty from different sources but major part of uncertainty was contributed by rainfall forecast.

Keywords

Uncertainty analysis, forecasted rainfall, observed rainfall, hydrodynamic (HD) model, real time flood forecasting.

The Application of SWAT for Developing Climate Model Evaluation Metrics within a Hierarchical Framework

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Abstract

Global climate models (GCMs) are the primary tools for climate forecasting, projection and hypothesis testing. However, projections generated with current GCMs are spatially coarse, requiring the use of "downscaling" to obtain greater spatial detail. Downscaling methods are characterized by large uncertainties despite advances in theories, observations, and climate modeling techniques. In response, the Framework for Assessing Climate's Energy-Water-Land nexus by Targeted Simulations (FACETS) project has been funded by the U.S. Department of Energy (USDOE) to develop an evaluation framework for climate downscaling techniques. The core of the framework is a set of metrics that include statistical measures of climate model performance (skill), phenomena-based diagnosis of inter-related model biases and multi-scale processes contributing to the phenomena, and metrics that are especially relevant to the energy-water-land (E-W-L) nexus. The goal of FACETS is to produce and disseminate a suite of metrics and analysis tools that can be used to evaluate different types of climate models and downscaling methods within the context of both fundamental and applied climate research.

The Soil and Water Assessment Tool (SWAT) ecohydrological model is being used within the FACETS framework to translate physical model output into metrics that are directly relevant to the E-W-L nexus and to produce hydrological variables that can be used to gain further insight into factors influencing the performance of specific climate models. Different combinations of climate models and downscaling techniques are used as input into SWAT to both to evaluate the realism of contemporary (baseline) climate simulations and to quantify uncertainties in future climate projections. Initial evaluations of several combinations of climate models and downscaling techniques have been performed using existing SWAT models constructed for the Upper Mississippi River Basin (UMRB) and Ohio-Tennessee River Basin (OTRB), which together comprise the majority of the U.S. Corn Belt region (https://doi.org/10.1016/j.jhydrol.2015.02.039). The process of developing hydrologic-based metrics from the UMRB and OTRB simulations will then be extended to the larger continental U.S. (CONUS) by constructing SWAT models within the Hydrologic and Water Quality System (HAWQS; https://epahawqs.tamu.edu/), which is a web-based interactive modeling system that provides pre-developed input data sets, the ability to construct and execute SWAT models, and to store and analyze output data.

We present initial precipitation, ET, water yield and other SWAT hydrologic indicators for the UMRB and OTRB using: (1) three GCMs in combination with statistical downscaling methods, and (2) two dynamical downscaling approaches. The process of developing metrics from the SWAT hydrologic indicators, which can then be used to evaluate the various types of climate models, will also be discussed.

Keywords

SWAT, HAWQS, FACETS, UMRB, OTRB, climate models, energy-water-land nexus, metrics

Assessement and comparison of socio-economic and climate change impacts on water resources in four European lagoon catchments

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Abstract

This study demonstrates the importance of considering potential land use and management changes in climate impact research. By taking into account possible trends of economic development and environmental awareness, we assess effects of global warming on water availability and quality in the catchments of four European lagoons: ***Ria de Aveiro*** (Portugal), ***Mar Menor*** (Spain), ***Vistula Lagoon*** (Poland and Russian exclave of Kaliningrad) and ***Tyligulskyi Liman*** (Ukraine). We use different set-ups of the process-based Soil and Water Integrated Model (SWIM), representing one reference and four socio-economic scenarios for the specific area, the so called "business as usual", "crisis", "managed horizons" and "set-aside". The models are driven by sets of 15 climate scenarios for a reference (1971-2000) and near future (2011-2040) scenario period. Modeling results suggest a large spatial variability of potential impacts across the study areas, due to differences in the projected precipitation trends and the current environmental and socio-economic conditions. While climate change may reduce the water and nutrients input to the ***Ria de Aveiro*** and ***Tyligulsyi Liman***and increase water inflow to the ***Vistula Lagoon*** the potential socio-economic changes and their implications may balance out or reverse these trends. In the intensely managed ***Mar Menor*** catchment, climate change has no notable direct impact on water resources but changes in land use and water management may certainly aggravate the current environmental problems**.** The great heterogeneity among the results does not allow formulating management recommendations at pan-European level, as initially intended by this study. It rather implies the need of a regional approach in the development of adaptation and mitigation measures for coastal areas under climate change.

Keywords

eco-hydrological modelling, socio-economic changes, land use and water management, climate change, European lagoons catchments

Assessing the Impacts of Climate Change on Dependable Flow and Potential Irrigable Area Using the SWAT model: The Case of Maasin River Watershed in Laguna, Philippines

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Abstract

Seasonal changes in rainfall and temperature brought about by climate change have been known to affect water resources availability. The study assessed the quantitative impacts of climate change on dependable flow and potential irrigable areas of the Maasin River in Laguna, Philippines. Projected variations of rainfall and temperature in 2020 and 2050 developed using PRECIS model based on Special Report on Emission Scenarios were used in this study. The Soil and Water Assessment Tool (SWAT) model was then used to simulate streamflow for each climate change scenario, from which dependable flows were quantified using flow duration analysis. Diversion water requirements for the rice areas in the watershed were determined using CropWAT. Based on dependable flows and irrigation demand, the potential irrigable areas were estimated. Calibration and validation of the SWAT model showed satisfactory performance in streamflow simulations. Results indicated that dependable flow in irrigation systems may decline by more than 50% in 2020 and by as much as 97% in 2050, because of seasonal changes in rainfall. Moreover, potential irrigable area may decrease to less than half of the current service area depending on the level of GHG emissions. SWAT water balance projections suggest potential measures to mitigate these future impacts scenarios. Surface runoff during wet seasons and increase annual groundwater recharge are possible sources of supplemental irrigation. Provisions of suitable storage reservoir facilities and groundwater development projects will alleviate water scarce conditions. The study demon-strated a technique that may be applied in other irrigation systems in the Philippines and in other countries with similar hydrologic conditions to quantify the effects of climate change on dependable flows and potential irrigable areas as a decision support tool. It can serve as a basis for policy recommendations for climate change adaptation and risk reduction strategies.

Keywords

climate change, dependable flow, potential irrigable area, diversion water requirement, SWAT

Evaluation of future climate change impacts on hydrologic processes in the Peruvian Altiplano region using SWAT

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Abstract

Sustainable water resource management is crucial in regions with scarce water availability such as the Altiplano region in the Peruvian Andes, where water resources are important for agriculture, hydropower production and water supply. While short-term regulation, for example of reservoirs, is applied to adjust the management to current weather conditions and water demand, long-term strategies are needed to anticipate probable changes in water supply and demand. More and more climate scenario information is available globally, but so far, they have not been translated into regional impacts in the Altiplano region. This study aims to assess the hydrological response to climate changes in 5 basins draining into the Titicaca Lake in Peru, the largest lake in South America and the world's highest navigable lake. For this purpose, the Soil and Water Assessment Tool (SWAT) model was setup for the first time for the Altiplano region, and climate scenarios based on the Representative Concentration Pathways (RCPs) have been downscaled using a statistical approach. In all basins, the results show a good model performance in the discharge and water balance components simulation (Nash Sutcliffe efficiency NSE > 0.8 and percent bias ≈ 0). A special focus in the calibration was on the baseflow simulation by contrasting the baseflow index (BFI) estimated by SWAT with the BFI estimated by the baseflow filter program (BFLOW), because BFI is highly sensitive to model parameters (e.g. curve number) and BFI proved to be important to achieve consistent model outputs regarding the discharge components (surface runoff and baseflow) in the target region. The assessment of climate change impacts was performed for four different RCPs covering moderate to high-end global warming with five climate model members each in order to quantify the propagation of scenario and climate model uncertainty. The study findings are highly relevant for sustainable water resources management in the Altiplano region, where it is necessary to guide sustainable development plans currently developed by government agencies.

Keywords

Hydrological modelling; Climate change impact; Altiplano; Titicaca Lake; SWAT

Hydrologic response to land use changes in Upper East Fork White River

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Abstract

Land use changes over the last four decades in the headwaters of Upper East Fork White river in Indiana state leaded to a more urbanized and intensively agricultural way of economic development. Water resources are directly linked with the land use changes and crop rotations as the most important components affecting water demand, surface – groundwater interactions and water quality. Expanding urban development and agricultural economy are the main drivers affecting the regional hydrological regime of this Wabash river sub-basins group. This research work attempts to assess the water – food production relations and focuses on the land use changes following a land accounting methodological framework and their impacts to water balance, water demand and sediments during the last 3 decades. Data sources from USGS, Indiana State Department of Natural Resources, USDA and NOAA provided the necessary data inputs for this study. The hydrological simulation was conducted via the ArcSWAT model and SUFI-2 algorithm has been utilized to calibrate its parameters and assess their sensitivity.

Keywords

land use changes, water balance, water demand, crop yield, SWAT, SWAT-CUP

Overcoming the challenges in hydrological modelling of irrigated catchments in SE Victoria

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Abstract

Irrigated agriculture in Victoria, Australia covers 3% in area and accounts for 79% of consumptive water use. Significant public and private investment has been directed to modernise irrigation infrastructure both at farm and regional levels with the aim of gaining most productive use of water whilst mitigating environmental impacts. Effectiveness and efficiency of the improved infrastructure are mostly assessed at catchment scales. Irrigation is the largest water balance term in these catchments. Therefore, irrigation data at the appropriate spatial-temporal scale is required as input in hydrological models to obtain reliable estimates of catchment water balance. However, irrigated catchments pose challenges in hydrological modelling due to the varied nature of irrigation systems (flood irrigation, subsurface drip and sprinkler irrigation systems) that is exacerbated by the on-farm reuse dams used to capture and recycle irrigation runoff. With the modernization of irrigation systems in Victoria, spatial-temporal irrigation data is increasingly becoming available and can be integrated in hydrological models. In our recent work, the spatial-temporal irrigation data was aggregated to catchment level for ease of application in SWAT. Incorporating aspects of both crop water requirement and variable irrigation application rates as is practiced by farmers improved water balance estimates simulated by SWAT. Limitations with the 'auto-irrigation' in SWAT were highlighted. Subsequent work to be presented includes i) development of a method for applying the spatial-temporal data in SWAT without aggregation. This involves writing code to process irrigation data at HRU level and writing it to SWAT *.mgt files, ii) adapting/modifying SWAT to include on-farm reuse dams and their operation so that their impact on water demand and environment can be assessed.

Keywords

auto-irrigation, SWAT, farm dams

Application of SLEEP and SWAT models for estimating streamflow with incomplete soil data in Krasioa basin, Thailand

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Abstract

Data on soil properties are indispensable for hydrological modeling by SWAT. Soil information of Thailand was primarily provided by the Department of Land Development (DLD), nevertheless soil data are available only in arable land whose slope is less than 35%. The steep-slope land was generally defined as Slope Complex (SC), there is no other data available. In this paper, soil-landscape modeling by SLEEP was applied for fulfilling the required soil data in hydrologic modeling for streamflow estimation in Krasioa basin, Thailand. The methodology included: (1) the development of regression model based on soil-landscape approach by SLEEP model for predicting the missing data on soil properties; (2) the development of SWAT-based hydrological model for streamflow simulation; and (3) the evaluation of model performance on streamflow estimation of Krasioa basin. The physical soil properties, predicted by SLEEP, included soil depth, fraction of soil particles (clay, sand, organic matter). The additional hydraulic soil properties (hydraulic conductivity, available water content) were estimated using pedo-transfer function approach by Rosetta. It was found that SLEEP model could provide consistent information on soil properties. The predicted soil properties from SLEEP model improved also the performance of SWAT model for reservoir inflow estimation in Krasioa basin.

Keywords

hydrology, soil-landscape modeling, SWAT, SLEEP

Simulation of runoff changes based-on land use/cover in Lam Pachi basin by CA-Markov and SWAT models

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Abstract

Surface runoff is a key component in hydrological cycle. The quantification of runoff indicates water resources availabilities in a basin and provides important information for water management. Land use/land cover are one of main factors affecting runoff processes. This research aimed to projecting the effects of land use/land cover change (LULCC) on runoff yield in Lam Pachi basin, Western Thailand. The methodology included: (1) the development of CA-Markov model for spatially projection of future land use/land cover; (2) the development of SWAT-based hydrological model for evaluating the runoff response to the projected LULCC; and (3) the simulation of impact of LULCC on runoff yield in the Lam Pachi basin by SWAT model. The result revealed that more than half of the Lam Pachi Basin covered by forest area. The CA-Markov model projected the future land use in the next 45 years. The forest area would decrease about 7.6%, while the agricultural area would increase at the similar rate. Simulation study by SWAT model also showed minor changes in term of water yield at the basin scale. More changes could be observed at subbasin level. Agricultural land yielded more water than forest in high land. The land conversion from forest to agriculture in sloped high-land resulted in increase of water yield, whereas the same conversion in flat low-land resulted in reduction of yield.

Keywords

hydrology, runoff, land use, CA-Markov, SWAT

Easy to Use Workflows for Catchment Modelling: Towards Reproducible Model Studies

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Abstract

Catchment-scale hydrological models have a variety of users who often need to adapt their model before it can be applied to their case study. To this end, most catchment models use a Graphical User Interface (GUI) to allow direct manipulation of the models. While a GUI is generally easy to use for novice users, it opens many sources of irreproducible research in the scientific community. Here we present a workflow for the Soil and Water Assessment Tool (SWAT) that promotes reproducible model studies while remaining user-friendly for both novice and expert users. The python-based wrapper that uses pre-processed input data and a namelist file to build the QSWAT model and run it without further user interaction. We then apply this environment to the Blue Nile catchment and show that it yields the exact same results as building the QSWAT model through the GUI. Our results indicate benefits using the automated workflow over the GUI in rebuilding earlier model configurations and implementing changes to an existing set-up while saving time in the model building process. All the while, the model configuration can still be viewed and modified in the GUI. We conclude that workflows can help reduce cases of irreproducible research in catchment modelling and offer benefits for researchers building upon existing model configurations. Workflows also open the opportunities for using high performance infrastructure for large catchment model setup without losing interoperability with GUIs. This workflow is publicly available with a minimal working example under the MIT licence on github: https://github.com/VUB-HYDR/2018_Chawanda_etal_EMS

Keywords

SWAT, reproducibility, hydrology,modelling, workflows.

SWAT Interoperability Using Web Service Workflows

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Abstract

The Soil and Water Assessment Tool (SWAT) is the preeminent hydrological modeling software. There are tools that facilitate data preprocessing (e.g. ArcSWAT, QSWAT) and model calibration (e.g. SWATCUP), and other useful software and scripts (e.g. solACE) that accomplish a variety of tasks. However, the transition from data to decisions is not seamless and this offers opportunities to improve interoperability.

The Open Geospatial Consortium Web Services (OWS) are set of standards for the exchange and processing of geospatial data. They cover a broad range of topics from sensor networks to data catalog indexing, static maps to moving features, and time series to location services. The purpose of these standards is to improve interoperability in the geospatial arena and promote the sharing of resources, and these benefits can be brought to SWAT.

The Web Feature Service (WFS), Web Coverage Service (WCS), Web Processing Service (WPS) are three OWS standards that handle vector data, raster data, and computation respectively. This work focused on combining these services into a seamless workflow for geospatial data that can be incorporated into a SWAT analysis to increase the speed, accuracy, and ease of managing the required geospatial data. The discussion of this work will cover the progress and future development intended to bring the full breadth of OWS benefits to SWAT analysis.

Keywords

SWAT, Web Services, Python

Developing a hydrogeochemical model for implementation in SWAT model at the global scale

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Abstract

Hydrological and geochemical processes, such as water routing and mineral dissolution, define water chemistry and impact on water quality. Understanding how solutes move and react inland and instream is important to estimate the chemical loads to rivers and oceans as well as to quantify biogeochemical rates. Models are useful tools for these analyses, but the development of hydrological and geochemical models has been advancing with little integration. The present study aims to develop a model at the global scale to quantify the major ion fluxes in river streams, and to integrate it in the widely used hydrological model SWAT (Soil Water Assessment Tool). For this purpose, the GloRiCh dataset (Hartmann et al 2014), with over 1 270 000 samples on more than 15 000 catchments, and the GLiM map (Hartmann and Moosdorf, 2012) have been explored together to investigate the statistical relationships between variables describing chemical fluxes in streams and the lithological composition of catchments. A set of equations describing these relationships were tested using cross validation to evaluate model performance and obtain a set of values for the estimators. The relationship exploration highlighted the strong relation of chemical fluxes with discharge, lithology and morphological variables such as slope and altitude. The validation of the model was performed in local catchments in Europe, not included in the GloRiCh database. These equations are then expected to be implemented in FORTRAN in SWAT to estimate chemical loads in catchments. This work will allow an integrative analysis of both hydrological and geochemical processes at a catchment scale.

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Keywords

Hydrogeochemistry; Conceptual model; Global scale

Coupling the SWAT+ and MODFLOW codes for enhanced surface / subsurface flow modeling in watersheds

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Abstract

A new version of SWAT-MODFLOW, called SWAT+MODFLOW (read as "SWAT plus MODFLOW), was developed to enhance surface-subsurface hydrological processes and provide various scenario options for watershed management. Linking SWAT+ with MODFLOW provides a prime opportunity to establish physically-based groundwater modeling in the new generation of SWAT modeling efforts. A spatial object-approach applied to the restructured SWAT+ code not only improves spatial representation of elements and processes but also provides more flexibility in defining spatial interactions of hydrologic objects in watersheds. The newly coupled SWAT+MODFLOW model employs these new capabilities from SWAT+. In SWAT+MODFLOW, MODFLOW grid cells are defined as separate spatial objects that receive/provide water from/to SWAT+ stream channels, making the interaction between the two models more efficient than the previous SWAT-MODFLOW code and allows for ease in its future code development. To encompass the intrinsic and extrinsic characteristics of watersheds, several dynamic functions that manage shallow water tables, irrigation-pumping interactions, and subsurface drains are implemented in the SWAT+MODFLOW model. The use of the model is demonstrated through two case studies: a 471 km^2 regional site in the Middle Bosque River Watershed in central Texas and the 334 km^2 Little River Experimental Watershed (LREW) near Tifton, Georgia. As this newly coupled SWAT+MODFLOW model offers more flexibility than SWAT-MODFLOW, with regards to the delineation and interaction of spatial objects in a watershed, it can be used, not only for groundwater-dominated watersheds that require a more detailed simulation of groundwater processes, but also in watersheds with a large degree of human management, i.e. via reservoirs, canals, wells, drains, etc.

Keywords

Spatial object; Interaction; SWAT+; MODFLOW

Using the SWAT model to simulate surface runoff under climate changes conditions in the Pontal watershed, Pernambuco, Brazil

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Abstract

Naturally, semi-arid basins experience climatic adversities. These adversities are related to low rainfall and consequently low, or virtually zero, water runoff. In addition to these natural variations, the IPCC reports have been indicating that the world's semi-arid areas will become more arid as climate changes intensify. The objective of this study is to evaluate the impact of climate changes on the surface runoff of the Pontal, Pernambuco, Brazil basin, using the SWAT model. In this study, the period from 2015 to 2030 was analyzed using the model previously calibrated and validated by Miranda (2017). Simulated temperature and rainfall data for this period were acquired from reanalysis by the PRECIS climate model. This model produces regional climate data for climate impacts studies. In summary, it is a regional climate modeling system, and its data served as inputs into the SWAT model in our study. The results showed that by 2020 we will still not have major changes in surface runoff. However by 2025, it is very likely that the surface runoff in the Pontal basin will present a significant variation when compared to present time, because of the intensification of extreme events. We concluded that according to the simulations of the PRECIS and SWAT models for the Pontal basin, until 2030 we will have influence from climatic changes in the surface runoff with significant occurrence of extreme events.

Keywords

management of water resources , Brazil, Semiarid, land use, climate change

SWAT-based simulation of climate change impact on water and sediment inflow to Lake Volta in West Africa

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Abstract

The Volta Lake is fed by the Volta river system of West Africa and it is one of the largest man-made lakes in the world. Located in Ghana, the Lake supports the generation of 1,060 MW of hydroelectric power and accounts for 85% of inland fish production. Sustainability of the benefits is dependent on, among other factors, water and sediment inflow, which are climate sensitive. Therefore, quantifying the impacts of climate change on water and sediment inflow can inform adaptation strategies and sustainable management of the lake. This paper uses the Soil and Water Assessment Tool (SWAT) and ensemble of 10 regional climate projections to quantify the impacts of climate change on water and sediment inflow to Lake Volta. Prior to the impact analysis, the SWAT model was adapted to the Volta Basin through calibration and validation of discharge and sediment at 3 guage stations on the 3 main tributaries (Black Volta, White Volta and Oti rivers) over a period of two decades (1991-2010). The climate scenarios consisted of projections from 2 regional climate models (RCA4 and CCLM) constrained with boundary conditions from 3 global climate models (MPI-ESM, EC-EARTH, and CNRM5) and driven by 2 IPCC most recent emission scenarios (RCP4.5 and RCP8.5). Biases in the projections from the regional climate models were corrected using the quantile-quantile transformation. The study baseline was set to 1983-2010 while 1951-2080 was used as the future horizon. The performance of the SWAT model in reproducing the monthly discharge and sediment in the tributaries feeding the Lake was largely good as the computed quantitative statistics (coefficient of determination, Nash-Sutcliff model efficiency, and percent bias) at calibration and validation were above the suggested minimum requirements for satisfactory calibration. Relative to the baseline, the future annual discharge into the lake from the three main tributaries combined is projected to reduce, on average, by 21% (ensemble range: -13% to -20%) and 27% (-22% to -32%) under RCP4.5 and RCP8.5, respectively. The projected reductions are more pronounced in the second half of the year, compared to the first half. Temporal patterns of discharge in the tributaries remain unchanged, with peaks in August/September. However, the peaks will be reduced substantially. Similar to discharge, suspended sediment inflow to the lake is projected to reduce, on average by 15%, with ensemble range of -29% to +3% for RCP4.5. Under RCP8.5, the projected reduction is lower, with ensemble mean and range of 4% and -15% to +6%, respectively. The projected changes in discharge and sediment will most likely result in significant reduction in future hydropower and fish production benefits from the Lake and therefore sustainable adaptation measures including exploring other sources of energy and fish production should be explored, going into the future.

Keywords

Climate Change, Hydrological modeling, Lake Volta, Suspended Sediment, SWAT, Volta Basin

Assessing impacts of climate change on priorities for land management strategies

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Abstract

Ecosystem service tradeoffs may be affected by climate change. Land management strategies designed to balance ecosystem conflicts may have to be adapted to account for these changes. The balance may be achieved either by segregating ecosystem services (land sparing) or integrating them (land sharing). This study assesses the potential impacts of future climate change on food provision on the one hand, and water quantity, water quality, and erosion regulation services on the other hand. The study is conducted assuming different scenarios of land use and management (actual, land sharing, land sparing) for the Broye catchment located in Western Switzerland. SWAT (Soil and Water Assessment Tool) was setup for this region for 1981 to 2015 including 5 years warm up period and parameterized for daily streamflow and monthly nitrate load. A climate change scenario (A1B) for the time horizon 2050 was fed into the parameterized SWAT model in combination with the three land management scenarios. Results revealed a general reduction in water quantity and quality under climate change for all three land management scenarios. Under climate change, the land sparing strategy becomes the least favorable, because of its negative effects on water quality and quantity due to increasing irrigation demands.

Keywords

Adaptation, ecosystem services, land sharing, land sparing, SWAT model, water quantity, water quality

Climate Change Effects on Flooding: a case study of flood, 2012 in Mighty Brahmaputra-Jamuna River at Bogra District.

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Abstract

Bangladesh is a country of natural disasters. Floods, Cyclone, River bank erosion, Tornado, Draughts are the common ones. Among of these, flood is the most common and normal phenomenon in the deltaic plains of Bangladesh. Different types of floods occur in this country but major is monsoon or river flood. The main causes of flood are unique geographical location, excessive precipitation, siltation of river bed, low topography and flat slope and climate change effect. In normal years, about 30% and in case of devastating floods about 50% to 70% of the land area is inundated in Bangladesh. The effects of flooding are mostly negative such as: dislocations of human normal life, damage to the agriculture and property, river bank erosion, siltation of river bed, deterioration to environment, increase the different water borne diseases. The flood problem in Bangladesh is extremely complex and the situation is deteriorating day by day. The main problems are the country is an active delta; it has extensive flood plains into which about 1.7 million sq. km drain; it has an extensive network of rivers and canals and the effects of climate change. This country is highly vulnerable to climate change impacts specially on flooding. Also the climate change effects are reducing the flow capacity of major river system and increasing sea water level in Bangladesh. As a result flood occurring in Bangladesh almost every year and devastating ones in every 5 to 10 years. Bangladesh in frequent is subjected to flood because much of the country occupies the deltaic flood plains of the Brahmaputra-Jamuna, Ganges-Padma, and Meghna Rivers, which is the second largest river system in the world. Brahmaputra-Jamuna is the biggest river system in Bagladesh, which originated from China. This mighty river is entered at Kurigram and flow through Rangpur, Gaibandha, Bogra, Sirajganj and Pabna district which is carrying about 93% water from outside of Bangladesh i.e. from China, India and Bhutan. The Brahmaputra-Jamuna river has 45 km length in Bogra district. Normally, the flood period of this river between mid of July to mid of September. It is ovserved that the severe floods in the year of 1988, 1998, 2004 and 2007 occurred on the above mentioned duration. But in 2012, first flood peak occurred at the end of May and second peak occurred first week of October which is very alarming. These two peaks of flood mainly occurred due to the effects of climate change which damaged lot of crops, infrastructures, human properties etc at Bogra district. Flood period in Brahmaputra-Jamuna River has been shifted due to the climate change effect. The climate change impacts analysis by the climate model. Also analysis of flood peak from the observed water level of mighty Jamuna river has been done by statistical indices and graphical interpretation. Essential and effective steps need to be taken to save human properties, crops, infrastructures like flood control embankment, river training works, road, bridge and culverts etc. from floods due to climate change of mighty Brahmaputra-Jamuna river at Bogra Disrtict.

The paper deals with the climate change effects on flooding in the mighty Brahmaputra-Jamuna river at Bogra District. Also this paper focuses on flood, 2012 on the same areas.

Keywords

Flood, climate change effect, Brahmaputra-Jamuna River, Bogra.

Crop rotation implications in water balance through land use change scenarios using SWAT model

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Abstract

Nowadays, SWAT model is widely used in hydrologic assessment of catchments. In Spain, in last decade some of SWAT models were implemented in different catchments to assess water balance, reservoir management, water foot print assessment, etc. Nevertheless, the focus on crop rotation and its implications remains under study. The aim of this research is to analyze the implications of crop rotation in the water balance components under three land use different crop rotation schemas. The case study is a sub-arid subbasin of Douro's River in Spain. The land use scenarios assessed in this research were defined from a stakeholder participatory exercise. The use of mapping strategy with stakeholder during a workshop was the tool that allowed to perform the allocation of land use change, based on three European narratives (Land Sharing (LSH), Land sparing (LSP), Land balance (LBA)). The preliminary results are highlighted by differences between reforesting transitions and crop clustering. The water balance components vary in terms of ET, aquifer recharge, and total flow. Lightly augmentation of ET (<1%) in sub arid regions could affect water availability in water channel (-1%) and aquifer recharge reducing around 2% respect to actual situation. Crop rotation in LSH scenario provide some key factors for further research because it implies more water availability in outflow in the channel (+ 1.5%) and (+1.7%) in deep aquifer recharge. Both components are commitments of the RBA (River Basin Authority) to achieve in next RBMP (River basin management plans).

Keywords

SWAT, Spain, Water balance, land use scenarios, crop rotation

Web Based Water Resources Information System Using SWAT model

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Abstract

The available river waters would fall short of demand in near future due to increase in the demand for water for domestic, industrial and municipal uses as a result of the development of civilization and the growth of cities. There is a continued steady increase in the utilization of river water, so much so, that the available river waters would fall short of demand in near future. The struggle to obtain adequate supplies of water for both large and small communities has continued to the present times. India supports 1/6th of the world population with about 1/15th of the world's land and only 1/250th the world water resources. India would have to lay serious consideration for fast emerging crisis in water related areas and adopt proper strategies to ensure integrated water resources management including floods and droughts. The erratic behaviour of Indian monsoon causes almost each year droughts and floods to occur simultaneously, sometimes even within the same state. The impact of floods is stronger today than ever because of rapid increase in population and resulting industrial and agricultural development and increasing occupation in the flood plains. Also the flood damage continues to show an increasing trend despite the introduction of substantial structural (embankments) and non–structural flood control measures during past several decades in the country. It is a big challenge in India to properly moderate floods and droughts together. Water logging and drainage congestion is also a serious problem in certain areas.Water resource management is of primary importance to the society, economy and the environment. Climate change is expected to have significant effects on the hydrological cycle. Formulation of adaption strategy for these changes requires an understanding of the complex consequences of climate change on the hydrology, human and environmental uses of water so that a sustainable option is selected.The study presents a web based water resources information system intended to meet the specific information needs connected with water related aspects of the various line departments of a typical state (Bihar, India). The Soil and Water Assessment Tool (SWAT) hydrological model with ArcGIS interface has been used to simulate various water balance components, flow, silt distribution and water quality. The above issues with special reference to the Bagmati sub-basin has been described and discussed in detail.

Keywords

Floods, Droughts, Silt distribution, waterlogging and drainage congestion, embankments, SWAT, Hydrological model, ArcGIS interface, Bagmati sub-basin

The multiple imputation approaches for interpolating rainfall data series and their applications to watershed models

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Abstract

Abstract: Rainfall data scarcity has caused enormous problems in hydrologic and non-point pollution (H/NPS) predictions, as rainfall data represent the key input to watershed models. In this study, the effects of different interpolation methods such as the data augmentation (DA) and the expectation maximization with bootstrap (EMB) algorithms on rainfall data scarcity were compared. The effects of different data scarcity rates and positions on model performance and prediction uncertainty were then quantified. Finally, the effects of different imputed data sets on H/NPS results were evaluated with the soil and water assessment tool (SWAT). A real case study in the Daning River watershed, Three Gorges Reservoir Region, China, was evaluated. The results indicated that rainfall data scarcity would result in poor model performance and large prediction uncertainty, especially during the low flow period. The imputation rainfall data and the H/NPS model performance obtained by the EMB algorithm were superior to the traditional DA and weather generator performances. This advantage of the EMB algorithm would be more definitive if a specific threshold of data scarcity was reached. This paper also noted that even if the best algorithm was used, the imputed value was always lower than the peak observed value. This paper reports important implications for the choice of imputation methods and the use of H/NPS models for solving data scarcity problems for watershed studies.

Keywords

Keywords: EMB algorithm; multiple imputation methods; non-point source pollution; scarce data; SWAT

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