INTERNATIONAL SOIL
AND WATER ASSESSMENT
TOOL CONFERENCE

SWAT 2019

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BOOK OF ABSTRACTS

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 2019 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 University of Natural Resources & Life Sciences (BOKU) along with Prof. Dr. Andreas Klik, Dr. Bano Mehdi, and the rest of the local organizing committee in Vienna 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.

Local Organizing Committee

Local organizing committee members are with University of Natural Resources & Life Sciences (BOKU), Vienna, Austria.

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Overview of SWAT+ options for simulating groundwater processes

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Abstract

One of the main advantages of SWAT+ compared to SWAT is the model's flexibility in representing spatial objects within a watershed and their connectivity. This opens new possibilities with regards to simulating groundwater processes. In this presentation, we explore some of these possibilities by comparing different model setups for the Little River Experimental Watershed in Georgia, United States. In the first setup, the subbasins of the watershed are divided into upland and floodplain landscape units and each landscape unit has an aquifer, resulting in a total of 1248 aquifers. In the second setup, these relatively small aquifers are aggregated into five larger aquifers. Accordingly, several streams receive groundwater flow from the same aquifer. The amount of groundwater flow each stream receives depends on its drainage area, which results in a better representation of seasonal drying and wetting of headwater streams. Finally, in a third setup, we use MODFLOW to simulate groundwater processes and the interaction of groundwater and SWAT+ river channels. We discuss the advantages and disadvantages of the three SWAT+ model setups and provide recommendations on when to use which option for simulating groundwater processes.

Keywords

spatial objects, connectivity, groundwater, MODFLOW

SWAT+ Estimates of Peak Flows for a Coastal Plain Watershed

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Abstract

Peak-streamflow estimates are required for assessment of flood risk, flood-plain management, and cost-effective design of structures. In watersheds with shallow water tables, peak-streamflow is heavily influenced by available water storage in the subsoil. Available storage is influenced by topography, geology, vegetation, antecedent rainfall, and climatic season. Accurate streamflow estimates must incorporate accurate representations of the available storage. We examined forty-five (1972-2016) years of streamflow data from the Little River Experimental Watershed (LREW) to test the ability of the SWAT+ model to estimate peak streamflow. The LREW is located near Tifton, Georgia, in the Southeastern Plains Ecoregion of the U.S.A. Flow within the watershed is heavily influenced by groundwater. The peak flow events from this period of record were examined based upon antecedent rainfall and climatic season. Comparisons were then made between the observed peak flow data and SWAT+ estimates of peak flow. The ability of the SWAT+ model to accurately estimate peak flow for the LREW based upon precipitation and climatic season was evaluated.

Keywords

Streamflow, hydrology, groundwater, antecedent soil moisture

Africa SWAT+ Model for Climate Change and Land Use Change Studies

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Abstract

Surface water provides several benefits to African communities. Over the years, surface water resources have undergone changes due to Climate Change (CC). There also have been significant Land Use and Land Cover Change (LULCC). In light of CC and LULCC, a continuous assessment of water availability is important. However, the assessment of water resources remains a challenge due to a complex and rapidly changing geography of water supply and use. Hydrological models have been applied to assess seasonal and geographic patterns as well as different scenarios. We elaborated a workflow that uses a Land Use Harmonisation project map to set up a hydrological model for Africa using the Soil and Water Assessment Tool Plus (SWAT+). The model has 5502 basins and landscape units and 448070 Hydrologic Response Units. We first set up and calibrated major river basins using a soft calibration technique, and then transferred the parameters to the continental model. The model performance was significantly improved by the soft-calibration in terms of NSE and PBIAS and it further improved after implementing reservoirs and wetlands. The SWAT+ model and results for Africa will provide support for the assessment of CC and LULCC impact on water availability in Africa.

Keywords

SWAT+, Africa, Climate Change, Land Use Change, Hydrological Model

How can we represent seasonal land use dynamics in SWAT and SWAT+ models for African cultivated catchments?

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Abstract

Hydrological processes are driven by soil properties, land use characteristics and topographic factors. In the SWAT and SWAT+ models, these variations are represented by Hydrological Response Units which are defined based on the DEM, land use and soil maps using a GIS interface which also provides a default model that uses a single growing cycle for agricultural land covers. However, agricultural land use typically consists of several cropping seasons following the dry and wet seasonal patterns. It is possible to adjust these default crop use settings manually, but this is rarely done, especially in Africa.

In this study, we propose a procedure to incorporate agricultural seasonal land use dynamics by linking Land Use and Land Cover maps to land use trajectories instead of land cover classes. This approach was tested in SWAT and SWAT+ models of the Usa catchment in Tanzania that is intensively cultivated by implementing the dominant dynamic trajectories. Our results were evaluated with remote sensing observations for LAI and ET.

Results showed an agreement between SWAT and SWAT+ model outputs of ET and LAI with remote sensing products. The values were slightly underestimated by the SWAT model and greatly overestimated by the SWAT+ model. However, an improved vegetation simulation by the trajectory models corresponding with the seasonal rainfall patterns was observed. It was concluded that the representation of seasonal land use dynamics through trajectory implementation can lead to more realistic temporal advancements of LAI and ET in SWAT and SWAT+ models. It is recommended to extend the land use maps towards land use dynamic maps through land use trajectories and to use this information directly by the SWAT and SWAT+ interface to generate a better default model especially for cultivated catchments.

Keywords

SWAT+, Landuse Dynamics, Trajectories, SWAT, LAI, ET

IPEAT+: FORTRAN-based Automatic Calibration Tool Coupled with SWAT+

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Abstract

In the past two decades, the Soil and Water Assessment Tool (SWAT) has been implemented to various research and engineering subjects in the world. However, the development of SWAT has been considerably restricted by the original platform despite its great success. Therefore, a fully restructured version, SWAT+, has been introduced recently with a new modular structure to facilitate model development. In SWAT+, users have more flexibility in updating/modulating source code with more powerful and reliable functions. Nevertheless, it is still inevitable that users may need to calibrate the model before conducting management applications such as conservation practices. In this study, IPEAT+ is developed to provide an efficient automatic calibration tool that is coupled with SWAT+ in the FORTRAN source code. IPEAT+ runs with SWAT+ jointly as a single executable without additional software installation. The features and capabilities of IPEAT+ are demonstrated through an application to the 471 km^2 Middle Bosque River Watershed in the Texas-Gulf Region of Central Texas, United States. Users can take this as an entry-level example to pursue more sophisticated tasks in the future.

Keywords

SWAT+; IPEAT+; Model calibration; Optimization

Framework for quantifying uncertainty, sensitivity, and estimating parameters for SWAT+ with MODFLOW routines

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Abstract

Integrated water resource management in river basins is often accomplished using complex coupled groundwater/surface water hydrologic models. A recent version of SWAT+ has been modified by including the physically-based, spatially-distributed groundwater flow model MODFLOW to improve the simulation of groundwater flow and groundwater-surface water interactions on the catchment scale. We present a general framework for performing sensitivity analysis, parameter estimation, and uncertainty analysis for integrated surface water-groundwater models, using SWAT+ with MODFLOW as an example. To jointly and simultaneously estimate the values and sensitivity of both land surface (SWAT+) and subsurface (MODFLOW) parameters in a single automated calibration method, the PEST (Parameter ESTimation tool) was used with a Python script for post-processing in batch mode. The framework is demonstrated through an application to the 471 km^2 Middle Bosque River Watershed in central Texas. Land surface parameters from SWAT+ [available water capacity of the soil layer (SOL_AWC), runoff curve number (CN2), soil evaporation compensation factor (ESCO)] and groundwater parameters from MODFLOW [hydraulic conductivity (K), specific yield (S_y), river bed conductance] were assigned as field parameters. Nine zones were used for K and S_y, and three values were used for river bed conductance, resulting in a total of 24 parameters. The model output was compared to streamflow at the watershed outlet measured from 1993-2012 and groundwater levels from two observation wells measured during 1985-1986. Comparison statistics such as the Nash-Sutcliffe Efficiency (NSE), R^2, and PBIAS were used to evaluate model results. Parameter estimation was performed for the data from 1985 to 2005 and the years 2005-2012 were used for validation. This framework can facilitate the use of integrated models worldwide to assist with finding technical solutions to water issues.

Keywords

SWAT+, MODFLOW, Uncertainty, Sensitivity, Calibration

Sensitivity Analysis of Runoff Using SWAT: a Case Study of Large Mountainous Watershed in North India

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Abstract

Hydrological models play vital role in understanding and management of the water resources especially in the region which are mountainous. The physically based distributed model, Soil and Water Assessment Tool (SWAT) is applied to the watershed lying north of Tehri Garhwal District, Uttarakhand at the Tehri Dam to determine the perturbations on runoff due to rainfall and temperature. This watershed lies between the latitudes $30^0$5'N to 31^0 40' N and longitudes 78^0 10'E to 79 ^{0} 25'E with an area of about 7296 sq.km. The model was calibrated for the period of 1985-2005 and validated for 2006-2013. The R^2 and NSE for the calibration dataset was 0.65 and 0.45 and for the validation dataset was 0.47 and 0.32 respectively. R^2 was set as the objective function. The major influencing parameter is found to be Initial SCS runoff curve number (CN2). The sensitivity analysis on runoff is performed with respect to rainfall (-5%, -10%, -15% and + 5%, +10%, +15%), temperature (+1^{0}C, +2^{0}C, +3^{0}C) while using them as an input data for SWAT. The study would be very useful in understanding the issues of sensitivity analysis in of Large Mountainous Watershed.

Keywords

Sensitivity analysis, SWAT, Large Mountainous Watershed

Regional Irrigation Water Demand: Addressing Uncertainties for Better Prediction

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Abstract

Agricultural water accounts for 70% of global water use. Therefore, its reliable simulation is extremely important for efficient water resources management. Hydrological simulations are always subjected to uncertainty due to input data, model parameters, model structure and the inherent randomness in the natural processes. It is a challenge in the hydrologic sciences to fully quantify and reduce these uncertainties, in particular when water management operations are included. The current study uses an ensemble approach to simulate the irrigation water demand by SWAT at regional scale while addressing together the parameter and model structural uncertainties. We have found that SWAT (Soil and Water Assessment Tool) is good at simulating the average irrigation water demand and crop yield but fails to simulate their overall variability. Physical process are well defined in small-scale agricultural models compared to regional models. Therefore, two field scale [DAISY and SWAP (Soil-Water-Plant-Atmosphere)] and one catchment scale (SWAT) models were used to check the whether a combined ensemble is a good predictor for irrigation water demand and crop yield at the regional scale. The parameter and model structural uncertainty was quantified for a sub-catchment of the Ilmenau River located in Lower Saxony, Germany. The results compare how multi-model and multi-parameter ensemble would reduce the overall model uncertainty and better simulate the irrigation water demand and crop yield compared to SWAT for four agricultural crops at the regional scale. This will help researchers to address uncertainties in irrigation prediction at regional scale e.g., in the context of climate change prediction or regional irrigation consulting.

Keywords

Irrigation water requirement, model structural uncertainty, parameter uncertainty, model ensemble

Calibration and validation in hydrologically altered basins: A case study involving the SWAT and AQUATOOL models in the Iberian Peninsula

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Abstract

Calibration of physically based hydrological models such as the soil and water assessment tool (SWAT) requires the availability of streamflow time series that adequately represent rainfall-runoff processes. However, in most rivers on a global scale this circumstance only occurs in the headwaters, due to the high regulation that the rivers present to satisfy the existing demands. This has led to hydrological models not adequately capturing the physical processes involved, since they can adequately characterize headwaters, while in subbasins associated with the middle and lower reaches of rivers the uncertainty can be significant. This paper presents a methodology tested in the Spanish part of the Duero river basin district (77.626 km^2), which aims to obtain a more reliable hydrological model based on the use during the calibration and validation process of a set of streamflow time series that correspond, both with gauging stations that record natural streamflow (12 were selected) and others reconstructed to natural streamflow (a total of nine) due to their significant hydrological alteration. To this end, the Decision Support System Environment AQUATOOL for water resources planning and management was employed. SWAT, was used here to model the hydrology, being the resulting model calibrated and validated considering sensitivity and uncertainty analysis. The regionalization of the model parameters was based on the measurement of the physical similarity between the parameters of the gauged and ungauged basins. The proposed methodology was successfully implemented, with the flows modeled properly portraying the overall hydrologic response of the basin.

Acknowledgements:

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Keywords

natural streamflow, hydrological regime alteration, uncertainty analysis, water resources planning and management, hydrological model

Hydrological Simulation of a Small Tropical Watershed in Central India Using SWAT

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Abstract

Various studies have been carried out in the past to analyze and quantify the numerous effects of increasing urbanization on various hydrological processes and subsequently on water resources in river catchment. In the present study, Soil and water assessment model (SWAT) was considered and applied over the catchment of Kharun watershed, Chhattisgarh, India to study the hydrological response. The primary objective of this study was to learn about SWAT model and test its efficacy for Kharun watershed. For calibration and validation purposes SUFI-2 algorithm was applied using SWATCUP2012 on a monthly basis. Based on the comparison of the simulated and the observed flow rates, the model was calibrated and validated for a period of 1990-2005 and 2005-2014 respectively. Therefore, for the monthly time step, the application of the NSE values was 0.79 and 0.61, the determining coefficient (R^2) was 0.85 and 0.51, while the value of PBIAS was 20.4% and 10.4%, and RSR values were registered as 0.46 and 0.63 for the periods of the calibration and validation process respectively. Thus, based on the results it can be inferred that the model has the strong predictive capability for Khaun watershed and can be applied over the catchment of Kharun watershed.

Keywords

Hydrological modeling, SWAT, calibration, validation, SUFI-2, SWAT-CUP

Assessment of Decades Groundwater Use, Forest Growth and Soil Loss Impacts on Watershed Hydrology of Geum River Basin in South Korea using SWAT

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Abstract

This study tries to quantify decades groundwater abstraction, forest growth, and soil erosion impacts on watershed hydrology for Geum river basin (9,645.5 km2) of South Korea using SWAT (Soil and Water Assessment Tool). The decadal-unit data of groundwater use (GU), forest height (FH) and soil depth (SD) by water erosion from 1976 to 2015 were prepared from the government statistical data, forest GIS database, and a distributed soil erosion and deposition modeling respectively. From 1976 to 2005, the GU increased 74.1%, the average FH increased from 3.8 m to 8.4 m, and the average SD decreased from 12.1 mm to 11.2 mm. For 10 years (2006~2015), the SWAT was calibrated with daily inflow and storage water level data of two dams (DCD and YDD), groundwater level data at five locations (JSJS, OCCS, BEMR, CASS, and BYBY) including over three years (August 2012 to December 2015) streamflow and storage water level data of three weirs (SJW, GJW, and BJW). The Nash–Sutcliffe efficiency (NSE) of 2 dams inflow and the coefficient of determination (R2) of storage water level were 0.55~0.70 and 0.67~0.75 respectively. The NSE of 3 weirs inflow was 0.57~0.77 and the R2 of storage water level was 0.62~0.81. The R2 for the 5 groundwater levels ranged from 0.53 to 0.61. After, the SWAT evaluated the past watershed hydrology by applying the prepared data of 1976~1985, 1986~1995, and 1996~2005 for each decade. Also, the SWAT runs the whole periods of 1976 to 2005 by fixing input on 2006~2015 database and compared this result with the 4 periods separate results to quantify how much the GU, FH, SD affected to the watershed hydrology for 40 years.

Acknowledgements
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Keywords

SWAT, Groundwater Use, Forest Height, Soil Erosion, Hydrology

Study on Impact of Land-Use Changes on Surface Runoff Modeling in Lower Thamirabarani Sub-Basin

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Abstract

Runoff is one of the important hydrological process in the watershed which is mainly responsible for the erosion of soils and sediments, carrying organic components and dispersing pollutants to the outlet. Mapping of spatial variability of surface water quantity is of vigorous importance and it is predominantly substantial where it is primary source of drinking water as well as for irrigation. The present study shows the effects of various land use scenarios (2017, 2005 and 1995) on surface run-off and streamflow in the lower Thamirabarani Sub-basin of Thamirabarani River in Tirunelveli district of Tamil Nadu. In this study, the hydrological model called SWAT was used to perform streamflow analysis for various land uses. The model divided the basin into 29 sub-basins and sub divided into 555 HRUs and the model was run. All the hydrological components are simulated and stream flow was considered at the Hydrological Response Unit (HRU) level. The process of calibration (2010 - 2014), validation (2015 - 2017) and sensitivity analysis were done using SUFI-2 algorithm. The model gave a p-factor of 0.83 and Nash-Sutcliffe (NS) of 0.86 during the calibration period and 0.86 and 0.83 respectively for the validation period of 2017 land use. Similarly, for land use of year 2005 and 1995 the model gave good results such as p-factor in the range of 0.78 to 0.82 and NS in the range of 0.78 to 0.84 during both calibration and validation period. This study shows that SWAT performs well with the observed streamflow data and its effects on different land use scenarios. The results of this study show that increase in urbanization and its impact on agricultural activities with respect to land use changes. To enhance the model performance, more number of observed streamflow gauge stations will be required for the study.

Keywords

Rainfall-runoff, Lower Thamirabarani, Hydrological model, Arc-SWAT, SCS-CN, DEM, Land use and soil map, HRU, SUFI-2, p-factor, NS

Time-scale effects upon SWAT simulations investigating urban watershed sediment export

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Abstract

Time-scale effects on the Soil and Water Assessment Tool (SWAT) eco-hydrological model were evaluated to assess its application toward identifying critical sediment source areas in a highly developed urban watershed. Sessom Creek is a headwater tributary of the San Marcos River in Central Texas. Its small watershed contributes a disproportionately large amount of sediment during storm runoff events which negatively affects aquatic ecosystem health and river recreation. A 3-meter elevation map was used to delineate the stream network in the 173-hectare watershed. Soils were characterized using US Soil Survey Geographic Database (SSURGO) information and a refined landuse map was used to locate impervious cover in the catchment (36% of total). Two SWAT simulations were prepared, one using a daily time step and another using a sub-daily time step. Stormwater runoff was estimated by the NRCS-CN method in daily simulation, while the Green & Ampt method, modified by Mein-Larson, was used in sub-daily simulation. An enhanced Variable Storage Coefficient method was used for dynamic channel flow routing. Flow and sediment yield were examined as response variables and calibrated against observed data collected during 12 storm events in 2018. We hypothesized that results from the daily simulation time scale would be unrepresentative if storm flow was flashy and short in duration, which was the case for Sessom Creek storms. Under these conditions, SWAT daily simulations tend to over-parameterize to compensate for computational gaps in hydrograph estimation. Sub-daily simulations more accurately represented short-duration storm events and provided better estimates of sediment sources. Differences between SWAT daily and sub-daily simulation results are presented.

Keywords

SWAT, erosion management, urban watershed, time-scale effect

Spatial variability of sediment loads under climate and land use changes in the Raba River catchment, Poland

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Abstract

As already reported sediment loads can be altered through the climate and land use changes. Modeling with SWAT is a noted tool to establish trends of sediment loads for specific parts of catchments and their changes under. Moreover, this tool enables sediment spatial variability analyses, and also tracking sediment transport in the catchment. Assessment of spatial variability for sediment loads released for the catchments has a crucial meaning from point of view of reservoir management, due to possibility of silting, but also water quality.

To study this issue the sediment quantity simulations in SWAT tool have been proposed for the Raba River catchment (Southern Poland). The Raba discharging into the Vistula River (134.7 km) has a catchment of a mountain character (Carpathian Foothills), although features a high share of agricultural land use. The Raba River supplies a drinking water reservoir, and its localization separates the whole catchment into two parts. The upper part located upstream to the reservoir, has a distinct mountainous character, while the one following the downstream reach of the river is considered a submontane. Both parts are very different in terms of soil types, land use and terrain. The Raba River catchment, especially upper part, is exposed to the erosional processes, controlled mainly by land slope, soil characteristics, and land use, what has an impact on reservoir silting and water quality of lower reaches. Research conducted in the past in this area suggests that there are significant suspended sediment loads, which will additionally vary depending on the location of the calculation profile.

The final result of the research involve the results of variant scenarios regarding climate change forecasts for this catchment and their impact on sediment loads in reaches compared to baseline simulation, emphasizing its spatial distribution. Analyses were carried out for 50 sub-catchments of Raba catchment with different erodibility conditions, and different reaction for forecasted changes scenarios. The results revealed changes in erosion and, therefore, sediment loads in reaches. Therefore, the spatial variations of erosion intensity in this catchment, and its changes in terms of climate conditions impact and land use types areas modifications, was investigated in this study.

The performed analyses are also helpful in answering one of the key questions for future water management in this catchment: i) What effects on the quantity of suspended sediment will be imposed by the expected climate changes (temperature and precipitation)? ii) Whether it is possible to limit this impact through alterations of the land use of the catchment? and iii) How the forecasted changes will affect the reservoir capacity, and potentially deplete its storage time?

Keywords

sediment loads, climate change, sediment transport, in-stream sediment

The effect of sampling frequency and strategy on water quality modelling driven by continuous monitoring data in a boreal catchment

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Abstract

With conventional water quality monitoring based on grab sampling, usually carried out once a month, it is quite challenging to obtain reliable sediment and nutrient loading estimates, which is a pre-requisite for testing of water quality models. Despite the growing availability of high-frequency water quality monitoring data obtained by using modern sensors, their use in the calibration of water quality models is still limited. The main objective of this study is to evaluate the continuous, six-year-long, high-frequency water quality monitoring data set as a source for the calibration and testing of the Soil Water Assessment Tool (SWAT) in a case study carried out in a medium-sized, boreal catchment in southern Finland. This objective is accomplished by developing a set of 'sub-sampling' scenarios focused on quantifying the effect of the sampling frequency (12 vs. 26 samples per year) and strategy (regular vs. flow-proportional sampling) on the model performance and output uncertainty. The goodness-of-fit of the model calibrated against high-frequency data ('benchmark'), evaluated using the Kling-Gupta Efficiency index for total suspended solids (TSS), nitrate and total nitrogen (NO_3-N and TN) and total phosphorus (TP) daily loads ranged between 0.76 and 0.83 (0.69 and 0.73 in validation period). Overall, the model calibrated against low-frequency data performed worse when evaluated against high-frequency data and compared with the benchmark model for each of the studied water quality parameters. The results show that increasing the sampling frequency from 12 to 26 samples per year leads to an improvement in the model performance, particularly for TSS and TP loads. In contrast to the sampling frequency, the evidence for the effect of the sampling strategy on the model performance was much weaker. The model output uncertainty due to different realizations of sub-sampling scenarios was high for four analysed output indices: basin-averaged, long-term average annual values of soil erosion rate, denitrification rate, NO_3-N yield and soluble P yield. This study demonstrates that more attention should be paid to calibration data as a source of uncertainty in model predictions. It also provides evidence for either a wider adoption of modern sensors providing high-frequency data, or for increasing the grab sampling frequency to reduce the uncertainty of loading estimates, particularly in rivers with flashy flow regime such as the Vantaanjoki River.

Keywords

sampling frequency; sampling strategy; observation uncertainty; high-frequency data

Identifying erosion hotspots in Lake Tana Basin from a multi-site SWAT validation: Opportunity for land managers

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Abstract

Extensive catchment degradation throughout the Ethiopian highlands induced by long-term intensified land use, erosion prone topography and climate cause substantial soil erosion that limits agricultural productivity and result lake sedimentation. However, before taking soil conservation measures, management of the soil loss problem essentially needs catchment level modelling to estimate the geographic distribution of erosion hotspots. With the increasing availability of sediment and spatial data and development of physically-based models, this study aims multi-site calibration of SWAT to map erosion hotspot areas and to assess the effect of well-known land management alternatives in sediment reduction in the Lake Tana Basin (LTB). The SWAT simulations indicated that the goodness of fit between predicted and observed data were satisfactory for all gauge-stations except for one, and the model performance was within acceptable evaluation ratings. Simulated average sediment yield (SY) for the period 2001-2016 at subbasin level varies from negligible to about 169 Mg ha-1 y-1 (basin average 32 Mg ha-1 y-1). High potential SY (> 50 Mg ha-1 y-1) was simulated for 23% of the subbasins in in Megech, upper Rib, upper Gumara and Gilgel Abay catchments due to steep slope topography, aggressive rainfall, croplands dominance and low rock fragment cover. The differences in level of erosion risk among subbasins help to prioritize and target specific areas of the basin that need urgent soil conservation activities. Scenario analysis also showed that implementing stone bunds, *Acacia decurrens* based crop rotation, reforestation and grass contour strips reduce the existing SY by 51–61% at basin level. The potential sediment production could reach tolerable levels by implementing stone bunds, tree-crop rotation and reforestation in steep slope areas and grass contour strips on gentle slopes. Overall, the multi-site calibration of SWAT model using the measured runoff and sediment data produces reasonable results that may support decision makers and planners to implement relevant land management measures and thereby reduce the alarming problems of soil loss in the basin and sedimentation of Lake Tana.

Keywords

multi-gauge calibration, sediment yield, land management alternatives, acacia decurrens, Lake Tana Basin (Ethiopia)

Evaluating Irrigation Water Resources Availability and Climate Change Impacts on Scheme Management – Case Study of Water Balance Simulation of Mwea Irrigation Scheme, Kenya

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Abstract

Mwea Irrigation Scheme (MIS) was established in the 1950s and rice is the predominant crop cultivated there. It is located about 100 Km North East of the capital city, Nairobi. The scheme is divided into five major irrigation blocks namely; Mwea, Thiba, Wamumu, Karaba and Tebere. MIS total area is 8,900 hectares. It is supplied by irrigation water from two main rivers, R. Thiba and R. Nyamindi via fixed weir intakes. The irrigation water is abstracted from the rivers and conveyed via lined and unlined canals to the paddy fields through gravity. Currently, the National Irrigation Board oversees the water management, operation and maintenance of infrastructure such as the intakes and canals, land administration and making of cropping programs. SWAT model was used to characterize the hydrology of the two main rivers and subsequently estimate the total available flow (i.e. water supply). The SWAT model inputs were; Digital Elevation Model (DEM), soil map, land use map, and weather data. The model was set up for running for daily simulation for the period 1979-2009. Calibration and validation of the model was done for the period 1981-1991 using the Sequential Uncertainty Fitting (SUFI-2) algorithm. The model simulation performance was: NSE for calibration and validation were 0.44 and 0.31 respectively; PBIAS for calibration and validation was 12.67 and 2.23 respectively. Irrigation water requirement i.e. water demand (for 2013-2016 cropping seasons) was calculated mainly based on crop evapotranspiration, percolation, and rainfall. From the preliminary hydrological modeling and irrigation water requirement assessment, the water demand outstrips the water supply across the three seasons analyzed. The current analysis focuses the water demand and supply scenarios. Further analysis will be conducted on the actual water deficit (duration and distribution) and farmers adaptation strategies to mitigate the water shortages. As MIS is currently building a dam to help address the water shortages, further hydrological modeling (on reservoir simulation) using future downloaded and downscaled climate data will be conducted with an aim of improving the overall scheme management (water allocation and distribution) and providing insights into the dam operation and management

Keywords

SWAT, water supply, water demand, scheme management

Using SWAT to asses potential hydropower impacts downstream in a data scarce region: Gabon case study

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Abstract

Africa's energy needs are becoming increasingly high as the continent develops technologically and population increases and becomes more urbanized. Under Gabon's "emerging Gabon" vision, a significant focus for economic development is through hydropower expansion. Gabon is a country rich in water resources and abundant natural resources, including pristine riverine systems with endemic species. Under Gabon's "Emerging Gabon" vision, a significant focus for economic development is through hydropower expansion. When not planned and managed properly, hydropower development can have deleterious consequences for ecosystem integrity and resilience. A foundational part of planning requires an understanding of streamflow and sediment regimes. There is a significant two-fold challenge faced in characterizing these processes for much of sub-Saharan Africa: the paucity of historical hydrometeorological data and the high variability and uncertainty in predicted climate change. Our objective in this study was to evaluate whether the SWAT model could effectively be used to illustrate the relative changes in stream discharge and suspended sediment downstream under ten potential hydropower scenarios given limited historical hydrometeorological data. Our purpose was to generate information that supports decisionmakers in assessing tradeoffs among different hydropower scenarios. We used limited historical discharge data at one location to establish area-discharge relationships within the Mbé-Komo and Abanga basins and then used this relationship to generate inflows at 12 locations where the Gabonese government is considering the potential for hydropower production. We calibrated the SWAT model to these inflow points using the SUFI-II algorithm in SWAT-CUP. Our results showed that in a data-scarce region where land use is homogeneous, and change has been limited due to the low human population, using known area-discharge relationships is an approach that can aid in model calibration by providing internal calibration points. This calibrated SWAT model will next be used for scenario analysis to assess the potential impacts of land management practices, for activities such as forestry and agriculture, as well as the influence of predicted climate change.

Keywords

Africa, reservoir, hydropower, parameter regionalization, conservation planning

SWAT Hydrological Simulation of Gongdo Agricultural Watershed in South Korea Using SM2RAIN Rainfall Derived from AMSR-E Satellite Images

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Abstract

Streamflow prediction performance from hydrological models largely relies on the spatial density of ground measured rainfall data. The rainfall information from satellite images are considered as the alternative way for watershed hydrological modeling. In this study, the Soil and Water Assessment Tool (SWAT) modeling were conducted using Advanced Microwave Scanning Radiometer E (AMSR-E) soil moisture data with Soil Moisture to Rain (SM2RAIN) algorithm. The SM2RAIN algorithm (Brocca et al., 2013) was proposed to estimate spatial rainfall from spatial soil moisture information. The AMSR-E soil moisture data for 10 years (2002 to 2011) were converted to daily rainfall data by applying SM2RAIN algorithm and prepared as SWAT rainfall data. The SWAT was calibrated and validated to a 366.5 km^2 agricultural watershed using 14 years (2002 to 2015) daily observed streamflow (Q). The SWAT result using ground rainfall data shows that the average Nash-Sutliffe efficiency (NSE) of Q and 1/Q with 0.78 and 0.58 respectively, and the SWAT result using SM2RAIN rainfall data will be evaluated.

Acknowledgements

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Keywords

SM2RAIN, Rainfall, Remote Sensing, AMSR-E, SWAT Modeling

SWAT Agricultural Reservoir Operation Modeling for Release of Paddy Irrigation Water and Environmental Flow in Gongdo Rural Watershed of South Korea

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Abstract

Recently in South Korea, the supply possibility of environmental flow become the hot demand to improve the stream water quality and aquatic ecology. This study is to estimate the reservoir operation rule in Soil and Water Assessment Tool (SWAT) to satisfy both irrigation water requirement (IWR) and environmental flow (ENF) from agricultural reservoir. The current SWAT reservoir simulation module was modified and established the model to Gongdo agricultural watershed (366.5 km^2) including three agricultural reservoirs (Gosam, Geumkwang, and Madun) governing irrigation area of 4,744.7 ha. The SWAT was calibrated and validated at the 3 locations with 14 years (2002~2015) daily observed streamflows (Q). The Nash-Sutliffe efficiency (NSE) of Q and 1/Q showed that 0.78 and 0.58 for normal years (2002~2006), and 0.86 and 0.76 for drought years (2014~2015) respectively. After SWAT setup, the possible ENF amount was evaluated under fulfilling the present IWR. Other scenario of reducing irrigation areas for supplying environmental flow was also tested.

Acknowledgements
This work was supported by Korea Environment Industry & Technology Institute(KEITI) through Advanced Wate r Management Research Program, funded by Korea Ministry of Environment(MOE) (83089)

Keywords

Agricultural water management, Irrigation water requirement, Multiple water supply, Reservoir operating rule curve, SWAT modeling

SWAT-MODFLOW: Recent Applications and an Introduction to Version 3

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Abstract

SWAT-MODFLOW, a surface/subsurface hydrologic flow model that couples the SWAT and MODFLOW modeling codes, is being used in many regions worldwide to address a variety of water supply and water management issues. A version of the code that employs the groundwater reactive transport code RT3D within MODFLOW also is being used to assess nutrient management in groundwater and surface water. This presentation summarizes the recent uses of SWAT-MODFLOW and outlines updates to the modeling code. The current published SWAT-MODFLOW code (Version 2 on the SWAT website) recently has been applied to watersheds in Oregon (USA), Colorado (USA), Mississippi (USA), the Ogallala Aquifer Region (USA), Canada, Wales, and Iran. This presentation introduces Version 3, which includes the following new features: (1) linking groundwater pumping to irrigation, with pumping rate dictated either by prescribed MODFLOW pumping rates or by SWAT auto-irrigation routines; (2) linking groundwater drainage from MODFLOW's drain package to SWAT subbasin channels; (3) the use of a groundwater delay term to represent groundwater travel time from the soil profile to the water table; and (4) an updated groundwater balance that includes recharge, drainage, groundwater discharge to streams, stream seepage to groundwater, groundwater storage change, groundwater inflow/outflow due to aquifer boundary conditions, and ET from shallow groundwater. Version 3 is accompanied by a revised tutorial that includes step-by-step instructions for including these new features into SWAT-MODFLOW applications. The tutorial also provides instructions for preparing RT3D input files for groundwater nutrient transport. The source code, executable, and tutorial for Version 3 are available on the SWAT website (https://swat.tamu.edu/software/swat-modflow/). Applications of Version 3 to watersheds in Denmark and Colorado (USA) are described briefly.

Keywords

SWAT-MODFLOW, watershed modeling, nutrient transport, model development

Enhancing SWAT+ groundwater flow simulation using MODFLOW routines

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Abstract

We present a modified version of SWAT+ that includes the physically-based, spatially-distributed groundwater flow model MODFLOW to enhance the simulation of groundwater flow and groundwater-surface water interactions in watershed systems. Making use of the spatial object approach employed by SWAT+, each MODFLOW River cell is defined as a separate spatial object that can provide groundwater to or receive water from a SWAT+ stream channel object. The connection between the River cells and the stream channels are specified in an input file (modflow.con). Interaction between River cells and stream channels occurs for each daily time step of the simulation. In addition, hydrologic response unit (HRU) soil percolation is mapped to MODFLOW's grid cells as recharge, using a groundwater delay term to represent vadose zone travel time; stream channel depth is mapped to MODFLOW's River cells for groundwater-surface water exchange rate calculations; and the difference between HRU-calculated potential and actual evapotranspiration (ET) is mapped to MODFLOW's grid cells to simulate ET from shallow groundwater. Daily, monthly, and annual basin-wide groundwater balance is output using groundwater storage change, groundwater inflow/outflow due to aquifer boundary conditions, recharge, groundwater discharge to streams, stream seepage to the aquifer, and ET from shallow groundwater. The use of the model is demonstrated for the 471 km^2 Middle Bosque River Watershed in central Texas. The model is run for the 1985-2012 time period and tested against a suite of measured watershed data: streamflow at the outlet; time-varying groundwater levels from 10 observation wells; relationships between annual rainfall and discharge, baseflow, recharge, runoff, ET, and aquifer down-dip flow; the relationship between contributing runoff area and stream discharge; and average annual water table fluctuation. Results are compared with the stand-alone SWAT+ model. Due to the spatial object approach of SWAT+, the SWAT+/MODFLOW code can be applied to watersheds with a high degree of human management, e.g. reservoirs, canals, pumping wells, and subsurface drains.

Keywords

SWAT+, MODFLOW, groundwater, groundwater-surface water interactions

Review on SWAT Integrated Models and Their Applications in Surface and Subsurface Flows

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Abstract

SWAT is a continuous time scale, quasi-distributed model which was developed to predict the runoff, water quality, sediment loads, and groundwater recharge for long periods of time. The limitations of SWAT in estimation of instantaneous peak flow, effect of groundwater discharge in basin during low flow period, optimum water allocation for domestic and irrigation demand and in simulation of hydrologic processes such as surface runoff, groundwater re-evaporation and baseflow have become the source for the development of integrated SWAT model techniques. There are distinct state of problems which distinguish the application of integrated SWAT model. SWAT-MODFLOW cope with the calculations of groundwater distributed parameters and its recharge rates. SWAT-TOP determines the saturation fraction based on the topographic index which will enhance physical representation of hydrological processes. To predict the instantaneous peak flow, machine learning techniques could be integrated into SWAT. Planning for efficient water allocation in present and future demand can be examined by using SWAT-MODSIM. This paper will discuss the following four SWAT Coupled models SWAT-MODFLOW, SWAT and Machine Learning, SWAT-MODSIM and SWAT-TOP and its applications. Due to the significance of groundwater flow analysis SWAT-MODFLOW was widely used among the other integrated models. SWAT Coupled Machine Learning algorithm is an emerging study for effective stream flow prediction analysis. The goal of this review is to interpret the applications and benefits of SWAT coupled models and furnish the researchers about certainty of using the integrated models in future scenario problems such as ambivalence of data feasibility, accuracy in prediction of model output, improve computational resources and model response time.

Keywords

SWAT integrated models, instantaneous peak flow, optimum water allocation, groundwater flow, groundwater re-evaporation

Climate Change Impacts on Hydrological Processes in Representative Basin of Brazilian Semiarid

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Abstract

Climate and environmental changes predictions have been increasingly studied by the scientific community in order to subsidize measures that minimize the possible impacts to the environment and, consequently, to society. The prediction of climate change is important in semiarid regions due to frequent droughts, alleviating desertification risks and aiding water resources management. The objective of this study is to evaluate impacts of climate change in short, medium and long terms in the Experimental Basin of the Jatobá Stream, Brazil, with an area of 13.50 km^2, located at a semiarid region. The Regional Climate Model (RCM) Eta-MIROC5 was adopted for the Representative Concentration Pathway (RCP) 4.5 and 8.5 scenarios. Future data from 2020 to 2099 of Eta-MIROC5 were submitted to trend correction procedures, and the distribution mapping (DM) method was the most efficient. Subsequently, the corrected data were used for two simulation of two scenarios of the hydrological processes using the Soil Water Assessment Tool (SWAT model), previously calibrated for Jatobá experimental basin. Outputs were divided in short term (2020-2040), medium term (2041-2070) and long term (2071-2099) for two RCP scenarios. Rainfall reductions were observed for all projections, varying between 8.1% and 34% relative the baseline. The model predicted an increase in temperature in all scenarios, with increases of up 4.65 °C at maximum temperature and 3.11 °C in minimum temperature for RCP 8.5 scenario in the long term. Also for such scenario, an increase of up to 11.45% in potential evapotranspiration was observed. Decreases in actual evapotranspiration were observed up to 46.8% in the RCP 4.5 scenario and up to 54.1% under the RCP 8.5 scenario. The same was observed for surface runoff, with reductions of up to 71.4% in the RCP 4.5 scenario and up to 78.4% under the RCP 8.5 scenario. For the annual and monthly streamflow, decreases were also predicted, with the values being more severe under RCP 8.5 conditions. It was observed for both scenarios an increasing of the interannual variability of the precipitation, and consequently for the extreme events in the long term. Results might support water planning, and contribute to minimizing the effects of climate change impacts on water resources at the river basin, thus ensuring a better coexistence with water scarcity in such semiarid region.

Keywords

Eta-MIROC5; hydrological simulation; Regional Climate Model; Representative Concentration Pathway; SWAT model

Development of a National SWAT+ Model for the US: Progress and Challenges

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Abstract

The USDA in conjunction with Texas A&M is developing a SWAT+ model of the contiguous US to support a variety of environmental policy and planning purposes. The current model is comprised of 6.9 million HRUs across 2,200 separate but linked SWAT+ simulations. The national model is constructed from a variety of publicly available data sources. In this presentation, we describe the construction of the model thus far and note the challenges that make continental scale modeling difficult.

Keywords

national scale

Introducing “A Scalable wAter Prognosis” (ASAP): a plug-and-play web platform for operational SWAT forecasts

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Abstract

In the “A Scalable wAter Prognosis” (ASAP) project we are developing a decision support and early warning tool, to alleviate the impacts of floods, drought and water pollution. ASAP is a new software solution that simply enables eco-hydrological forecasts for any location in the world. ASAP is a scalable, global, flexible, and extendable forecast service that integrate state-of-the-art eco-hydrological modelling with global geographical and weather data sources in a cloud based internet service. For SWAT users, ASAP may provide a “plug-and-play” solution for already existing SWAT applications (or new ones) and as such bring SWAT setups to life with operational forecasts on, for example, river discharge, soil water content and reservoir dynamics. As a user of the web-platform you may customize 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 ASAP and hope to get ample input from the audience on the concept and relevance of the forecast service.

Keywords

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

High-resolution large-scale modeling framework for a transboundary watershed: a climate change assessment of nutrient loads and possible environmental consequences

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Abstract

The study provides an in-depth analysis of the transboundary Nemunas River watershed and possible future changes to the streamflow, hydrologic regime, sediment, Total Nitrogen and Total Phosphorus loads from the Nemunas river to the largest coastal European lagoon: the Curonian Lagoon, under different climate change scenarios thru high-resolution modelling. The sub-basins of the Nemunas River tributaries and the main river branch were modelled using the Soil and Water Assessment Tool (SWAT). The model was setup using the developed customizable Matlab scripts for an advance Hydrologic Response Unit configuration. Model discretization was carried out by the combination of sub-watershed and hillslope delineation to produce physically more realistic model configuration. Soft calibration techniques were utilised for the entire area, prior to the hard calibration against measured data. A multisite manual model calibration and validation followed, using the observed discharge, Total Suspended Solids, Total Nitrogen and Total Phosphorus. The calibrated and validated model was used to assess the changes in the watershed under two Representative Concentration Pathways (RCP): RCP4.5 and RCP8.5 for near-term (up to 2050) and long-term (up to 2100) periods, compared to the baseline. The findings of the study suggest that most changes for the near-term and long-term periods will likely occur in winter season, especially in January and February. Coupled with the projected increased flows in winter, the projected nutrient load changes during winter season indicate an up to two-fold increase in sediment, up to 42% and 62% in TN and TP load to Nemunas River and, subsequently, to the Curonian Lagoon. The combination of hydrologic changes in the watershed and interseasonal variation of pollutant loads to the lagoon might result in various system behavior responses, ranging from increased cyanobacteria blooms, to an increase of net nutrient export to the Baltic Sea.

The modeling framework will be further used to assess scenarios related to Best Management Practices for nutrient load reduction and retention measures, as well as assessing the supporting, provisioning and regulating Ecosystem Services. 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.

Computationally efficient calibration strategies for complex large-scale SWAT applications

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Abstract

Soil and Water Assessment Tool (SWAT) calibration becomes challenging with the increasing complexity of model set up. Auto-calibration using optimization algorithms requires thousands of model evaluations to identify best parameters for the watershed. Simulation time increases with model complexity and generally, parallel computing and surrogate model approaches are utilized for calibrating such complex SWAT models. The goal of this study was to develop computationally efficient calibration approaches for large scale SWAT applications. The study developed a comprehensive SWAT model for Susquehanna River Basin (SRB) located in Northeastern United States covering 71,251 km^2 with 911 sub-basins and 52,289 HRUs. A single model calibration run with 15 hydrology related parameters and 13 years takes about 18 hours to execute in Linux environment with dedicated core, which includes about 8 hours of just model simulation. This makes it difficult to do traditional auto-calibration of model even with parallel computing procedures. Two computationally efficient calibration approaches were explored in this study. The first approach used a multi-stage calibration with the first stage of auto-calibration using a dominant HRU (one HRU per sub-basin) based model and second stage of manual calibration of comprehensive model starting with the calibrated parameters from first stage. The dominant HRU model significantly reduced the computational complexity of model with only 911 HRUs in the model. The second approach included surrogate modeling using Neural Networks (NN). A surrogate model was developed using ensemble simulation of comprehensive model with selected calibration parameters. The surrogate NN model was then used in auto-calibration instead of SWAT simulations, the final calibrated parameters were evaluated again using the comprehensive model. Both approaches significantly reduced computational complexity and derived satisfactory hydrology calibration results for SRB.

Keywords

computationally efficient calibration, surrogate model, dominant HRU, Susquehanna River Basin

Climate change impacts on crop water productivity across Africa

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Abstract

Crop Water Productivity (WP), a framework for evaluating the performance of agricultural production systems from the field to basin scale, is useful for the management of water resources. Defined here as the ratio of the physical mass of production, yield, against the water consumed, evapotranspiration (ET), WP can be used for intercomparison across different crops types at the farm level but also for assessing the impact of agricultural systems at the basin level. ET has a large impact on water resources from the global to the field scale; a correct simulation and evaluation of this key variable is therefore central in WP studies. Despite its importance, little is known on climate change impacts on ET and associated WP over Africa. Here we quantify climate change impacts on WP across Africa using a ET estimates from several remotely sensed derived products, a SWAT+ simulation tailored for Africa and models from the ISIMIP agriculture, biomes and global and regional water sectors. Both the spatial distribution and possible biases in magnitude as well as variations between the SWAT+ model with other ISIMIP models are investigated. Current and future simulations will be investigated. We thereby anticipate results to show more accurate estimations of water productivity at the crop level from the agricultural and biomes models and more accurate estimation at the basin or continental scale from the SWAT+ model and other hydrological models.

Keywords

Water Productivity, Climate Change, SWAT+, Evapotranspiration

Analysis of climate scenarios and effects on water availability for irrigation in Río Dulce irrigation system, Santiago del Estero, Argentina

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Abstract

Climatic change has already altered hydrological cycles and will undoubtedly alter availability of water for irrigation during the coming decades. The objective of this study was to quantify future water balance and availability of water for irrigation under different climate change scenarios in the upper Salí-Dulce watershed located in northern Argentina. This basin is home to one of the most important irrigation systems in Latin America actually covering about 82000 hectares located entirely in Santiago del Estero province. In order to generate tools for sustainable agricultural development, future analysis of water balance and water availability for irrigation, the SWAT model was used and linked with projections from nine models that participated in the Coupled Model Intercomparison Project Phase 5 (CMIP5) and downscaled to Salí-Dulce catchment. The simulation was carried out for four futuristic periods: P1(2020–2039), P2 (2040–2059), P3 (2060–2079) and P4 (2080-2099) under two Representative Concentration Pathways RCP 4.5 and RCP 8.5 and was contrasted with a baseline scenario simulated for a period of 50 years (1968-2017) on a monthly scale. Monthly model calibration approaches gave good results based on a statistical fit with Nash Sutcliffe Efficiency (NSE) and Coefficient of Determination (R^2) of 0.7 and 0.71 for calibration period (1988–1999), and 0.68 and 0.69 for validation period (2000-2008), respectively. The CC projections show an increasing trend in precipitation and discharge throughout the basin of 8% and 11% and an increasing trend in ET of 12 and 14% for both CC pathways respectively (RCPs 4.5 and 8.5) throughout the basin. Outcomes of this study give insight on future evapotranspiration, water balances and availability of water for irrigation and possibility to increase irrigated area to system potential of 120000 hectares. It is also an important tool during the decision-taking process to sustainably develop this watershed´s irrigation system taking into account all different interests of all involved actors and by this means assure productivity for future generations.

Keywords

Climate Change; SWAT; Irrigation; Scenarios; Argentina

Assessment of Future Agricultural Water Supply Capacity Under Extreme Climate Condition of Geum River Basin Using MODSIM-DSS Model

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Abstract

This study is to evaluate future agricultural water supply capacity in Geum river basin (9,865 km2) using SWAT (Soil and Water Assessment Tool) and MODSIM-DSS (MODified SIMyld-Decision Support System). The MODSIM-DSS model was established by dividing the basin into 14 subbasins, and the irrigation facilities such as agricultural reservoirs, pumping stations, diversions, culverts and groundwater wells were grouped within each subbasin, and networked between subbasins including municipal and industrial water supplies. The SWAT was calibrated and validated using the 11 years (2005-2015) daily streamflow data at two dams (DCD and YDD) and over 3 years (August 2012 to December 2015) data at three weirs (SJW, GJW, and BJW) considering water withdrawals and return flows from agricultural, municipal, and industrial water uses. The Nash–Sutcliffe efficiency (NSE) of two dam and three weirs inflows were 0.55~0.70 and 0.57~0.77 respectively. Using the MODSIM-DSS with help of SWAT watershed hydrologic cycle, we evaluated the agricultural water supply capacity under future extreme climate conditions extracted from the 10 RCP 8.5 GCMs scenarios by 3 projection periods (2020s: 2011-2040, 2050s: 2041-2070, 2080s: 2071-2100) and compared with Historical (1975-2005) condition. We will attempt to find out the future agricultural water deficiency for each subbasin whether they endure the future potential droughts and suggest the possible ways of new agricultural water supply facilities to fulfill the necessary water use.

Acknowledgements

This subject is supported by Korea Ministry of Environment (MOE) as “Water Management Research Program (RE201901057)”

Keywords

SWAT, MODSIM-DSS, Agricultural water supply capacity, Irrigation facilities, Extreme climate condition, Agricultural drought

Establishment of Climate Change Adaptation Strategy of Stream Flow and Water Quality Maintenance for A Watershed Receiving Water from Neighbor Watershed

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Abstract

This study is to evaluate the stream flow and water quality of a watershed receiving water from neighbor watershed to adapt the future climate change condition. For Mangyung river basin (1,602 km^2) in South Korea, the Soil and Water Assessment Tool (SWAT) was calibrated for 3 years (2012-2014) and validated for 3 years (2016-2018) at two stream flow and water quality gauging stations considering water transfer from 2 reservoirs of neighbor watershed and water intake in the receiving watershed stream. The average Nash-Sutcliffe efficiency (NSE) for streamflow at the two locations was 0.49~0.51 and the average determination coefficient (R^2) of stream water quality for suspended solid (SS), total nitrogen (T-N), and total phosphorus (T-P) was 0.73, 0.78, and 0.72, respectively. Using HadGEM3-RA RCP (Representative Concentration Pathway) 4.5 and 8.5 scenarios of Korea Meteorological Administration (KMA) and with the present receiving water amount, the future stream flow and water quality will be evaluated. By referencing the results, the future necessary amount of water transfer from neighbor watershed will be estimated for each scenario to satisfy both the required agricultural and municipal demands and stream water quality.

Acknowledgements

This work was supported by Korea Environment Industry & Technology Institute(KEITI) through Advanced Water Management Research Program, funded by Korea Ministry of Environment(MOE) (83089)

Keywords

SWAT, Climate Change, Water Transfer Change, Withdrawal and Water Use

Water protection in a vulnerable agricultural area - the soil type based approach

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Abstract

Objective of our work is to study nitrate leaching pathways in an agriculturally important alluvial plain in Slovenia. The area features vulnerable soils, and agriculture is commonly blamed for the nitrate contaminated groundwater. Extant water protection measures were implemented on a quite broad scale and are not effective enough, so there is a need for a more local approach. The influence of local soils on leaching has not been studied before, so a survey of soil water retention characteristics was done prior to modelling. The SWAT model was used to study the nitrate pollution pathways and evaluate different water protection and climate change scenarios. Best management practices were distributed based on soil types. The soil type analysis together with SWAT model results for nitrate leaching will enable us to determine which water protection measures to implement with each soil type in the area for maximum efficiency. In the end we will also discuss possibilities of implementing water protection measures in a way not to inhibit the balanced agricultural development. Further work will focus on development of a locally-based method for allocation of water protection measures in agricultural areas.

Keywords

water protection measures, agriculture, soil types, nitrate leaching, SWAT

Enhancement of degraded watershed through Restoration (plantation) and its effects on steam-flow in West Seti Watershed in Nepal

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Abstract

Watershed degradation is caused by various factors, including land use change which deteriorates in hydrological behavior of river systems and reduces the health and potential of land and water. Human induced activities are the main factors of land use change in West Seti Watershed of Karnali River Basin, Nepal. Migration of urban and sub-urban areas, deforestation, urbanization and inefficient policy are the main causes of land use change. The sloppy area where deforestation is highly susceptible to stream flow, soil erosion, fertility loss. This study quantifies the effects of the land use change impact on stream flow in West Seti River Watershed.

Land use areas and its change was evaluated using Geographical Information System (GIS). 2000, 2010 and 2015 land use map were used. Forest restoration activities were prepared and updated on 2015 land use map. Hydrological modeling: Soil and Water Assessment Tool (SWAT) was used for hydrological simulations and quantification of the effect land use change on stream flow in West Seti watershed.

The result of the study showed that from 2000 to 2015, forest area is increasing. But, forest area per years is decreasing in period 2010-2015 years then 2000-2010. In 2000-2015 period, shrubland, agriculture land, water body and snow/glacier are decreasing while barren land and grassland is increasing. The SWAT model result showed that decrease in stream flow due to increase in forest and grass land and decrease in agriculture land mainly.

The results showed that the effect of change of mainly on forest area had a greater effect on stream flow. So, watershed managers and policy makers must consider policies regarding forest restoration for stream flow (runoff) management.in degraded watershed.

Keywords

Degraded Watershed, Restoration, Plantation, SWAT, Stream flow

Modeling the impacts of best management practices on water quality of El Beal wadi (SE Spain)

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Abstract

Intensive agriculture and abandoned mining site are a potential threat for the environment, producing an important ecological deterioration of its surrounding areas. Both situations occur in El Beal watershed site in Campo de Cartagena, which flow into Mar Menor coastal lagoon with great quantities of sediment and nutrients. Mar Menor is one of the largest coastal lagoons in Europe with unique environmental values and a very emblematic place for the Region of Murcia (SE Spain). El Beal watershed has been simulated using SWAT model. For the calibration and validation process, remote sensing evapotranspiration data from GLEAM were used due to the unavailability of recorded discharge measurements in the study area. Using the previously calibrated and validated model, five agricultural management practices (BMP) were implemented in SWAT: Contour Planting, Filter-Strips, Reforestation, Fertilizer Setting and Check Dams Restoration in order to assess their impact on sediment and nutrient yields. The model performance was acceptable in calibration (KGE= 0.78; NS= 0.58) as well as in validation (KGE= 0.67; NS= 0.53). Results show that Check Dams Restoration is the most effective BMP with a reduction of 90% in sediment yield (S), 15% in total nitrogen (TN) and 22% in total phosphorus (TP). Followed by Reforestation (S= 27%, TN= 16% and TP= 20%), Contour Planting (S= 6%, TN= 10% and TP= 8%), Filter-Strips (S= 4%, TN= 7% and TP= 5%) and Fertilizer Setting (TN= 2%). Despite the model uncertainties, the results of this study could help decision makers in developing a code for good agricultural practice in order to improve the water quality in the Mar Menor coastal lagoon.

Keywords

SWAT model; ET data; GLEAM; Best Management Practices; Mar Menor

Investigating the Impact of Crop Rotation at Different Levels of Implementation and Spatial Distribution on the Total Phosphorus Loading Using the SWAT Modeling Tool

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Abstract

One of the tools used in agricultural watersheds to mitigate the excessive transfer of nutrients into water bodies is the implementation of Beneficial Management Practices (BMPs). The main purpose of modeling agricultural BMPs is to evaluate their efficiency and estimate their impact on reducing nutrient (phosphorus) transfer into bodies of water. Medway Creek sub-watershed, located in southwestern Ontario, Canada is one of the agricultural landscapes across which crop rotation is implemented as BMP over approximately 40% of the total agricultural landscape. Using the Soil and Water Assessment Tool (SWAT) to simulate the transfer of nutrients at the Hydrologic Response Unit (HRU) level, this study aims to assess the influence of different levels of implementation and their spatial distribution on phosphorus loading as the considered criterion for water quality.

The modeling stage of the study consists of four distinct scenarios considering 0% (the current land use), 10%, 20%, and 30% increase in crop rotation for the landscape under study. To assess the impact of the spatial distribution of crop rotation, both random and targeted spatial distribution of this BMP will be investigated across the target landscape. In both models, HRUs are defined by filed boundaries in the landscape under study.

Keywords

Crop rotation, field boundary, Hydrologic Response Unit, phosphorus loading, level-of-implementation, spatial distribution

Probabilistic approach for uncertainty-based optimization of best management practices under multiple types of rainfall-runoff events

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Abstract

In this paper, an uncertainty-based optimal placement of best management practices (BMPs) based on a probabilistic approach is proposed for reducing nonpoint source pollution under multiple types of rainfall-runoff events. This approach entails a two-stage procedure. First, the uncertainty of event-based BMPs effectiveness was probabilistically quantified by the Hydrological Simulation Program-FORTRAN (HSPF) with statistical inference. Second, the uncertainty of event-based BMPs effectiveness and concept of margin of safety are incorporated into the optimization of BMPs placement using the chance constrained programming model which is solved by searching the cost-effective Pareto frontier. A case study in a rural catchment in the Three Gorges Reservoir area in China was conducted to demonstrate the design process. Two preference-oriented scenarios considering different event types were targeted to validate the applicability of the proposed approach. Probability density distributions of different structural and managerial BMPs (e.g., vegetative filter strips and nutrient management) were first obtained under different types of rainfall-runoff events. The intensity of rainfall-runoff events determined the level of uncertainty of BMPs effectiveness, while very heavy and extremely heavy types of rainfall-runoff events resulted in the highest uncertainty in terms of distribution statistics. Then this approach ensured optimal tradeoffs between environmental risks and system costs, that is, the designed BMPs schemes could operate at high efficiency to achieve the expected confidence levels of water quality under uncertainty, while the total costs were minimized. The results also implied the importance to deal with extreme heavy events in different preferences (i.e., cost-oriented and effectiveness-oriented). The proposed approach and presented results have important implications for decision-making under uncertainty in event-based watershed management.

The presented approach has important implications for SWAT model users. In this study, the representation of BMPs by the HSPF model entails identifying the watershed processes affected by the BMPs implementation and then selecting and adjusting related parameters based on the function of BMPs. This representation procedure shares the same philosophy with the SWAT model because both SWAT and HSPF models are process-based and semi-distributed. The conceptualization of the land-soil-water system is also similar between the two models. The uncertainty of BMPs effectiveness derived from BMPs-related parameters is inherent in the simulation with hydrologic models. How to consider this uncertainty and incorporate it into BMPs optimization has become a critical issue that both SWAT and HSPF model users must deal with.

Keywords

best management practices; nonpoint source pollution; uncertainty; optimization; HSPF; rainfall-runoff event; effectiveness; cost

Combined impacts of future climate and land use changes on hydrological process of Upper Awash River Basin, Central Ethiopia

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Abstract

Flooding due to urbanization from regular rainfalls and water scarcity is a common challenge. Moreover, climate change is expected to intensify the extreme flow including high and low flow. In this research, the potential impacts of future climate and land use changes on the hydrological process of the Upper Awash River Basin is assessed using Soil and Water Assessment Tool (SWAT) and Catchment Hydrologic Cycle Assess Tool (CAT) hydrological models. The SCS-CN for SWAT and Green-Ampt for CAT is used to model the infiltration process. The calibrated (1994-2004) and validated (2005-2009) hydrological model is used to evaluate the potential impact of future climate and land use changes on the hydrological process. Two GCMs were selected among 8 after conducting uncertainty analysis proposed by Kim et.al (2019), which decompose total uncertainty to components from individual stages. The two GCMs were used to assess the impact of climate change on hydrological process considering RCP 4.5 and 8.5 scenarios in the near future (2030-2059). Simple Quantile Mapping (SQM) and Spatial Disaggregation-Quantile Delta Mapping (SDQDM) downscaling methods were applied using the climate data acquired from APEC Climate Center. The future land use change scenarios were predicted using ANN from historical land use maps. The study shows, in the near future the climate change is expected to increase the high flow during summer season. Similarly, the model response to land use changes indicated an increase in high flow from regular storms and a decrease in the low flow during the dry season. The land use change impact is observed to be more dominant compared to the climate change impact and the combined impact will be expected to intensify the flooding and water scarcity depending on the season. The analysis of the result also indicated that the urbanized subbasins are more dominate in runoff generation. Although the combined impact of climate and land use changes assessment result shows an increase in high flow and decrease in low flows, appropriate adaptation measures by policymaker will play a key role in curbing the combined impacts in a sustainable manner. The study showed that well calibrated and validated hydrological models could help in understanding the combined impacts of future climate and land cover changes on the hydrological process. However, the uncertainty should be carefully quantified to increase the reliability of model prediction and forecasting to achieve sustainable development in the future.

Keywords

Curve Number, Green-Ampt, High Flow, Urbanization, Water Scarcity

The hydrological characteristics of Hehuan Mountain watershed and impact assessment of climate variation

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Abstract

Due to the variations of the global climate, the hydrological system has undergone tremendous changes in many places of the world including Taiwan. To delineate resilience of a hydrological system to the impact of climate variation, the use of hydrological model is challenging. Hehuan Mountain watershed in Taiwan is chosen as the research site. The catchment is with few anthropogenic activities. It is located at central Taiwan with an area of 1.52 km^2, a slope of 14.94°. SWAT model is adopted and conjunctively used with MODFLOW to establish the hydrological model. Through SWAT-MODFLOW, the variation of groundwater level can be simulated more properly. After model is calibrated and verified, future meteorological data projections including rainfall and temperature from GCM model using Coupled Model Intercomprison Project Phase 5 (CMIP5) experiment scenarios are used. In this study, we chose RCP2.6, RCP4.5, RCP6.0 and RCP8.5 which were defined in IPCC AR5 as scenario simulations. With downscaling meteorological data, hydrological response to the climate simulation are simulated. Results show that hydrological components react differently for the near future scenarios compared to the baseline (1985-2005). Precipitation changes toward increasing in wet seasons for most 100% and decreasing in dry seasons to 40%. Temperature consistently increases for around 2℃. Percolation and outflow highly correspond to the precipitation. Groundwater is very sensitive to the change of precipitation. ET is significantly influenced by temperature. All these hydrological components show fractal in time series with spectrum analysis. The hydrological components can be inversely derived from the rainfall using the transfer function through this characteristic. Based on this approach, the data-driven model may serve as an alternative of the physics-based model for hydrological modeling. Even more, we suggest that this characteristic implies that the high resilience of Hehuan Mountain watershed to the impact of climate variation.

Keywords

Hydrological system, resilience, climate variation, Hehuan Mountain watershed, SWAT-MODFLOW, GCM, transfer function.

Evaluation of future climate change impact on the inflow of Chungju Dam during flood season using multiple GCMs and SWAT model

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Abstract

In this study, the change of dam inflows according to the future climate change was analyzed for the Chungju Dam watershed in Korea. Based on the uncertainties due to the GCMs, climate data derived from 16 GCMs were downscaled to the watershed and used as input weather data of SWAT model. We divided the future into three periods (near: 2010~2039, middle: 2040~2069, far: 2070~2099) and analyzed the monthly inflow and maximum daily inflow from SWAT simulations. The monthly inflow was expected to increase greatly in July and August on average although there was a difference depending on the GCM. The maximum daily inflow also increased significantly in the same period. In addition, monthly inflows and maximum daily inflows were significantly increased during the far future rather than near future, and it was expected to increase even more in RCP 8.5. Especially for the far future (2070-2099), the maximum daily inflow in August was expected to increase more than twice the average inflow. Therefore, it is expected that the flood changes due to climate change will increase more and more in the future.

Acknowledgement

This research was supported by a grant from a Strategic Research Project (20190153-001) funded by the Korea Institute of Civil Engineering and Building Technology.

Keywords

Climate change, Chungju Dam, GCM, SWAT

Impact of climate change on water resources in the Guajoyo River Basin (El Salvador)

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Abstract

A hydrological modelling at a catchment scale has been used to assess the impact of climate change on water resources in the headwaters of the Guajoyo River Basin in Central America using SWAT model and the Climate Change Toolkit (CCT). Guajoyo River is a tributary of the Lempa River, the largest and most important river in El Salvador. This watershed has an area of 156.4 km^2 with a tropical climate. The model simulation period was divided into calibration (2006–2009) and validation (2010–2012) periods. The Nash-Sutcliffe model efficiency (NSE), percent bias (PBIAS) and ratio of root mean square error to measured standard deviation (RSR) for monthly flow was 0.66, -16.53%, 0.58 during calibration period and 0.65, -11.39%, 0.60 during validation periods, respectively. The predicted future climate change by two climate change scenarios (RCP 4.5 and RCP 8.5) and five general circulation models were considered. A statistical analysis has been performed to identify which general circulation model is better in terms of goodness of fit to variation in means and standard deviations of the historical series. Comparing the long-term (2080-2099) to baseline (1994–2013) periods, this study showed that the annual average streamflow would decrease by 25%-57% in the future periods under RCP 4.5 and RCP 8.5, respectively. The annual average temperature would rise by 3.4 °C and 6 °C, and annual precipitation would decrease by 20%-42%. These findings provide local water management authorities useful information in the face of climate change.

Keywords

SWAT model, Hydrologic model, Climate change, Tropical watershed, El Salvador

Assessing the impact of climate change for Aracthos river basin (NW Greece) using SWAT model

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Abstract

The present study focuses on the impact of climate change on water resources, in the Aracthos river basin (NW Greece) that drains into the closed Amvrakikos gulf. Amvrakikos has a great ecological interest, being part of the international Ramsar agreement. In general, the phenomenon of climate change is predicted to influence hydrological processes worldwide, in both spatial and temporal scales. Specifically, this study analyses the alterations that water resources will endure, during the 21st century. With the use of SWAT program (Soil and Water Assessment Tool) for the delineation of the watershed and with the help of the large-scale global circulation model (NorESM1-M), future flows were evaluated and compared with the historical ones. The model was calibrated, with the use of SWAT-CUP (SWAT Calibration and Uncertainty Program) for the 1992-2002 period and was validated for the years 1982-1991, at a monthly timescale. For the calibration part, the Nash Coefficient (NSE) was 0.54 and the Kling Kupta efficiency (KGE) was 0.55, while for validation they were 0.52 and 0.46 respectably. The scenarios RCP 4.5 and RCP 8.5 were simulated for the period of 2080-2099 and were compared with the historical flow-out of the period 1982-2001. The results showed that for the RCP 4.5, the water resources of the watershed will be reduced by 3.17%, while for the RCP 8.5, there will be a reduction of 12.7%.

Keywords

SWAT model; Aracthos river basin; climate change; NorESM1-M

Impacts of climate change on watershed systems and potential adaptation through BMPs in a drinking water source area

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Abstract

Climate change, in terms of changes in temperature and patterns of precipitation, has significant impacts on water resources and watershed ecosystems. Adapting to climate change is becoming an important strategy for watershed management. The goal of this study was to quantify the impacts of climate change on watershed hydrological processes and water quality, to evaluate the efficiency of Best Management Practices (BMPs) and the possible effects of a changing climate, and to configure cost-effective BMPs at sub-basin scale using a multi-objective optimization method to mitigate climate effects on water resource. The Soil and Water Assessment Tool (SWAT) model was used to simulate the possible effects of changing climate on watershed hydrological and water-quality processes and adaptation options in the Miyun Reservoir Watershed (MRW). Climate change had significant impacts on water balance components such as precipitation, runoff, and evapotranspiration (ET) and on water-quality components such as sediment and nutrient loads. A substantial decreasing trend of runoff indicated that the Miyun Reservoir faced a more acute challenge of insufficient water-supply capacity. Compared with baseline climate, climate change represented by precipitation and temperature regimes resulted in substantial increases in sediment load (12.95%) and nutrient losses (7.26% for TN and 9.56% for TP) on average all sub-basins. Climate variability had significant effects on BMP efficiency through effects on watershed hydrology, soil erosion, and nutrient losses. Results highlight the importance of optimal configuration of site-specific BMPs at sub-basin scale for adaptation to climate change. The methods and findings presented here hold promise to enhance the resilience of the watershed system to current and future climate change.

Keywords

Climate change; Nonpoint source pollution; BMP efficiency; Miyun Reservoir Watershed.

SWAT as an educational resource at the University of Alcalá: Expanding the SWAT community in Spain by teaching

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Abstract

The research group in Water, Climate and Environment at the University of Alcalá (Madrid, Spain) started working with SWAT in 2010 thanks to the celebration of the European SWAT Workshop in Toledo, becoming then one of the first groups in Spain to incorporate SWAT in its research activities. After several years of experience with the use of the model, the group realized about the value of SWAT as an educational resource: it is an open source, computationally efficient software and it has a graphical guided interface that allows addressing complex modelling studies in a relatively simple way. Thus, the group started incorporating SWAT in its teaching programmes.

In this work we present the teaching activities and the students' profiles at Alcalá University that, since 2015, have involved SWAT. The activities include a Postgraduate Course in Hydrological Modelling (2015) and four hydrological modelling workshops at the Alcalá University Summer School (2016-19). SWAT has also been used for teaching purposes in the MSc programme in Geographical Information Technologies (2017-2019) and in the BSc programme in Environmental Sciences (2019). As a result, around 100 students of many different backgrounds have been in contact with SWAT, including BSc, MSc, PhD students, lecturers, professors and professionals from private companies related to soil and water resources management.

The feedback received by the students is always positive. Some of them have started using the model in their own research or working teams, enlarging the SWAT community in Spain. That being said, our experience confirms the suitability of SWAT as a tool to incorporate in teaching activities related to water resources at various educational levels.

Keywords

Educational resource, modelling, Spain, SWAT, teaching, University.

Evaluation of Baseflow and Lateralflow using measured Slope and Slope length at Doam Dam Watershed

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Abstract

Recently, since non-point source pollution is occuring frequently, non-point pollution reduction countermeasures such as selection of pollutant management area which is vulnerable to the rainfall, Best Management Pratices (BMPs) and Low Impact Development (LID) are being implemented. Non-point source pollution is unable to certify its source, thus, SWAT model which can simulates hydrology and water quality is widely used from various non-point source pollution studies. However, SWAT model is considering mean slope when calculating slope and slope length of HRUs and this derives limitation while analyzing accurate soil loss and outflow characteristics analysis. This study applied Spatially Distributed-HRU (SD-HRU) module, which considers measured slope and slope length, to the SWAT model and simulated Doam dam watershed where designated as non-point source management area. And conducted comparative analysis between SD-HRU simulation and previous method. As a results, among three runoff components (direct runoff, lateral flow, and baseflow), lateral flow and baseflow show difference from the SWAT model simulation results. This study is expected to be utilized as base material for various non-point source management studies.

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Keywords

SWAT, Mearsured Slope, Mearsured Slope Length, SD-HRU, hydrological components

Development of framework for the application of coastal, riverine, environmental and socio-economic modeling tools to predict the values of indicators for Ecosystem Services

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Abstract

The main research idea of this study is to combine multidisciplinary expertise to predict the future ecosystem services in the coastal Lithuania (area of the Curonian Lagoon and Nemunas delta). This involves not only mapping and modelling ecosystem services in the area, which in turn is a challenging task itself, but rather predict using both environmental (biophysical) modelling tools and socio-economic scenario development the future ecosystem services in a view of global change. Combination of these two (biophysical and socio-economic modelling) approaches is still a challenge not only in Lithuania (where there were no such attempts at the date), but also at the global scale. The watershed model (SWAT) is applied to build basis for the application of the state-of-the-art models, such as transitional waterbody models (SHYFEM), Life Cycle Assessment models and the economic evaluation models, which would evaluate environmental quality improvements that respond to end-user needs. The framework of models can be then applied in the watershed and coastal zone for an analysis of the existing Ecosystem Services and its values under different climate change scenarios, derived from the IPCC AR5 RCP4.5 and RCP8.5.

The SWAT model of the entire study area is developed, calibrated (8 years) and validated (5 years), for flow, sediment and nutrient loads. The model was run to assess the projections of future climate change that would affect the ecosystem services in the study area. Downscaled climate timeseries from five Global Circulation Models under the conditions of RCP4.5 and RCP8.5 were used to drive the SWAT model to analyze the changes of water and biogeochemical cycles. The projection indicates that a net annual increase in flow is projected under the conditions of the RCP4.5 (up to +10%), while a decrease is simulated under RCP8.5 (by up to -12%). A shift in the hydrological regime through the seasons is projected under both scenarios: with a more significant flow projected in mid-winter and early spring and a decrease in the warm season (late spring to early fall). The projected nutrient loads are also subject to change in a similar manner, with a higher load in winter and early spring.

The studies tasks include the socio-economic modeling linkage to explore feedbacks between the effect of climate change on the existing ES, the changing societal needs and new emerging ES that may respond to the environmental pressures. The future projections and the set-up of “what-if” scenarios will help to explore the possible impacts and responses of the system and will lead to the optimization of socio-economic services. 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

SWAT model, Curonian Lagoon, Ecosystem Services, Climate change

The Proposal of Management of Bathing Water Reservoir for Elimination of Eutrophication

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Abstract

Phosphorus and its compounds are key factors of eutrophization. Consequent high concentrations of cyanobacteria and algae in the water cause problems mainly due to deterioration of the organoleptic properties of water. Another negative impact is the production of toxic substances that cause health issues. These issues are adressed by the Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC in order to determine the potential health risks.

Here, we focus on Hostivar Reservoir in Prague which is jeopardized by phosphorus pollution from various sources. The reservoir catchment is significantly built-up with a dense network of transport infrastructure. The most of remaining catchment area is intensively farmed.

Also, an extensive pond system is present in the catchment. The ponds are important inoculum of phytoplankton into the reservoir.

The main focus of the study is to identify the pollution sources of reactive phosphorus and nitrogen forms in the sub-catchments, which is the fundamental prerequisite to being able to identify suitable remedial measures to achieve good ecological and chemical status of surface water in the catchment of the Hostivar Reservoir. Point and non-pointsources of nutrients were determined by field research and implemented in Soil and Water Assessment Tool (SWAT) model.

Remedial measures have been proposed to decrease the intake of phosphorus into the reservoir. Different scenarios were proposed to assess the potential of different measures to reduce the phosphorus intake into the reservoir. The considered measures are: reducing the use of agricultural fertilizers, eliminating diffusive sources, and improvement of the technology in waste water treatment plants.

Keywords

SWAT, GIS, watershed management, water quality, eutrophication

Simulation of the water supply of Short Rotation Coppices on sandy fields

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Abstract

The production of woody biomass from short rotation coppices (SRC) for energy and material purposes has become a viable option for regions with marginal land where other agricultural practices are not productive. The EU-Horizon-2020 Dendromass4Europe project aims at establishing and assessing sustainable SRC-based regional cropping systems. A major focus of our sub-project is the variation of water availability for the growth/yield of SRC plantations, mostly of poplar clones.

We have set up three monitoring sites with comparable conditions regarding soil characteristics, topography and climate. There, soil moisture (water content, matrix potential), depth of the groundwater table, transpiration and throughfall are permanently measured. The sites differ in the connection to the groundwater table with a close, medium and far to surface table depth, respectively. We used the model APEX to simulate the water balance of the three sites and calibrated the model with the data from our monitoring set up. Aim of the simulation is to 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. First monitoring and simulation results show that the sites with a close-to surface groundwater table have higher biomass production and evapotranspiration rates compared to the sites with lower groundwater levels.

Keywords

Short Rotation Coppices, APEX, water supply

Comparing SWAT and InVEST models on water conservation calculation

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Abstract

Abstract: The provision of fresh water is an ecosystem service that contributes to the welfare of society, ensuring the development of irrigation agriculture, improved living qualities, flourished industry and tourism activities. The calculation and mapping of water conservation are of great importance to water resource planning and management. This paper explores how different models affect water conservation calculations in the Luanhe River Basin, China. The Basin is a critical part of Beijing's metropolitan area because its downstream portion includes a water conservation project, the Panjiakou Reservoir, which start its ability to supply drinking water to Beijing-Tianjin-Hebei region in 1988. InVEST model (Integrated Valuation of Environmental Services and Tradeoffs) and SWAT model (Soil and Water Assessment Tool) have been selected to calculate quantity and space distribution of the water conservation in this area. SWAT model is operated on a monthly time scale while InVEST model worked on an annual scale. To detect the difference in these two models, the water conservation map in 2010 and 2015 have been created. SWAT models were used to reproduce hydrological cycles in the Luanhe River Basin, and the results were suitable for the simulation of drought transmission processes. The results showed that: (1) Two models have good agreement in space distribution on water conservation, both simulation results indicate the highly consistent with precipitation, which has trend to decrease from north to South. The precipitation is the dominant factor in the distribution of water conservation. (2) InVEST model and SWAT model have significant differences in the calculation results of total water conservation. In 2010, the InVEST model and SWAT model calculated 4.8 billion cubic meters and 11.2 billion cubic meters, respectively, while in 2015, the results become 5.1 billion cubic meters and 120.8 billion cubic meters, respectively. (3) InVEST model has much higher prediction amount in water conservation than SWAT model. The key differences between these models are in both their structure and assumptions. This work will make reference for selection of model in calculating water conservation.

Keywords

SWAT, InVEST, Water conservation, Water yield

Dynamic water environmental capacity calculation based on SWAT model under the changing environment

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Abstract

Nowadays, management of the water environmental contamination have received much focus, particularly for non-point source (NPS) pollution. 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. In addition, the environment we living in is changing every moment. The changing environment will have great effects on the hydrological processes, then further affect the NPS pollution discharge and transportation in the environment. Thus, taking the change of environment into consideration should be paid more attention to when performing the simulation in NPS models. Thus, how to achieve the dynamic data for WEC calculation under the changing environment need to be further studied.

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 daily flow, water temperature were directly used as the inputs of DE algorithm to calculate the WEC, which make the dynamic calculation of WEC in a daily step possible. In this way, the impacts of changing environment on WEC simulation were considered. 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. Based on the WEC calculation results, BMPs implementation could be optimized spatially for each subbasin.

The results showed that the changing of hydrological conditions leaded to the fluctuation of WEC in a daily step, indicating that changing environment did have great impacts on WEC calculation. The WEC showed the smallest value in wet season, and the WEC of nitrogen and phosphorus in organic species was more affected by seasons change than that of nitrogen and phosphorus in inorganic species. Thus, more attention should be paid to the implementation of BMPs which could effectively control the discharge of organic nitrogen and phosphorus, especially in wet season. Spatially, the channels in the middle and southeast of the study area had the smallest WEC and negative values even occurred, which indicated that more BMPs should be applied to these areas. The WEC calculation methods used in our study was more detailed, automatic and the dynamic change of the input conditions was better considered, which could provide better support for the optimization of BMPs in the watershed.

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Keywords

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

Impact of Land Use Change on streamflow by linking the CA-Markov and SWAT models

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Abstract

Water resources has become a significant driver to address environmental crises, improve human well-being, and achieve sustainability. However, streamflow generation is a complex process influenced by precipitation intensity, soil permeability, slope and vegetation, etc. How to effectively assess water flow changes caused by land use change remains a challenge. Understanding the impacts of land use change on streamflow is essential for effectively managing the water crisis in future. This study examined the impacts of future changes in land use/land cover (LULC) on streamflow in the Luanhe River Basin, China. The study area is a critical water supply area for Beijing-Tianjin-Hebei region. Studying future water flow changes may help alleviate the water crisis among the most serious problems facing Beijing metropolis, such as water shortage, water pollution and soil erosion. First, the CA-Markov model was used to simulate land use/land cover (LULC) change following the social development in the study catchment from 2030 to 2100. Second, the streamflow in future periods under these scenarios was simulated by the Soil and Water Assessment Tool (SWAT) model. The corrected model had high accuracy and was suitable for the simulation processes in future. In this study, ten years average streamflow from 2005 to 2015 have been selected as the baseline. Future land use has been divided into four stages: 2030s, 2050s, 2070s, 2090s. Ten years average streamflow for each stage have been calculated by the same climate factor with baseline. For the baseline, the ten years average streamflow was 464.2 m^3/s. The results showed that: (1) The streamflow under current climate with four stages (2030s, 2050s, 2070s, 2090s) have increased by 0.13%, 0.56%, 0.68% and 0.98% m^3/s, respectively. Overall, the trend is upward. (2) Due to the effective policies and ecological actions, this basin has been well protected, almost away from human activities. From 2015 to 2100, the forest and shrub increased by 22.2% and 19%, respectively, while grassland have decreased by 43%. Urban land use increased by 16%, which mainly located in the northern part of the study area. (3) Increase of urban land use at the study river basin export may be one of the reasons for increase of streamflow in future. A large number of forests and shrubs may reduce evaporation of water, this may be the second reason for the increase in streamflow. Land use change does have a positive impact on streamflow in the study catchment, but the impact of different land use types on streamflow needs further studies. In particular, this explore would be useful for those policymakers and stakeholders to whom intend forecast the impacts of climate and land use policies on water availability. The limitations and shortcomings for this study, including accuracy in predicting the future land use/land cover (LULC), and streamflow estimating.

Keywords

LULC, CA-Markov, SWAT, streamflow

Effects of Land Use Land Cover Change on Stream Flow (Case of Wabe Watershed, Omo-Gibe Basin, Ethiopia)

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Abstract

The main objective of this study is to evaluate the effects of land use land use land cover on the Stream flow. The Wabe watershed is situated in the north eastern part of omo-gibe basin with a total area of 1803 km^2. The land use land cover changes within the watershed were examined through classification of Satellite images with integrated use of ERDAS imagine (Version 9.1) and Arc GIS software. The SWAT model was used to examine the impact of land use land cover change on stream flow of the study area. The model was set up using readily available spatial and temporal data, and calibrated against measured discharge. Land cover change analysis has shown that the cultivated land has increased from 28% to31.21%, settlement area from 16.26% to 22.35% between 1973 and 2000, while forest area has decreased from 16.78% to 9.48% and bushes and shrub land from 36% to34.96%. Sensitivity analysis result shown that both Curve Number (CN) and Alpha factor are the most sensitive parameters affecting the hydrology of the watershed. The model was calibrated from 1993-1998 and validated from 1999-2001. The performance of the model was evaluated on the basis of performance rating criteria, coefficient of determination (R^2), Nash and Sutcliff efficiency (NSE), and percent difference. The R^2 and NSE values for the watershed were 0.87and 0.79 for calibration, 0.89 and 0.81 for validation respectively. The evaluation of the model indicated that the mean annual surface flow for 2000 land cover was increased by 46% than 1973 land cover. Similarly the 1986 land cover mean annual surface flow was higher by 20% than 1973 land cover. Generally, the analysis indicated that the mean wet monthly flow for 2000 land cover was increased by 9.43% than 1973 land cover. Similarly the 1986 land cover mean month flow higher by 4.3% than the 1973 land cover flow of wet months. On the other hand dry average monthly flow was decreased by 33 % for land cover of 2000 than that of 1973 and by 24 % for land cover of 1986 than that of 1973 land cover.

Keywords

Wabe watershed, Land use land cover, remote sensing, GIS, Stream flow: SWAT

Modeling runoff and evapotranspiration responses to land use changes using SWAT model in the Mundaú watershed, Brazil

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Abstract

Land use change has great influence on runoff and evapotranspiration processes of any watershed and the deepening of this theme is important to assist decision making, within the scope of water resources management. The present study was conducted for Mundaú River Basin (MRB) using Soil and Water Assessment Tool (SWAT) model. The aim of the study is assessing the issue of land use change and its effect on evapotranspiration, surface runoff and sediment yield. Input data like land use, topography, weather and soil data features are required to undertake watershed simulation. Two scenarios of land use were analyzed over a period of 30 years, which were: a regeneration scenario (referring to use in the year 1987) and another scenario of degradation (referring to use in the year 2017). Land use maps for 1987 and 2017 were acquired from satellite images. Overall, during the last three decades, 76.4% of forest were lost in the MRB. On the other hand, grazing land increased in 2017 at little more than double the area that existed in 1987. Changes in land use over the years resulted in an increase of about 37% in water yield of the MRB. Changes have led to increased processes such as surface runoff and sediment yield, and in the decrease of evapotranspiration. The spatial and temporal distribution of land use controls the water balance and sediment production in the MRB.

Keywords

hydrology, water balance, water management

Application of the SWAT model and remote sensing techniques to assess flooding in basins of the Pampas region

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Abstract

The pampas plain of Argentina, a region that alternates areas of very low slopes with slightly rolling sectors, is a scenario of great fragility under extreme hydrometeorologic events. The increase in the frequency of intense rains in short periods of time, in a context in which basins are unable to evacuate large volumes of water, has increased the risk of flooding and persistent flooding over time. Floods have severe social and environmental impacts, producing serious losses in agricultural activity as well as in installed infrastructure. These damages can be minimized through the implementation of better management practices and adequate land use planning. The Soil and Water Assessment Tool (SWAT) model is a continuous hydrological model that is not usually used to study specific flood events. However, the long periods of runoff in the Pampas basins, with a recession curve greater than 25 days, limits the use of the classic simulation models of flood events. The aim of this study was to analyze the suitability of the SWAT model to represent flood events in the Arrecifes river basin during the period 2012-2017. The results obtained with SWAT were combined with remote sensing techniques applied to Sentinel-1 radar images, delimiting it to a particular flood event, in order to estimate the resulting spatial affectation. Calibration (NSE 0.78) and validation (NSE 0.71), on a daily time scale, indicated a good performance of the model. As a result, preliminary maps of the flooded areas were obtained, which could be associated to the discharges and propagation time of the flood wave for the event studied. This approach allowed to combine two techniques that laid the basis for a flood risk study in a rural basin and that could be used as a planning tool for end users located in the Pampas region.

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Keywords

Flood, hydrological model, continuous simulation, Sentinel-1

Evaluating spatial scaling effect of baseflow and baseflow nonpoint source pollution in a typical nested watershed

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Abstract

Environmental problems such as eutrophication caused by excessive nutrient are global challenges. Effective water-quality management requires fully understanding of the nonpoint source (NPS) pollutants pathways at different spatial scale as the formation and transportation processes of NPS pollution varied among multi-scale watersheds. In this study, by using the Soil and Water Assessment Tool (SWAT), the contribution of baseflow NPS across different spatial scales and the potential mechanism of scale effect were investigated based on spatial scale of 17 levels of nested watersheds within Daning River watershed, China. The results indicated that baseflow became an important NPS pollutant pathway as the increase of scale, with average baseflow NPS contribution overall increased from 0.27 to 0.45 from the headwater small watershed to the outlet of the watershed. The potential mechanism of spatial scale effect BFI and baseflow NPS contribution rate (CR) in tributaries and main stream were different. The baseflow index (BFI) and its NPS contribution in tributaries were closely related to landuse type and distribution, while those in main stream were under the complex influence of both landuse and tributaries inflow. Furthermore, the spatial scale effect of BFI was less obvious in dry period, whereas that of baseflow NPS CR didn't show significant difference among hydrological periods. Special attention should be paid to the control of baseflow pollution during dry period when baseflow NPS contributed about half of the river pollutants. Uncertainty caused by concentration was stressed in this study and after comparing the 90%, 95% and 99% lower limit, we found it might be reasonable to adopt 90% as lower limit as it basically captured baseflow NPS featured and allowed for enough samples. Further research is needed to assess the finer mechanism of baseflow NPS pollution and reduce uncertainty based on finer monitoring data and tracer-based methods across time and spatial scales.

Keywords

Nonpoint source pollution; spatial scale effect; Pathway; Soil and Water Assessment Tool; Nested watershed; Uncertainty

A long-term water balance analysis of urban watershed in Korea

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Abstract

In this study, long - term runoff analysis of Seoul metropolitan urban area was conducted to perform water balance analysis. The SWAT-K model is used to analyze the evapotranspiration and runoff using urban land use and soil map data. The results of the hydrologic parameters calculated for the target watershed are determined by comparing with the available observations to confirm the validity of the modeling results. Since groundwater recharge is not available, there is no direct comparison between the observed and the simulated values. Therefore, if the simulated values of the total runoff are highly correlated with the observed values, the validity of the simulated runoff components is shown. This also demonstrates the quantitative validity of groundwat recharge with high correlation with baseflow from a long-term perspective. In order to estimate the recharge of groundwater in this watershed, a total of 10 years daily based hydrologic component from 2008 to August 2018 was simulated using the SWAT-K model. As a result of showing the runoff hydrograph obtained by comparing the observation value and the simulation value, the determination coefficient (R2) of the simulation value for the observation value is 0.82. In addition, the baseflow of the upstream watershed and the SWAT-K simulated values were also highly correlated (R2 = 0.76). The results of water balance analysis (2008 ~ 2018) using SWAT-K showed that the discharge rate was 60.5%, the evapotranspiration rate was 39.5% and the rainfall rate was 22.2% compared with the average annual precipitation.

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Keywords

SWAT-K, Water balance analysis, Groundwater Recharge, Seoul metropolitan urban area

Effect of reforestation after the decay of spruce stands on the hydrological conditions of the Leśnianka and Malinowski Stream catchments in the Silesian Beskid

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Abstract

The reforestation process with beech, fir and sycamore using the natural regeneration of spruce in mountain catchments, resulting from the disintegration of spruce monocultures is an important element of the management strategy towards the reconstruction of a sustainable and stable forest ecosystem (Bréda et al 2006, Schütz et al., Svoboda et al., Durło et al. 2015). This strategy primarily concerns the improvement of retention conditions and the limitation of uncontrolled runoff of rainwater, the consequences of which are dangerous both for the stability of soils on steep slopes and low-lying areas in the vicinity of surface watercourses, reservoirs and hydraulic structures.

In this paper an analysis of selected parameters of the water balance of the two mountain catchments which were reforested after the disintegration of spruce stands was carried out. The research was conducted in 2012-2017 in the eastern part of the Silesian Beskids. The data on land cover and soils were obtained from the SILP PGL LP database and on the basis of high resolution photographs taken from the UAS/UAV. Hydro-meteorological data were obtained from the RSOML LKP database of the Silesian Beskids Forest. SWAT (*Soil and Water Assessment Tool*) and SWAT-CUP (SWAT *Calibration and Uncertainty Programs*) (Arnold et al. 2012, Abbaspour et al. 2014) tools were used for modeling. 27 sub-catchments, 288 HRU (Hydrologic Response Unit), and 720 LSS (Landscape/Landuse Slope Soil Unit) units were identified in the study area.

As a result of geostatistical analysis carried out in the ArcMap environment (ESRI Inc.) indexes of renewals within the sub-catchments were determined in subsequent years, initial and final parameters of retention and speed of water outflow were determined on clearcuts – as of year 2012 and forest crops in autumn 2017. As a result of analyzes water balance parameters, a slight but significant improvement in the water balance of the basin was noted as a result of favorable retention changes on the examined area, which increased by an average of 6.4% and the outflow rate of water from the studied area decreased by 4.2% on average compared to 2012. The parameters obtained with the use of the SWAT model were evaluated using the SUFI-2 (95PPU) algorithm. Obtained results of determination coefficient (R2 = 0.77), model efficiency coefficient (NS = 0.680 and percent bias (PBIAS ± 16%) indicate very good match of modeling results in relation to measurements.

The positive effect of reforestation 8 years after planting the seedlings in the catchment gives hope for the improvement of water conditions and reduction of adverse erosive effects on catchments in the future until the formation of mature, stable stand.

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Keywords

SWAT, water balance, spruce decay, reforestation

Improved simulation of groundwater-surface water interactions between oasis and catchment systems in Morocco using MODFLOW and SWAT+

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Abstract

For proper management of oasis environment, it is important to understand the hydrological processes which are driven by surface-groundwater interactions. The quantification of these interactions requires the coupling of groundwater and surface water models. In this study, we aim at comparing groundwater recharge and discharge in the catchment/oasis using MODFLOW that is calibrated using groundwater depth and SWAT+ that is calibrated using surface water observations. An agreement in groundwater recharge and discharge by MODFLOW and SWAT+ is seen as first step towards a coupled MODFLOW-SWAT+ modeling system.

In groundwater models, such as MODLFOW model, the recharge from surface water and rainfall is one of the input data. However, the lack of observation of recharge creates the difficulty to quantify this value. In most cases, hydrogeologists estimate this value by using a theoretical number of percentages of the rainfall. This difficulty could be solved with the help from surface water balance models such as SWAT. Especially in my study area: the TOS (Tafilalt Oasis System), which underlies the plain of Tafilalet, corresponds to the sub-basins of Tizimi and Tafilalet. It is located in southeastern Morocco in a pre-Saharan zone bordered on the north-east by the erosion limits of the Hammada and to the west and south by the ancient massifs of the Atlas, The Tafilalet oasis system is occupied by one of the largest palm groves in the Maghreb (north-west Africa). Traditional irrigation is practiced and agriculture is the main activity (representing approximately 37 % of the total area of 637 km2). Although it is quite diversified, agricultural production remains insufficient in the current unfavorable conditions. The area is irrigated mainly by the surface waters of the Ziz River and by water released from the Hassan Addakhil dam, located 70 km in the North of the region, along the riverbed released from diversion dams located on the Rheris River, but these contributions are irregular and short-term.

At the other hand, catchment models such as SWAT have difficulties to validate their groundwater component. A comparison with MODFLOW simulations could be useful to better understand the interactions between Groundwater and Surface water.

Keywords

ModFlow, SWAT+, groundwater-Surface water interractions,Oasis

Combined use of SWAT and ANN models for hourly peak flow estimation in Chungju Dam watershed, South Korea

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Abstract

The instantaneous peak flow data is essential for flood frequency analysis, hydraulic structure planning and design, flood prediction, and dam operation. The objective of this study is to propose a method of linking SWAT model and artificial neural network (ANN) model to generate hourly peak flow data for the Chungju Dam watershed, South Korea. Firstly, two types of ANN structures were constructed to estimate hourly peak flows, one using the observed daily dam inflow data as inputs and the other using the historical daily rainfall data as well as the daily inflow records. From the comparison of the generated and observed hourly peaks, the ANN model with additional consideration of daily rainfall showed better performance for the flood events from 1990 to 2017. Then, the SWAT model was used to simulate the daily inflow data which have been further used as inputs to ANN models for estimating hourly peak flows. The results showed that the combination of the SWAT and ANN models can be successfully used in transferring from daily data to hourly peak flow.

Acknowledgments: This research was supported by a grant from a Strategic Research Project (20190153-001) funded by the Korea Institute of Civil Engineering and Building Technology.

Keywords

instantaneous peak flow, SWAT, artificial neural network, hourly peak

Estimation of hourly peak flows at multi-sites using SWAT in the Chungju Dam watershed, Korea

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Abstract

In general, the use of instantaneous peak flow data rather than daily flow are required for flood analysis. To estimate sub-daily flow data at the site of interest, the traditional event-based model is mainly used. Event-based model needs sub-daily rainfall input data and streamflow data for verifying the model simulation. However, most of the cases are lack of long-term rainfall and streamflow data. In this study, SWAT modeling was performed by dividing the Chungju Dam watershed (~6,648km^2) into 22 subbasins for the period of 1986~2010. The simulated results showed a good agreement with the observed inflow at the Chungju Dam. The model performance statistics of R^2 and NSE were at more than 0.8. SWAT simulations for each outlets of subbasins were converted to hourly peak flows using Sangal's method. Annual maximum peak flows were constructed at the multi-sites. In order to verify the estimated peak flows, we compared with the results of applying event-based model, storage funtion model (SFM) for the same period. Finally, the applicability of SWAT for flood analysis and problems depending on scale of subbasins were evaluated.

Acknowledgments: This research was supported by a grant from a Strategic Research Project (20190153-001) funded by the Korea Institute of Civil Engineering and Building Technology.

Keywords

SWAT, Sangal's method, peak flow, multi-sites, storage function model

Evaluation of the SWAT model performance for a small agricultural catchment in Austria

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Abstract

Hydrological models enable comprehensive examination, understanding and quantification of hydrological processes under the influence of characteristics describing rainfall and catchment features. These processes are strongly influenced by human activities like agriculture and urbanization. The Soil and Water Assessment Tool (SWAT) is typically applied to study effects of such activities at mesoscale catchments. Here we want to test the applicability of SWAT for very small hydrological units. Thus the objective of this study is to apply the Soil and Water Assessment Tool (SWAT) to a small agricultural watershed, calibrate and validate it with measured runoff, sediment yield and crop yield data and test effects of parameters with different spatial resolution.

The investigated watershed is situated in Petzenkirchen in the western part of Lower Austria (48° 9' N, 15° 9' E), 100 km west of Vienna and has an area of 66 hectares. Elevations range from 268 to 323 m a.s.l. The climate is humid with mean annual temperatures around 10°C, and annual precipitation of around 800 mm. The subsurface consists of Tertiary sediments of the Molasse zone and fractured siltstone. Soils include Cambisols and Planosols with medium to poor infiltration capacities. Gleysols occur close to the stream. Detailed soil physical and chemical properties of the catchment containing information about organic matter content, clay, silt, and sand percentages at multiple depths is also available. A detailed high resolution digital elevation model (DEM) raster is available for the catchment area. The DEM was used to extract hydrological parameters of the watershed.

The natural surface water outlet of the catchment is the Seitengraben stream with a mean annual flow of 4.1 L s^{-1}. At present, 87% of the catchment area is arable land, 5% is used as pasture, 6% is forested and 2% is paved. The agricultural activities mainly involve wheat based crop rotation including winter wheat, winter barley, sweet and silage corn, canola etc. The catchment is divided into 37 fields and for each field exact information about tillage date and type of implement used, date of planting and harvest and date and amount of fertilization and plant protection are available. All this information is considered when setting up the model.

The procedures of model set up, calibration and validation are outlined. A Sequential Uncertainty Fitting (SUFI-2) procedure is used to auto-calibrate and validate the SWAT model. The model calibration is based on the daily discharge of the stream, daily sediment yield and crop yield. As a first result, model performance on the small agricultural catchment will be presented. Further on we are planning to investigate on the scaling of different input parameters.

Keywords

Model performance, hydrology, surface runoff, sediment yield, model calibration and validation

Using SWAT and the chloride mass balance method to improve the modelization of basins under significant groundwater exchanges

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Abstract

In high-permeability bedrock areas, the geographical boundary of a basin does not necessarily coincide with the underlying aquifers boundaries. In such cases, the groundwater exchange must be considered in order to improve the hydrological modelling. This is the case of the headwaters of the Castril river basin (CRB) in southern Spain, where the runoff coefficient is above 1 due to the groundwater incoming from the hydrogeologically connected upstream basins, being an exceptional case in continental Spain. In this study, the CRB has been modelized using the SWAT model while the chloride mass balance method was used for a preliminary evaluation of the external groundwater contribution to the CRB, after checking that recharge equates discharge in upstream basins. The results show that model performance clearly improves when groundwater exchanges are taken into account. It has been estimated that about 40% of the groundwater of the CRB comes from upstream basins. The methodology used in this study is proposed in other areas where groundwater exchanges play an important role in surface hydrology.

Keywords

SWAT model; Chloride mass balance; groundwater exchange; Castril river basin

Analysis of agricultural drought through hydrological analysis of agricultural reservoir watershed

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Abstract

To analyze the agricultural drought through hydrologic analysis of the agricultural reservoir watershed, SWAT was used to simulate the detailed hydrology and HOMWRS(Hydrological Operation Model for Water Resources System) was used to estimate the agricultural water supply. HOMWRS is a program that is implemented in an integrated system of watershed inflow, irrigation needs, water balance analysis and unit water amount estimation to establish agricultural water supply plans in agricultural reservoirs. The watershed includes the Songsan Observatory (3,300ha), which is located in the watershed reservoir watershed of Korea, as the watershed outlet. Model validation result confirmed that the model efficiency is 0.9 and that the simulation results of the hydrological elements (rainfall, runoff, infiltration, evapotranspiration, infiltration, soil moisture) are summarized by simulating 2001 ~ 2016. From 2001 to 2016, mean precipitation was 1429.3 ㎜, discharge was 817.9 ㎜, infiltration was 532.3 ㎜, evapotranspiration was 584.9 ㎜, percolation was 319.0 ㎜ and soil water was 134.2 ㎜. During the agricultural drought period, mean precipitation was 1194.6 ㎜, discharge was 612.6 ㎜, infiltration was 423.2 ㎜, evapotranspiration was 579.0 ㎜, percolation was 218.0 ㎜ and soil water was 131.9 ㎜. HOMWRS was used to calculate the daily inflow and the required amount, and the water budget for the simulated operation of the reservoir was calculated to estimate the amount of water supplied. The irrigated area of the watershed was 1,497 ha, and the average irrigation requirement was 693.5 mm and it was 840.1 mm in the drought years. During the drought period, decreased precipitatio 16.4%, discharge 25.1%, infiltration 20.5%. During the drought period, irrigation demand increased by 21.1%.

This research was supported by a grant(2019-MOIS31-010) from Fundamental Technology Development Program for Extreme Disaster Response funded by Korean Ministry of Interior and Safety(MOIS).

Keywords

SWAT, hydrological, agricultural reservoir , agricultural drought

Impact of headwater stream burial on downstream processes within Kemptville Creek subwatershed in Ontario, Canada

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Abstract

Headwater streams can compose up to 80% of the total stream length within a watershed but remain most susceptible to stream burial during land-use change. Stream burial within agricultural landscapes involves rerouting streams into tile drains, culverts, and non-perforated pipes in order to increase crop production area and manage irrigation. Stream burial alters the stream's physical, chemical and biological processes resulting from land-use change. This study models the impact of headwater stream burial within an agricultural landscape, to quantify the impacts of headwater stream burial at a subwatershed scale. We used the Soil and Water Assessment Tool (SWAT) to model the impacts of headwater stream burial on downstream processes in the Kemptville Creek subwateshed of the Rideau River Watershed in Kemptville and surrounding area, Ontario, Canada. Model inputs include physical, chemical and biological data available for Kemptville Creek subwatershed. Headwater streams were delineated at a 10-hectare threshold. Ground-truths resulted in 50 and 40% of the delineated streams to be actively flowing during a daily mean flow of 10.999 cubic metres per second in March and 24.401 cubic metres per second in April, respectively. Headwater stream burial is implemented within the model at 25, 50, 75 and 100% of the total headwater stream length. The removal or "day-lighting" of existing tile drainage was also simulated to examine how the current state of Kemptville subwatershed might change if tile drainage within headwater reaches was removed. The model demonstrates the value of headwater streams during high precipitation events and for ecosystem resilience by examining contributing discharge, chlorophyll A and dissolved oxygen to downstream ecosystems. Results from this work will highlight the importance of headwater streams to subwatershed dynamics, including subwatershed hydrological dynamics and biological productivity following headwater stream burial. This research contributes to the understanding of ecosystem response as hydrologic regimes are altered following stream burial within agricultural landscapes.

Keywords

Headwater streams, ecosystem response, land-use change, hydrologic regimes

An integrated GIS and SWAT model approach to assess past, present and future land use changes and related water management impacts in the upper Amazon region of Ecuador

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Abstract

Land use change can have a significant influence on catchment runoff and sediment characteristics. Therefore, related tools for analysis and prediction are essential for land policy planners to understand the problems and take action for improvement in soil and water conservation measures. The main objective of this study is to assess the land use change and its impact on the water balance of the Coca River basin, located in the upper part of the Amazon region in Ecuador. The study of this catchment in terms of land use change and its impact on the water balance is of high importance for Ecuador, since this basin is the one that provides the necessary flow for the operation of the largest hydroelectric plant in the country (Coca Codo Sinclair). The Soil and Water Assessment Tool (SWAT model) was used to analyze the influence of the past, present and future land use change on water and sediment balance in the study area. The model has been calibrated and validated in SWAT-CUP. The observed monthly stream flows from 1982 to 2000 were used for calibration, while the data from 2001 to 2016 were used for validation. Land use changes of 1990, 2000, 2008 and 2016 were analyzed and a Markov Chain model was used to predict 2026 land use according to three scenarios: A) Trend scenario: Which maintains the probabilities of change in land use that the Markov Chain Model (after having been validated for 2016) predicts for the year 2026. B) Best-case scenario: Which addresses the probabilities of change in land use, within the Markov Chain Model, towards a balanced scenario between conservation of natural ecosystems and productive activities within the basin, by the year 2026. And C) Worst-case scenario: Which addresses the probabilities of change in land use, within the Markov Chain Model, towards a scenario where extractive activities prevail and the productive areas in the basin increase by the year 2026. Also, different land management practices were incorporated into the best-case scenario simulations. Results show a link between land use and the Sediment Yield (Soil Loss) in the catchment. Different land uses in the catchment contribute differently in the annual amount of soil loss, however, the highest annual rate of soil loss within the catchment is found in the agricultural areas and specifically in zones with a slope percentage between 20% and 30%. The results also show that the annual average discharge in the catchment did not change significantly over the past years. Based on this, we used randomized past climate observations as hydrometeorological forcing for the future scenarios. Overall, the model results support the existing efforts of the Coca River Basin land managers to protect the area along the Coca river against agricultural expansion and natural forest cover reduction and indicate that additional emphasis should be placed on improving land management practices. The results of this study are important for developing soil and water conservation programs, extending future SWAT modeling studies and disseminating these results to other basins in the Ecuadorian Amazon region.

Keywords

Land Use Change, Water Balance, Hydrological Modelling, SWAT, Markov Chain, Future Prediction, Integrated Watershed Management

Modelling a semi-arid catchment with a large number of horizontally connected reservoirs in Brazil

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Abstract

The semi-arid Northeast of Brazil is prone to severe floods and droughts. In the Upper Jaguaribe River Basin a high-density reservoir network has been developed, which has a considerable impact on the hydrological flow regime. The Conceição River catchment, a sub-basin of the Upper Jaguaribe River Basin in the state of Ceará, was subject to this study. Four strategic reservoirs, i.e. large dams that are managed by the governmental authorities, are located inside the study catchment. More than 200 small private, unmanaged reservoirs were registered.

The aim of this study was to set up a physically based, semi-distributed hydrological model of the catchment applying SWAT (Soil and Water Assessment Tool). The reservoirs of different types should be implemented such that the horizontal hydrological connectivity and the impact of these human structures on runoff are reflected by the model scheme.

As data on the small reservoirs were scarce, a field and remote-sensing investigation on the nature of these dams was conducted prior to modelling. The strategic reservoirs and 13 of the small private reservoirs located on main river reaches were implemented into the SWAT model as reservoirs (impoundment situated on the main river). All other small dams were implemented as ponds (water impoundment situated on tributary). In case that a sub-basin contained more than one pond, the group of small reservoirs was aggregated considering both their spatial arrangement and the single drainage areas. The model was calibrated and validated for each sub-catchment of the monitored strategic reservoirs comparing the simulated and observed hydrographs of daily storage volumes. Subsequently, the remaining sub-basins were calibrated and validated with daily streamflow measurements at the outlet of the catchment (Malhada gauging station) applying three statistical evaluation criteria (NSE, RSR, PBIAS).

Storage volume showed to be simulated with reasonable accuracy for all strategic reservoirs both for the calibration and the validation period, with the spilling being simulated realistically during extreme flood events. Model performance in simulating streamflow was good (NSE = 0.69, RSR= 0.59) for the calibration period, however, underestimating discharges in average by 41 % (PBIAS). Flood peaks and dry years were simulated well by the model. This indicates that the network of small reservoirs is adequately represented and reservoir capacities are reasonably estimated. The high PBIAS could be related with a bad model performance in simulating flood recession curves following a rainy period. We conclude that SWAT has some weakness in the representation of the transmission loss processes and the river-aquifer-interaction, which might be improved further or require coupling of groundwater models.

Keywords

reservoir, pond, horizontal connectivity, semi-arid hydrology, SWAT

Application of SWAT model to assess hydrological balance and mass transport within medium size catchments

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Abstract

Currently there are many tools available to model hydrological processes (typically at a smaller, detailed scale) including HYDRUS, MODFLOW, MIKE SHE, WMS, etc. but very few of these tools can be applied at larger scales. Most of mathematical models at a small scale are physically based, which means a more realistic description of processes, but also higher input data requirements. It rare that these models can also be applied to larger catchments. The Soil and Water Assessment Tool (SWAT) is a very powerful tool that can be applied to regional and even continental systems that many other modelling software systems cannot simulate. SWAT has previously been used to model the impacts of climate change and water management strategies across large areas of the United States, India, and Europe. In the presented study, SWAT is utilized to assess the effects of regional landuse changes in evapotranspiration (ET) rates, surface runoff, infiltration, soil erosion and discharge projections in central Europe to verify potential positive or negative effects of measures designed to improve the hydrological regime of agricultural landscape.

Principles and preliminary results of the model are utilized to document long-term changes across Hydrological Response Units (HRUs). With land-use and land-management changing effectively in real time, SWAT gives us a vector to predict and document shifts in the region's water balance in the face of further industrialization and climate change. This model will be used as tool to extrapolate results from experimental plots and small experimental agricultural catchments generalized by small scale detailed physically based models, to medium and large scale. Results can then be applied to support strategic land managment decision-making under different climatic and economic conditions in Europe and China.

Presented research has been performed within project H2020 No. 773903 SHui, focused on water scarcity in European and Chinese cropping systems.

Keywords

agricultural watershed, watershed management, water balance, mass transport

Analysis of Pollutants Load from Nationwide agricultural Fields Considering Future Climate and Seasonal Prediction Using Model APEX

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Abstract

Recently, excessive usage of chemical fertilizer and agricultural pesticides is deriving imbalance of soil environment and domestic soil nutrient balance is getting unstable. And flood and drought due to global climate change is another major factor of the imbalance of the soil nutrient. These are accelerating crop productivity and a decline in water quality. Therefore, a systematic soil management plan based on nutrient distribution analysis is necessary. This study aimed to analyze pollutant load from the agricultural area of South Korea in the province unit about past and future. Basic geological data such as area, slope, slope length, location, and elevation of the agricultural field was collected from National Geographic Information Service and Korea Agency of Education, Promotion & Information Service in Food, Agriculture, Forestry & Fisheries(EPIS). For past period analyze, observed weather data for 30yrs(1983~2012) from the National Weather Service was utilized. And for future period analyzation, predicted weather data for from APEC Climate Center (APCC) was utilized. For predicted future weather data, 2 scenarios from each 9 GCMs(Global Climate Models) were reflected in this study in 3 phase which is 'the near future' (2010~2039), 'the future' (2040~2069), and 'the far future' (2070~2099). And analyze using seasonal prediction data which is six months term from APCC is added in this study additionally. For farming crop data, statistics from the National Statistical Office(NSO) was considered. Pollutant load simulation result for the past period was within a range proposed by the National Institute of Environmental Research(NIER). In case of future period simulation, pollutant load results were showing different load trends depending on the soil, and GCMs. Lastly, simulation result using seasonal prediction was also within the load unit from NIER. It is proven that the pollutant load was highly influenced by the rainfall in this study. Results of this study are expected to be utilized as a base material for agricultural best management practices policy and countermeasure for fertilizer application guide policy. As a conclusion, T-N pollutant load was vary depending on the climate characteristics, crop, and soil. T-N pollutant load results from this study were distributed within unit load from National Institue of Environmental Research. T-N pollutant load results were having similar trends with rainfall in seasonal prediction results, thus rainfall is considered as the major factor for T-N pollutant load.

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Keywords

APEX model, Future Climate Scenario, Seasonal Prediction, Pollutants Load, Nationwide Modeling

Design and development of a Python-based interface for processing massive data with the Load Estimator (LOADEST)

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Abstract

The Conservation Effects Assessment Project (CEAP) is a national multiagency effort to quantify the environmental benefits of conservation practices across the conterminous United States (US). This effort was evaluated by building and analyzing many hydrologic models across country, which have to be calibrated using publicly available datasets. Major data sources are from the United States Geological Survey (USGS), but it is very difficult to process them manually for so many stations. In this study, a Python-based interface was developed for handling massive data with the Load Estimator (LOADEST) model. It would be easier for users to process data for bulks of stations involving multiple constituents. The interface contains directly downloading flow, sediment and nutrients for any available stations from the USGS, formatting data for LODEST model, parallelly running the model and extracting results from the model outputs. Regarding to stations with an error of failure to converge, it has a function to automatically find the best window period to simulation constituents for these stations. Users can also specify output format for facilitating the process of calibrating some hydrologic models (such as SWAT+). A case study was conducted to demonstrate the capability of the interface for simulating various stations with multiple constituents and picking the best performance model for the estimation for each constituent. This tool can help provide a convenient approach for collecting calibration data for hydrologic models and serve as a communication tool for some users in large watershed applications.

Keywords

LOADEST interface; Massive data; Flow; Nutrient; Sediment

Simulation of nitrous oxide emissions in typical agricultural catchments in Austria

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Abstract

In Austria, nitrous oxide (N_2O) emissions from the agricultural sector contributed 4.5% to Austria's total greenhouse gas emissions in 2015. The reactive nitrogen (Nr) which occurs in different forms (e.g. NO_3^- and N_2O) mainly stems from nitrogen fertilizer application and has negative impacts on water quality and climate change. Therefore, the aim of this study is to simulate reactive nitrogen emissions in typical agricultural catchments in Austria. The eco-hydrological model Soil and Water Assessment Tool (SWAT) was set up in three Austrian agricultural catchments (lower Mur, Marchfeld, and Melk) each located in a different agricultural production region to simulate Nr emissions. However, SWAT does not simulate N_2O emissions as an output variable, therefore this study focuses on an approach to apply equations that integrate NO_3^- concentration, organic C and the most important impact factors related to denitrification in Austrian agricultural soils to calculate N_2O emissions.

The impact factors related to denitrification rates and amounts vary spatially and temporally, leading to much heterogeneity, which is rarely considered. Therefore, we undertook a literature review to categorized environmental factors (e.g. soil characteristics and climate), management related factors (e.g. fertilizer type and crop type) as well as measurement factors (e.g. measurement period) to describe the impact of each factor on N_2O emissions.

Keywords

nitrous oxide, SWAT, agricultural catchments, impact factors

Assessing Influence of climate change on the fate and transport of fecal coliform bacteria using the modified SWAT model

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Abstract

Fecal coliform bacteria (FCB) contamination of natural waters is a serious public health issue. Therefore, understanding and anticipating the fate and transportof FCB are important for reducing the risk of contracting diseases. The objective of this study was to analyze the impacts of climate change on the fate and transport of FCB. We modified both the soil and the in-stream bacteria modules in the soil and water assessment tool (SWAT) model and verified the prediction accuracy of seasonal variability of FCB loads using observations. Forty bias correcting GCM-RCM projections were applied in the modified SWAT model to examine various future climate conditions at the end of this century (2076–2100). Lastly, we also compared the variability of FCB loads under current and future weather conditions using multi-model ensemble simulations (MMES). The modified SWAT model yielded a satisfactory performance with regard to the seasonal variability of FCB amounts in the soil and FCB loading to water bodies. The modified SWAT model presented substantial proliferation of FCB in the soil (30.1%–147.5%) due to an increase in temperature (25.1%). Also, increase in precipitation (53.3%) led to an increase in FCB loads (96.0%–115.5%) from the soil to water body. In the in-stream environment, resuspension from the stream bed was the dominant process affecting the amount of FCB in stream. Therefore, the final FCB loads increased by 71.2% because of the growing peak channel velocity and volume of water used due to an increase in precipitation. Based on the results of MMES, we concluded that the level of FCB would increase simultaneously in the soilas well as in streamby the end of this century. This study will aid in understanding the future variability of FCB loads as well as in preparing an effective management plan for FCB levels in natural waters.

Keywords

Climate change, Fecal coliform bacteria, Soil and water assessment tool, Fate and transport

Landscape level exposure assessment of pesticide concentration at drinking water abstraction points – a study on spatio-temporal controls using SWAT.

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Abstract

Surface water is an important source for drinking water supply in many European countries. The exposure assessment of plant protection products (PPP) at drinking water abstraction points is hence of specific interest and included in the EU regulatory framework (regulation 1107/2009). However, exposure assessment for drinking water abstraction in the EU and member states is limited so far on very simplistic edge-of-field approaches. For example, in the Netherlands the mixing factor for drinking water is estimated by empirical relationships (e.g. contributing crop area, use intensity) from country-specific characteristics. Our work explores the mixing factor at landscape level to get a better insight into more realistic scenarios using the Soil and Water Assessment Tool (SWAT). Particular focus was on the controlling factors of pesticide and water transport in connected surface water systems, for example application timing, weather forcing, dissipation and entry path into the water system.

On this account, we applied SWAT to selected and potential vulnerable catchments in Europe under different scenarios and worst-case assumptions. First simulation results with runoff-induced PPP entry indicate that the mixing factor strongly depend on the spatial crop distribution and the relative location of the abstraction point within the channel network. Furthermore, spray drift potentially has significant impact on the spatio-temporal PPP distribution in surface water. Therefore, we would like to consider the drift entry component with a modified SWAT version in future simulations to explore the interaction of runoff and drift components in more detail.

It is expected that these insights regarding key factors of PPP mixing in surface water can be used to derive representative scenarios on EU level for specific crop and PPPs.

Keywords

landscape level, exposure assessment, drinking water abstraction, mixing factor, spatio-temporal controls, SWAT, pesticide

Integrated water quality management model for rural cross-border river basin: The case of Sotla/Sutla river

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Abstract

The intensive use of soil and water of the river basin results in the need to achieve balance between the environmental and developmental objectives of the river basin by using a water quality management model for the risk of eutrophication, especially downstream of dam/reservoir such as in the case of the Slovenian-Croatian cross-border Sotla/Sutla River basin. **The aim study is to develop a water quality management model of the rural cross-border river basin within integrated water management to achieve the environmental objectives of the river basin.** The selected model is based on the selection of the optimal water quality management scenario on the Sutla River basin implements on the use of the Driving Forces, Pressures, State, Impact, Response (hereinafter: DPSIR) approach, climate change models and the Soil and Water Assessment Tool (SWAT model), and the „tailor-made“ measures of the river basin including ecosystem services and human well-being.

Keywords

water quality, integrated river basin management, cross-border

Parameter estimation in SWAT with ensemble Kalman filter considering characteristics of ordinary and rainfall flow

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Abstract

In schemes for nutrient reduction from watershed such as a master plan for sewerage system propagation, flow and nutrient behavior in watershed is critical to make an effective plan to fulfill environmental standard of water body. There are many uncertainties in constructing a watershed model. These includes: First, observation frequency of concentration of water quality, which is a target of such scheme on nutrient reduction, is not enough since observations conducted in public water are infrequent, for example, only once a month in Japan. Second, unit loads, which are expressed as mass per unit area or capita per unit and are used for watershed loading determination from various pollutant load, can be fluctuated from place to place. Third, there are many parameters of watershed models which should be calibrated including parameters related to pollutant load from non-point source. To address these problems, this study applied a data assimilation method called ensemble Kalman filter (EnKF), to SWAT (Soil and Water Assessment Tools) model, which can simulate flow and nutrient cycle in watershed, and conducted parameter estimation aiming at flow and nutrient load at ordinary and rainfall flow, where nutrient load in ordinary flow is dominated by point source while that in rainfall flow is greatly influenced by non-point source.

Keywords

Data assimilation, Ensemble Kalman filter, water quality, SWAT

Application of wetlands, lakes and reservoirs in Africa using SWAT+

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Abstract

SWAT+ is a new version of SWAT that with clear differences in the model code structure and high flexibility in model application, reflected by object-oriented elements representing land and water features with flexible interconnections between them. In addition, SWAT+ implemented the principles of decision tables to implement management decisions, for instance for irrigations or reservoir management. These functionalities strongly facilitate the implementation of wetlands and reservoirs.

Wetlands and reservoirs cover a small fraction of catchment area but have a huge impact on catchment hydrology. In this study, we present a methodology to apply wetlands and reservoirs in a SWAT+ model for Africa. Wetlands are identified as areas that periodically cover large areas of land with water through river flooding processes.

A different approach was used for the implementation of wetlands and reservoirs, with distinct parameter sets. They represented by wetland units that are linked with landscape units in SWAT+. The reservoirs are linked to decision tables to represent the flood control.

The SWAT+ application for Africa consists of 5502 sub-basins, 5502 Landscape units, 89614 Hydrologic Response Units, 140 reservoirs and 5 wetlands. For West Africa, there are 680 sub-basins, 680 Landscape units, 10060 Hydrologic Response Units, 22 reservoirs and 1 wetland. After the implementation of the wetlands and reservoirs, the simulations improved significantly for Africa.

Keywords

reservoirs, wetlands

Re-conceptualizing HRU threshold definition in the Soil and Water Assessment Tool

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Abstract

The Soil and Water Assessment Tool (SWAT) model discretizes watersheds into sub-basins and subsequently into smaller hydrological response units (HRU), each of which represents a unique combination of land use, soil and slope. The user-defined thresholds to define HRUs in ArcSWAT often results in considerable loss of landscape biophysical information especially at higher thresholds. Areas of HRUs within a subbasin that fail to qualify the user-defined threshold for land use would get reapportioned to the remaining qualified HRUs based on area dominance irrespective of their landscape characteristics. This study reconceptualizes the HRU threshold allocation in ArcSWAT model setup which would reduce the loss of landscape biophysical information without lowering user-defined HRU thresholds. We propose a revised algorithm which reapportion below-threshold HRUs to other HRUs of similar land or soil class such that biophysical characteristics are conserved. Model setups were compared for a case study catchment in Pennsylvania, USA to examine the efficacy of the new method to retain these land characteristics and provide predictions that are closer to a zero-threshold or full-HRU model. Outcomes demonstrate that the improved method could retain land use and soil characteristics similar to the full-HRU model and enhance the hydrological and water quality predictions when compared to default threshold SWAT model. Distribution of several land use and soil parameters in the model were also better characterized with the improved HRU definition method. The new method significantly reduced number of HRUs from 29,288 in full-HRU model to 934 HRUs while retaining similar landscape information. The new HRU threshold definition will help modelers to have more computationally efficient modeling framework without compromising accuracy of biophysical inputs to model.

Keywords

HRU threshold, Hydrological Response Unit

SWAT-P: A modified SWAT model to simulate dissolved reactive phosphorus in tile-drained landscapes

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Abstract

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 discharge for all sub-catchments 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. SWAT-P performed considerably better than SWAT. Additionally, calibrated DRP concentrations were unrealistically high for SWAT, whereas calibrated 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 tile 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 tile drainage water and the deep aquifer in the SWAT-P input files. 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

APEX-MODFLOW: new integrated model to simulate water and nutrient transport at the watershed scale

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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 hydrological processes. In this study, the APEX (Agricultural Policy/Environmental eXtender) watershed modeling code is amended to include physically-based, spatially-distributed groundwater flow modeling using the MODFLOW code. The APEX subarea deep percolations rates are transferred to MODFLOW grid cells using a groundwater delay function, and the MODFLOW River package is used to estimate stream-aquifer water exchange rates. The difference between subarea potential ET and actual ET is used by MODLFOW to simulate ET from shallow groundwater. Simulated cell-by-cell groundwater head from MODFLOW is used to determine the depth to water table for each APEX subarea. The RT3D groundwater solute transport code is also imbedded within MODFLOW, to simulate N and P transport in the aquifer and mass loadings to streams. Required pre-processing includes preparation of linking information between APEX subareas and MODFLOW grid cells for transfer of recharge and ET, and between APEX subareas and MODFLOW River cells for groundwater/surface water interaction. The resulting model therefore is capable of simulating coupled surface/subsurface flow and nutrient transport in a watershed setting. Model application is demonstrated for the Middle Bosque River Watershed (471 km^2) in central Texas. Future research includes adding salt chemistry routines to allow simulation of salt ion fate and transport in the soil, groundwater, and surface water systems. 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

APEX, MODFLOW, nutrients, watershed modeling

Assessing Salt Ion Fate and Transport in Arid Regions using SWAT-Salt

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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. Using salinized groundwater for irrigation leads to decreased crop productivity, and loading of salinized groundwater to surface water features impacts agricultural productivity of downstream cultivated areas. Models can be useful in assessing baseline salinity conditions, identifying causes of groundwater and surface water salinization, and exploring the effects of proposed remediation strategies. In this study, the recently developed model SWAT-Salt is applied to arid regions to investigate mass transport patterns in the coupled land surface / aquifer system and to identify possible remediation strategies to enhance crop production. SWAT-Salt is a modified version of SWAT2012 that simulates 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. The model is applied to two salinized alluvial river valleys in the western United States: the Arkansas River Valley in southeast Colorado (732 km^2 sub-region) and the Rio Grande River Valley near New Mexico-Texas state line (watershed area: 6000 km^2; irrigation district area: 400 km^2). Model results are tested against total dissolved solids (TDS) in the root zone, groundwater salt ion concentrations from a network of monitoring wells, groundwater salt loadings to the river, and in-stream salt concentrations and loadings. In the next phase of the study, the models will be used to explore land and water management strategies aimed at decreasing salinization in river basins. Such strategies may include on-farm management, lining irrigation canals to reduce saline canal seepage, dry-drainage practices, and reducing volumes of applied irrigation water.

Keywords

Salinity, SWAT, Arid Climate

Estimating the hydrological impacts of droughts in California using SWAT: the Tijuana River Basin

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Abstract

California is one of the regions most vulnerable to meteorological droughts in the world. During 2014-2015, this region has faced its most intense and severe drought since 1895, with a total statewide economic cost in 2015 estimated in $2.7 billions. On top of that, climate change scenarios project to augment the duration, frequency and severity of droughts, so water manager will face hard challenges regarding water availability.

Modelling tools accounting for multiple environmental stressors are needed to assess the hydrological management in regions like California, allowing the analysis of drought occurrence and intensity at different scales. In this work, we have assessed the impacts of recent drought periods at the Tijuana River basin, located at the Mexico – U.S. border, with the SWAT model, evaluating the variations in the hydrological behaviour. Three major drought periods were identified: 1999-2003, 2006-2008 and 2014-2015.

SWAT was successfully calibrated (2000-2005) and validated (2006-2009) in the Tijuana River basin. The calibrated model was run during the drought periods above. Results showed that precipitation reductions between 12% and 40% leaded to much higher streamflow decreases, varying from 44% to 77%. The model simulated a high loss of water via evapotranspiration during drought periods, up to 96%, leaving no water available for surface runoff and aquifer recharge. Results of this study might provide guidelines to decision makers as to how droughts affect water availability in this region, and the model might be used to test future scenarios.

Keywords

California, Droughts, Hydrology, Modelling, SWAT

SWAT-MODFLOW implementation at a highly drained agricultural catchment in Denmark

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Abstract

Denmark is a lowland, agricultural country (with 67 % of its surface being farmed) and around half of the agricultural surface is artificially drained. Besides, groundwater contribution to streamflow plays an important role in many Danish rivers. These characteristics challenge model applications to Danish catchments with difficulties in representing all the streamflow components accurately.

The Javngyde catchment is a small rural catchment in the centre of the Jutland peninsula characterized by complex hydrogeological structure and land use dominated by agriculture, with more than half of the area being tile drained. Besides, monitoring data reveals a water balance error in the catchment, which we hypothesize could be lost either via drain flow across the flat catchment boundaries or via groundwater flow, diverging water to neighbour catchments. Water balance wise it is a challenging catchment to characterize and model, and we have therefore tested the ability of SWAT and SWAT-MODFLOW to model its hydrology. We tested four models and calibration schemes: (1) SWAT, (2) SWAT with streamflow removal in the upper catchment (to simulate loss out of the catchment), (3) SWAT-MODFLOW with SWAT-calibrated parameters and (4) pre-calibrated SWAT-MODFLOW.

The four model approaches all fairly reproduced the timing of the observed discharge, but not the magnitude, particularly during peak flows, revealing a flow overestimation. Statistically, the best model was SWAT with removal due to a better representation of peak flows. On the other hand, SWAT-MODFLOW versions reproduced better the recession peaks and simulated lower groundwater contribution to streamflow than SWAT alone. This suggests that SWAT-MODFLOW is somewhat better, probably because it allows diverging water across the topographical catchment boundary. Further work might improve these results, including a revision of the boundary conditions in the MODFLOW set-up and a full calibration of the SWAT-MODFLOW model.

Keywords

Lowland catchment, hydrology, modelling, SWAT-MODFLOW, tile drains, water balance.

Self-Organizing Maps of soil properties for improved hydrological modeling

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Abstract

Spatially distributed data on soils are crucial for studying the hydrological behaviour of catchments. Maps of soil types are available at different scales but horizon-specific soil properties are scarce and often homogeneously defined for taxonomic units, thus limiting their value for modeling purposes. As exhaustive field sampling campaigns are expensive and time-consuming, using geostatistical methods, such as Kriging, in combination with machine learning algorithms, such as Self-Organizing maps (SOM), can be a useful approach to map and classify soil properties. The aim of this work is to study the influence of different soil maps and resolutions on the hydrological model performance for a sub-arid watershed in Central Spain. For this purpose, the Soil and Water and Assessment Tool (SWAT) was used to assess the global hydrology response of five different soil property maps. One map was provided by the FAO Harmonized World Soil Database at the scale of 1:1,000,000, while the four others were based on a kriged raster map of soil properties (sampled in different campaigns), aggregated either for taxonomic soil units, available at the scale of 1:400,000, or soil units generated using SOM.

The SWAT model was calibrated and validated for each of the five soil maps. We found that the model using SOM-clustered soil properties clearly outperformed the other two models and conclude that by effectively clustering spatial input data, SOM can be a useful method to improve the quality of hydrological model predictions.

Keywords

soil properties, Self Organizing Maps, hydrological modeling, SWAT.

Modelling the flow dynamics of groundwater-surface water interactions of the Lake Tana Basin, Upper Blue Nile, Ethiopia.

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Abstract

The Lake Tana basin is selected as a development corridor by the Ethiopian government for its groundwater (GW) and surface water (SW) potential. However, there is little knowledge about the flow dynamics of GW and SW in the Lake Tana basin. Mostly, water from the aquifer system is extracted in an unplanned and unregulated manner that could result in over-pumping of the aquifer system. Therefore, this study aims to investigate the flow dynamics of GW-SW systems on a spatio-temporal basis as well as to understand if there is a hydraulic connection between GW and SW systems of Gilgelabay, Gumara and Ribb catchments, Lake Tana basin, Ethiopia. Here, the SWAT-MODFLOW model, which is an integration of SWAT (Soil and Water Assessment Tool) and MODFLOW models and which is capable of characterizing the catchment scale GW-SW interaction, is used. The model performance is evaluated based on Nash-Sutcliffe efficiency (NSE) value computed using measured and simulated daily streamflows data and the results indicate a reasonable performance (NSE>0.5) in all catchments. Our results reveal that the mode of GW-SW flow system is bi-directional i.e. from the SW to the GW (mainly at the highlands) and from the GW to SW (mainly at the lowlands). Moreover, the flow pattern differs in the three catchments due to spatial variations of the aquifer parameters and morphological heterogeneity among the catchments. In Gilgelabay catchment the flow from the aquifer to the river cells dominates, whereas in Gumara and Ribb, the main flow is from the river cells to the aquifer system. Differences in the hydraulic head between the wet and dry seasons vary from 1 to 2 m. In conclusion, this study provides a first insight for understanding the catchment scale flow dynamics of groundwater and surface water system by applying the coupled SWAT-MODFLOW model in the Lake Tana basin in particular, and in Ethiopia in general. The derived models are useful tools to study impacts of climate change on groundwater resources in the region.

Keywords

Flow dynamics; groundwater-surface water interaction; SWAT-MODFLOW, Hydraulic head, Lake Tana.

How increased nutrients and organic carbon recovery and reuse may affect their emissions to water bodies? A framework based on three Baltic case studies

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Abstract

Soil organic carbon (SOC) content is one of the key indicators of soil degradation. SOC decrease occurring in many European countries is considered a major threat to crop productivity and, in some cases, a reason for increased nutrient emission. Another key threat is over-supply of nutrients to soils in some areas, which in the case of nitrogen (N) may lead to leaching to groundwater, and in the case of phosphorus (P) to excessive accumulation in the soil and subsequent P transport by erosion and leaching to water courses. On the other hand, recovery of the organic carbon (OC) and nutrients from three major waste streams: agriculture (raw manure, biomass residues), sewage and food chain waste is increasing worldwide thanks to investments in recovery eco-technologies such as anaerobic digestion, composting, struvite precipitation or pyrolysis. It remains largely unknown how growing application of such eco-technologies and subsequent production and application to soils of 'new' products such as digestate, compost, struvite or bio-char may affect N, P and OC emissions to surface waters. This knowledge gap is currently being addressed by application of the SWAT model in three catchments draining to the Baltic Sea: Słupia (Poland), Fyrisån (Sweden) and Vantaanjoki (Finland) within the framework of the BONUS RETURN project.

In this talk we will present the current results and an outline for future work. The SWAT models have been set up, calibrated and validated in all three catchments achieving satisfactory or good goodness-of-fit for discharge, total suspended sediment, total nitrogen and total phosphorus. Furthermore, the SWAT-DOC model has been applied in the Finnish catchment to quantify emissions and loadings of dissolved OC in addition to nutrients. General assumptions for scenario development in all three catchments have also been established: (1) the amounts of external OC, N and P that could be recovered in each catchment using the aforementioned eco-technologies; (2) estimations of changes in SOC levels and other related soil parameters such as hydraulic conductivity or available water capacity due to an increased application of reused soil amendments; (3) changes in fertilization patterns related to manure recovery and production of struvite; (4) reductions of loadings from the wastewater treatment plants due to an increased recovery of nutrients and carbon from the wastewater and sludge. Preliminary results of scenario testing with SWAT will also be presented.

Keywords

soil organic carbon; nutrient recovery; nutrient reuse; soil amendments;

Land use optimization based on modeling, metaheuristics, and multi-criteria decision analysis.

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Abstract

For the 140 km^2 Lossa catchment in Central Germany, we utilized SWAT and random forest models to simulate agricultural yield, streamflow, water quality, as well as the breeding habitat of birds for a set of stakeholder-defined land use scenarios (land sparing, land sharing, and business-as-usual). The scenario results indicate strong trade-offs between agricultural production and both bird habitat and water quality. In order to minimize these trade-offs, we applied a genetic algorithm to explore the Pareto-optimal spatial targeting of scenario options at the level of HRUs. We found that all scenarios can be dominated in multiple objectives at the same time. To eventually identify preferable land use configurations, we applied a multi-criteria decision analysis based on stakeholder interviews.

Keywords

Land use optimization, genetic algorithms, multi-criteria decision analysis, agricultural yield, streamflow, water quality, biodiversity

Water Ecosystems Tool (WET): a way to simulate water quality in lakes and reservoirs from SWAT simulated watershed outputs

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Abstract

The Water Ecosystems Tool (WET) is inspired by the release of the first QSWAT version. WET provides an easy-to-use tool for user adaptation and application of state-of-the-art aquatic ecosystem models and is build on the idea to make it easy to bridge SWAT simulations of a watershed with model simulations of the associated water quality in lakes and reservoirs. WET is an open source QGIS plugin written in Python operating the coupled hydrodynamic-ecosystem model GOTM-FABM-PCLake. The GOTM-FABM-PCLake model itself is also open source and has demonstrated good performance when applied to both shallow and deep, fully-mixing and stratifying waterbodies worldwide. Albeit being one of the most complex lake and reservoir models available, several core developments are currently undergoing implementation to advance the conceptual representation of the model even further.

In WET users can run climate and nutrient load change scenarios, and estimate how these affect an individual aquatic ecosystem. WET can link to the SWAT model and this link enables assessments of how land use change scenarios created in SWAT affect aquatic ecosystems in WET. We provide an overview of the concept of WET and the core model behind. Based on examples of applications, we point to potential utilizations within the SWAT community and present upcoming developments (more info on www.wet.au.dk).

Keywords

Water quality assessments, aquatic ecosystem modelling, holistic modelling, QGIS plugin

Using the SWAT model in monitoring the impact of agricultural practices on the basin of Puck Bay in Poland- application WaterPUCK.

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Abstract

The Puck Bay is part of the Gulf of Gdansk and belongs to the Baltic Sea. The Puck Bay is protected area (Natura 2000) even then it has a problem with eutrophicationan. The predictive environmental information service created with the use of the SWAT model can help farmers from the Puck community to optimize the usage of fertilizers applied to arable fields, therefore minimizing the number of nutrients reaching the ecosystem. In addition, it can increase residents' awareness on the impact of their farming practices on the condition of the environment, surrounding watercourses and the whole bay. This model can also be used as a supporting tool for local government organizations. Based on the multivariates analysis of the impact of land use changes, in combination with agricultural practices, on the number of nutrients flowing into the Bay. The model can be used as an aid in planning community' agriculture or tourism areas.
The WaterPuck service is an interactive prognostic tool powered by meteorological data from the University of Warsaw forecasts. The presented application enables selection of the area, current type of cultivation and agricultural practices (with particular reference to the types and doses of fertilizers and other plant protection products). The response will show the number of nutrients and pesticides that come with surface runoff to the Bay. Output data from the SWAT model can be used as a boundary condition for the integrated dynamic bay model.

Keywords

SWAT, prediction model, coastal waters, agricultural catchment, WaterPuck

Development and testing of high-resolution global soil database for improved hydrologic model prediction

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Abstract

Spatially distributed hydrologic models at high spatial resolution are becoming the norm across the globe for assessing the water resource potential of the river basins. Such models become the basis for evolving better water and watershed management strategies to mitigate the impacts due to landuse change and climate change. However, the availability of high-resolution soil database for better hydrologic representation of the watershed is often a major impediment in developing such spatially distributed hydrologic models. Simulation of major components of the hydrologic cycle such as runoff, infiltration, and evapotranspiration are highly sensitive to the soil hydraulic properties. Hence, uncertainties in the spatial representation of the soil and its hydraulic properties used for model development, adversely impact the confidence levels in the simulation of major components of the hydrologic cycle.

Recently International Soil Reference and Information Centre (ISRIC), adopted machine learning and statistics to develop “SoilGrids” at 250m, 1km, 5km and 10km resolutions across the globe. SoilGrids adopts a system for automated soil mapping based on global soil profile based on covariates from time series of satellite imageries. In this study, we will evolve optimal segmentation strategies based on this high-resolution digital soil database to identify geographically unique soil clusters that would increase the confidence levels in the model simulations while minimally impacting the model runtime. For each cluster of unique soils, pedo-transfer functions such as the ones developed by Saxton will be used to derive soil storage and hydraulic properties for hydrologic model development.

The objective of this study is to evaluate the flow prediction accuracy gains by adopting the optimally segmented SoilGrids if any, in comparison to previously availed databases (e.g. FAO) using un-calibrated SWAT (Soil and Water Assessment Tool) hydrologic models. Upper Nile Basin in Ethiopia and Upper Krishna river basin in India will be used as the test beds to evaluate the new soil database. The performance of the un-calibrated models will be evaluated using streamflow at these river basins. Further, evapotranspiration output from the respective models will also be compared to remote sensing derived evapotranspiration estimates from satellites (MOD16 ET and ALEXI) for assessing the spatial variability in the model performance. The results from this study will provide a comprehensive framework to evaluate the hydrologic model performance due to uncertainties in soil data and suggest ways to reasonably incorporate these uncertainties in the model results.

Keywords

SoilGrids, Pedo-transfer function, uncertainty, Streamflow, evapotranspiration

Using digital soil mapping for SWAT soil input data, case study from small scale watershed (Czech Republic)

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Abstract

Spatial soil information plays crucial role in hydrological models. Soil capability to infiltrate and store water significantly affects water balance in watershed. Unfortunately it is difficult to extract appropriate soil properties from traditional soil maps of taxonomic units. Soil properties in watershed of interest can be spatially estimated from existing soil survey by digital soil mapping (DSM) through predictive models. The study deals with development of soil input data from available soil survey and assess SWAT model performance in comparison with model using global soil dataset SoilGrids in Olešná reservoir watershed (33 km^2) in Czech Republic. Information about particle size distribution and organic carbon content was harmonized into 4 depth ranges and spatially predicted by random forest approach using geomorphometric parameters derived from digital terrain model. From particle size and organic carbon content, maps of saturated hydraulic conductivity and available water content was derived by pedotransfer functions. Resulting pixels were clustered by k-means algorithm into 4 clusters representing mainly soil texture classes. SWAT model was then set up with both soil input datasets. Performance of water discharge prediction before and after automatic parameter optimisation was compared. Before parameter optimisation model based on DSM data performed better than based on SoilGrids data. After optimisation procedure both model set ups reached satisfactory performance for daily time step and good for monthly. Despite that with less detailed soil dataset we can obtain comparable results for outlet discharge prediction, more detailed dataset allows to credible spatial results enabling e.g. better decision for allocating of management practices.

Keywords

legacy data, random forest, SoilGrids, soil texture, SWAT, water discharge

Identification of Relationships among Morphometric Parameters and QSWAT Model Output

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Abstract

Morphometric parameters of a drainage basin are quantitative attributes of the landscape that are derived from the elevation surface and drainage network. The drainage characteristics of the Upper Tapi river basin, India were analysed by SRTM DEM using GIS tools and the hydrologic parameters were calculated using QSWAT model. The QSWAT model was calibrated for the period 1991 to 2005 including three years warm up period (1988-1990) with Sequential Uncertainty Fitting (SUFI-2) algorithm in SWAT CUP (Calibration and Uncertainty Program) and validated for the period 2006 to 2013. The model performance is evaluated based on R^2 (0.75), *NSE* (0.75) and *PBIAS* (1.1) values which indicate very good agreement between observed and simulated discharge. The study area has been subdivided into 14 sub watersheds using 300km^2 area threshold values in QSWAT model and 22 morphometric parameters have been calculated under three broad categories viz. linear, aerial, and relief characteristics. Morphometric and hydrologic parameters were calculated at Sub- basin level. The various morphometric and hydrologic parameters have been correlated with each other to understand their underlying relationship and control over the basin hydro-geomorphology. The R^2 values for drainage density (D_d) and sediment yield, evapotranspiration, soil water content were 0.33, 0.40 and 0.30. Similarly, the R^2 values for stream frequency (*Fs*) and potential evapotranspiration, base flow, deep percolation, water yield were 0.99. 0.98, 0.98 and 0.58. The relationships among form factor (R_f) and Ruggedness Number (R_n) and potential evapotranspiration, base flow, surface runoff shows the R^2 values as 0.62, 0.50, 0.60 and 0.40, 0.50 and 0.60. Therefore, integration of morphometric parameters, GIS and QSWAT model have been done in this study to overcome the challenge of scarcity of observed data. In the absence of observed data, relationship between hydrological and morphometric parameters could be used to gauge the effectiveness of output of the SWAT model.

Keywords

Basin, Morphometric, GIS and QSWAT

CESApp: an Earth Observation Product for pollution monitoring based on Swat and Swat-HM module

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Abstract

Earth observation has become an essential element in assessing and monitoring pollution. It can provide synoptic overviews which can be used for situation assessment and change detection. Furthermore, Watershed-scale Water Quality (WWQ) models are now widely used to support management decision making.

In this study a multi-model approach was first used to evaluate metals dispersion at the watershed scale, then an Earth Observation Product allowed to report model's input and output data, future scenarios and projections, with an intuitive and user-friendly web interface.

Specifically, SWAT model has been coupled with SWAT-HM (SWAT Heavy Metals Module), a new and innovative module (Y. Meng et. al., 2018) that simulates the main reactions in soil-water system that trigger metal transport and spread. A set of Climate Models Ensemble was then used as input for future projections and scenarios. All these tools are interfaced with CESApp web application.

CESApp is an Application based on a PostGIS Geodatabase and client-server technologies, developed to expose on the web SWAT and SWAT-HM outputs in a user-friendly environment. The architecture is based on the client server technology and works directly on any web browser without any external programs or plug-in. CESApp has been developed with the Alto Framework (www.altoframework.com), a web-based solution for sharing data, SWAT model results and knowledge. Within Alto, the CESApp project can be further developed to extract information and grant new services to the community.

The system connects to SWAT and SWAT-HM data; visualizes the data, (graphs, texts, tables) and digests SWAT and SWAT-HM simulations to produce reports accessible on the web. The system provides institutions with complete control on the selection of data they wish to process and want to expose. Contents are assessed based on users and roles (e.g. "public", "private"): in this way the software can be easily customized to adapt to the needs.

Keywords

Swat, Swat Heavy Metal, Pollution, Web GIS, EOP, Earth Observation Product, Database, Cespp, Sardinia, Metals

IPEAT+ UI: An Automatic Calibration Tool with User Interface for SWAT+

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Abstract

SWAT+ provides substantial advantage over SWAT due to improvements in coding structure and flexibility for general users. However, the adoption of SWAT+ is challenged by the lack of tools for performing automatic calibration before applying alternative case scenarios such as management practices. In this study, a user-friendly interface was developed to set-up and run automatic calibration for SWAT+ models dubbed, IPEAT+UI. Automatic calibration routines can be conducted by optimization techniques such as Dynamically Dimensioned Search (DDS) algorithm. The interface takes the user through a five-step procedure to conduct automatic calibration routines with minimum effort. These steps include selection of (i) TxtInOut directory; (ii) model parameters; (iii) observation data; (iv) calibration settings; and, (v) run SWAT+. When calibration is in progress, convergence information is displayed in real-time within the interface. We have tested the tool in and successfully calibrated SWAT+ catchment model for several catchments in Africa such as Upper Blue Nile and Limpopo River Basins. Computational efficiency of IPEAT+ has been shown effective and its user-friendliness is important for the SWAT community adopting SWAT+.

Keywords

SWAT+, IPEAT+ UI, Automatic Calibration, Hydrological Model

Utilizing SWAT+ for ecohydrological and climate change studies

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Abstract

The SWAT+ model, in comparison to SWAT2012, has an improved ability to spatially represent processes and features located within the watershed. One of several improvements included in SWAT+ is the creation of Landscape Units (LSU) which represent floodplains and uplands. Creation of LSU allows routing of runoff across the landscape before it reaches the streams. The new SWAT+ also includes the interaction between wetlands and the river, which allows to represent flooding processes. This study explores the opportunities and challenges involved in applying SWAT+ for large scale and ecohydrological studies focusing on the floodplains and water dependent habitats. Large scale testing of the SWAT+ tool was carried out for two basins in Poland. Input data from a SWAT2012 model setup for the Vistula watershed was utilized. Methods of establishing threshold values of streamflow at bankfull flow to identify inundation and flooding events were identified. Furthermore, a preliminary assessment for applying SWAT+ to climate change studies was included. Climate change is expected to impact the water cycle through changing the precipitation levels, river streamflow, and soil moisture dynamics and therefore pose a threat to surface-water fed habitats and their biodiversity. The outcomes of this research are expected to lay the groundwork for future ecological and climate change applications of the SWAT+ model.

Keywords

Large-scale, ecohydrology, SWAT+, floodplains, climate change

Influence of Wetland component in SWAT+ used for the Upper Biebrza catchment model

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Abstract

The Upper Biebrza catchment (UB) in Poland, is characterised by wetlands and pastures. In such catchments, the role of the wetlands on the water balance is significant and should be taken into account in hydrological modelling. However, this has not been done in previous SWAT modelling works for UB.

The new version of SWAT model, SWAT+, gives users much flexibility in setting up models and creating connections between objects such as Hydrological Response Units (HRUs), Landscape Units, channels, reservoirs on rivers and reservoirs on the landscape (wetlands, ponds and etc.), groundwater bodies and more. In this study, we apply SWAT+ in UB and implement wetlands covering HRUs which fall within and compare with the model simulations without this component.

The results from simulations show that the inclusion of wetland component influences the hydrology of the landscape and the river. The river flow is reduced for the higher peak values, which is improving flow simulation in a wetland type catchment.

Keywords

SWAT+, wetland, hydrological modelling

Simulation of Dates Palm Trees in the Boudenib Oasis in Morocco using SWAT+ and Remote Sensing Data

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Abstract

Oases are part of the natural wealth and heritage of Morocco and contribute to the social, economic and touristic development. Morocco has lost more than two-thirds of its oases during the past century due to climate change, and water overexploitation. Palm trees are rarely implemented in hydrological models. This poses challenges in using these models in arid areas. Also, in SWAT+ there have been no studies about dates palm trees. In this study, we estimate crop parameters for dates palm trees from literature to update the crop database. This database is used in the setup of a SWAT+ model for Boudenib oasis that belongs to Guir catchment. The simulation results of the growth of the dates Palm trees in Boudenib oasis are compared against Leaf Area Index (LAI) from Remote Sensed (RS) data. We expect a similar pattern in LAI timeseries, however, the peaks derived from SWAT+ might be higher than RS due to pixel averaging in RS products. Results from this research are going to facilitate and improve hydrological modeling in catchments especially in arid areas that contain dates palm trees.

Keywords

SWAT+, Dates Palm Trees, Oasis, Hydrological Modeling, LAI, Remote Sensing Data

A frequency-domain nonstationary multi-site rainfall generator for use in hydrological impact assessment

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Abstract

Growing concern about the hydrological impacts of climate variability and climate change means it is imperative to construct plausible meteorological scenarios suitable for the vulnerability assessment. A new nonstationary framework for multisite rainfall generation is proposed for use in decision-centric hydrological impact assessment. The framework has three main components, including (1) a spatiotemporal rainfall field, described as spatial modes and their corresponding temporal evolution based on empirical orthogonal function analysis (EOFA). (2) The time series of these spatial modes, decomposed into intrinsic mode functions (IMFs) with characteristic frequencies (periods) using Hilbert-Huang transform (HHT). (3) Stochastic simulation (SS), achieved by assigning random phases to the noise IMFs and adjustment factors to the residuals and the amplitudes of the signal IMFs. An application of the EHS (EOFA+HHT+SS) rainfall generator is presented for the Xiang River basin to demonstrate the tool's ability. The ability (reproducibility) of EHS model in term of reproducing the spatiotemporal statistics of the historical rainfall field is first examined. We further illustrate the ability (variability) of this rainfall generator to act as a scenario generator for generating a wide range of possible rainfall sequences. The results show that EHS rainfall generator has sufficient capacity in reproducing the original spatiotemporal structure especially the temporal statistics such as the autocorrelation and low-frequency variability. In the meanwhile, the EHS model exhibits advantages to perturb the temporal characteristics of rainfall and/or alter their behavior based on the intrinsic spatial patterns. This nonstationary feature makes EHS model very useful to test the sensitivity of the hydrological system to different aspects of climate variability and climate change.

Keywords

Principle Component Analysis, Empirical Mode Decomposition, Hilbert Spectral Analysis, weather generator

Impacts of climate change on water quantity and quality in the Dyfi Catchment, UK: Implications for drinking water supply

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Abstract

Climate change is likely to threaten the consistent provision of clean drinking water in the UK, in terms of both water quantity and quality. Projected increases in extreme weather events in particular, such as droughts and flooding, are likely to exacerbate both of these factors further.

Our study uses SWAT with UK Climate Projections 2018 data to model the impacts of a worst case scenario in terms of global emissions (RCP8.5), on water quantity and quality for the Dyfi catchment in Wales, UK. We use an ensemble of 12 regionally downscaled climate models as inputs to account for uncertainty in the projections and take twenty year snapshots for 2020-40, 2040-60 and 2060-80. We focus on five specific water quality variables: stream temperature, nitrates, phosphorous, sediment load, and persistent bacteria.

SWAT is calibrated using river flow data only, due to the lack of water quality measurements. SWAT parameters related to water quality are kept at their default values. While our approach increases the uncertainty related to the specific values of water quality variables, it does provide the relative changes in specific water quality variables under future climate conditions. This information would still be useful for water resource management planning, especially in terms of the potential adaptation measures required to cope with the additional treatment required at water treatment works. By taking snapshots, our study also allows for short, medium and long term solutions to be planned for both water treatment measures and water security provisions.

Keywords

Climate change, water quality, water quantity, drinking water

Climate and land use management changes on the provision of multiple ecosystem services in Western Switzerland – Are there risks of maladaptation?

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Abstract

Ecosystem services are under increasing pressure from a growing population, climate change, and land use change. These pressures affect the provisioning of multiple ecosystem services. Land use and management strategies should aim at preventing the degradation of ecosystem services. Here we apply SWAT (Soil and Water Assessment Tool) for the Broye catchment in Western Switzerland. The Broye model was parameterized for daily discharge, monthly nitrate load, and annual crop yield for the 1981-2015 period. We analyzed selected ecosystem services including water quantity and quality regulation, food provision, and erosion regulation. Four projected climate models (1981-2099) for emission scenario RCP8.5 were employed to assess climate change impacts on ecosystem service indicators in three periods: base climate (1986-2015), the near future (2028-2057), and the far future (2070-2099). Furthermore, tradeoff and synergies of land use and management strategies were examined to identify possible solutions to recommend as climate change adaptation options. For this reason, three land use and management strategies were examined: Baseline (actual land management), land sharing, and land sparing scenarios. The results suggest a shift in hydrological regime (reduction of flow in summer and increase in winter) in the future. Consequently, water quality and crop productivity would likely be affected. Increases in rainfall amount and intensity and loss in plant biomass may negatively affect soil erosion in the future. In the far future, crop productivity may suffer because of stress factors such as water and nutrient limitation. Increasing fertilizer application may solve the crop productivity problem, however, at the detriment of water quality. Decreases in water availability for spring crops could be a limiting factor in the future, making the land sparing scenario less preferable due to higher irrigation needs. Contrary to the reduction in spring crops productivity, grasslands productivity would probably increase in the future. Decreases in spring crop shares in rotations and transformation of arable lands to the forest or permanent grasslands reduce stress factors (nutrient, water, and temperature). These changes improve the soil cover to improve soil erosion regulation service. An optimum adaptation strategy for multiple ecosystem services could be based on a combination of these beneficial options of each scenario.

Keywords

SWAT model, water quantity, water quality, sediment transport, crop productivity, land sharing, land sparing, multifunctionality, climate change.

Retrieval of Land Cover Management Practices Information for SWAT Model at a National scale for India

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Abstract

Land cover and crop management practices play significant role in hydrological behavior of river catchments and their realisticparametrizationenhances the accuracy and reliability of hydrological model predictions. SWAT is a conceptual continuous time model developed to assist water resource managers in assessing the impact of crop & water management practices in watersheds and large river basins. The establishment of a model framework in SWAT preliminarily requires information on land cover, soil and topography. India is an agriculture dominant country with diverse cropping pattern hence, realistic definition of land cover with its management practices will improve the correctness of the SWAT model simulations.This study aims at retrieval of land cover information, specifically agriculture class utilizing the available geospatial and statistical datasets. In Natural Resources Census (NRC) Land Use Land Cover (LULC)data developed by the National Remote Sensing Center (NRSC) of India, an agriculture class is specified with season. A revised crop map was prepared where season specific agriculture classes were reassigned with crop specific information using district statistical data on source of irrigation, District map, irrigation command area map and Global Irrigated Area Map (source: IWMI). The crop type was assigned to this reclassified class by comparing the areal extent of each agricultural class with district wise crop area and crop productivity statistics for the years 1997-2010 as recorded by Directorate of Economics and Statistics. Crop calendar information (sowing and harvesting dates) to be defined in the crop growth model embedded in SWAT was retrieved from district wise crop calendar defined by NSSO. Since this information from statistical data does not account for the spatial distribution of the stages of the crop which is prevalent in Indian scenario, it is proposed to extract distributed crop phenological information, from time series satellite dataderived crop indices (NDVI & LAI). The crop specific sowing and harvesting dates can be derived from the temporal profile of remote sensing derived indices.Using crop datasets, the model simulations were obtained for Mahanadi basin. On incorporation of crop management practices Nash Sutcliffe Model Efficiency (NSE) increased from -23.36 to 0.15 at a gauging site up stream of Hirakud reservoir and the co-efficient of determination (R^2) between model simulated evapotranspiration (ET) and Moderate Resolution Imaging Spectroradiometer (MODIS) satellite derived ET was observed to vary from 0.0289 to 0.035, for the un-calibrated model. It can be concluded that appropriate definition of the land cover type and crop management practices enhance the hydrological model performance with respect to reservoir simulation and other hydrological fluxes.

Keywords

Hydrological Model, SWAT, Management Practices, Crop Growth Model

Hydrological forecast model of the Puck community in Poland

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Abstract

Coastal basins are particularly exposed to the adverse impact of anthropogenic stress. In many places, despite only the seasonal increase of the number of residents, progressive urbanization and associated changes in the catchment characteristics are noticeable. The Puck Bay is part of the Gulf of Gdansk and belongs to the Baltic Sea. The Puck Bay is protected area (Natura 2000) despite this it has a problem with eutrophicationan. Despite many tourist attractions, the Puck community area is mainly used for agricultural purposes. The SWAT model was used to determine the agricultural impact on the sensitive ecosystem of a shallow bay.
The model calculates 17 subbasins with a total area of 168 km2, composed from designated channels: Reda, Gizdepka, Płutnica, and Błądzikowski Stream. The model is based on meteorological data from 1979-2019 and on the real-time weather forecasts. Calibration of the model was based on the results of hydraulic and physicochemical measurements made in 2005-2008 and 2017-2019, as well as information provided by the catchment monitoring system. The results consist of the forecasted loads of nutrients and pesticides that will go to the Puck Bay from the agricultural areas of the Puck community.

Keywords

SWAT, prediction model, coastal waters, agricultural catchment, WaterPuck

Evaluation of Land Use Change Impact on Hydrology and Water Quality in Geum Reiver Basin by Indexing Watershed Health

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Abstract

This study evaluated the status of watershed health in Geum River Basin (9,645.5 km^2) by SWAT (Soil and Water Assessment Tool) model. The watershed healthiness from watershed hydrology and stream water quality was calculated using multivariate normal distribution from 0 (poor) to 1 (good). Before evaluation of watershed healthiness, the SWAT calibration for 11 years (2005~2015) of streamflow (Q) at 5 locations with 0.50 ~0.77 average Nash-Sutcliffe model efficiency and suspended solid (SS), total nitrogen (T-N), and total phosphorus (T-P) at 3 locations with 0.67~0.94, 0.59~0.79, and 0.61~0.79 determination coefficient (R^2) respectively. For 24 years (1985~2008) the spatiotemporal change of watershed healthiness was analyzed with calibrated SWAT and 5 land use data of 1985, 1990, 1995, 2000, and 2008. The 2008 SWAT results showed that the surface runoff increased by 40.6%, soil moisture and baseflow decreased by 6.8% and 3.0% respectively compared to 1985 reference year. The stream water quality of SS, T-N, and T-P increased by 29.2%, 9.3%, and 16.7% respectively by land development and agricultural activity. Based on the 1985 year land use condition. the 2008 watershed healthiness of hydrology and stream water quality decreased from 1 to 0.94 and 0.69 respectively.

Acknowledgements

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Keywords

SWAT, Hydrology water quality healthiness, Multi normal distributed landuse change

Characteristics of heavy metals from nonpoint source in an urban watershed under the rapid urbanization

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Abstract

The influence of heavy metals from nonpoint source in watersheds under the rapid urbanization should be paid attention to. To control nonpoint pollution in the stream ecosystem, it is essential to analyze the characteristics of heavy metals in road dust and to simulate their impact on the ecosystem. In Wenyu River Watershed, Beijing is a typical city of rapid urbanization which impact the river water quality largely. Heavy metals in road dust on impervious surfaces of Beijing can be transmitted to the Wenyu River with surface runoff, aggravating the water pollution.

Urban road dust in Beijing were collected in June 2016 and the characteristics of heavy metals were analyzed. The concentrations of most heavy metals in road dust were higher than their background values and the entire study area suffered potential ecological risks. In spatial, higher concentrations of most heavy meatal were located within the 5th ring road, especially the northern area. Based on positive matrix factorization, four factors were identified as the main sources of heavy meatal in road dust. They were traffic-related exhaust, fuel combustion, the manufacture and use of metals components, and the use of pesticides, fertilizers, and medical devices. Traffic-related exhaust accounted for the largest part of heavy metals (34.47%). The transmit process of heavy metals from road dust to the watershed showed that the concentrations of most heavy metals in runoff decreased after rained for 150 min. The temporal variation of Cu, Mn, Zn, and Fe in surface runoff were similar, all in U-shaped curves during 20 to 150 min. Their concentrations decreased after 10 or 20 min, and reached their lowest values after 50 min, and then increased until 150 min. Concentration of As increased and reached the highest values after rained for 20 min and then kept decreasing. Concentration of Cr, Ni, and Hg were below their detection levels.

Heavy metals in urban areas are important nonpoint source in the watershed. However, the significance of nonpoint source in urban area to the watershed is underestimated in SWAT, and the importance of heavy metals in the watershed has not been paid enough attention. Simulation model for heavy metals in urban areas should be developed and incorporated into SWAT. In this study, a simulation module for heavy metals in urban areas was developed and incorporated it into the widely used Soil Water Assessment Tool (SWAT) model. The simulated processes in the developed model include sources of heavy metals and characteristics of rainfall runoff in road dust. This developed module was used for watershed-scale simulation of heavy metal processes in the Wenyu River Watershed for the first time.

Keywords

Urbanization; Nonpoint source; Urban watershed; Heavy metal; Road dust

Uncertainty based metal budget assessment at the watershed scale: A coupled SWAT-Heavy Metal model (SWAT-HM)

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Abstract

Heavy metal (HM) pollution is a serious and urgent issue of integrated watershed management in China and worldwide. To determine the effective management strategies aimed at controlling and reducing metal pollution, it is essential to quantify the input and output fluxes of metal and its inherent uncertainties. Process-based metal models can simulate the metal budget on a watershed scale, therefore, provide important information. However, there has been little effort to quantify uncertainty in their metal flux predictions. In this work, we modified a previously built SWAT and heavy metal model (SWAT-HM) and coupled it with the SWAT Calibration and Uncertainty Programs SWAT-CUP. The modified SWAT-HM model was applied to the upper Liuyang River watershed, a Xiangjiang River tributary, in south central China. Six-year daily streamflow, daily sediment load and monthly total Zinc load, at the watershed outlet, were simultaneously used to do calibration and uncertainty analysis. Furthermore, the major input and output Zn fluxes both in the upland (soil) and channel (bed sediment), and their uncertainty (95% confidence interval) were quantified. Among all the upland Zn fluxes, particulate Zn flux through soil erosion shows the largest variability, which mainly comes from the uncertainty of the sediment modeling. In the channel phase, bed sediment was identified as the important Zn sink. This study provides a scientific basis for environment policy making, and the model and method developed are general thus can be applied to other metal polluted regions in the world.

Keywords

Input flux, Output flux, Mass balance

SWAT Watershed Modeling of Inter-Basin Water Transfer for Dealing with Water Dispute between Basins

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Abstract

The Yeongsan river basin (3,371.4 km^2) has the chronic problem of streamflow deficiency by big streamwater withdrawals for agricultural activities and they cause the poor stream water quality. The deficient waters are now come from the neighbor Seomjin river basin (4,896.5 km^2) for about 27 % of Seomjin water resources to upstream of Yeongsan river basin by government decision since 1991. Other 54 % of Seomjin water are transfered to 2 river basins (Dongjin and Namhae). Thus, the Seomjin river has problem of minimum streamflow during drought periods and salt stress moving upstream from river mouth. In this study, the SWAT (Soil and Water Assessment Tool) was established considering the inter-basin water transfer for Yeongsan and Seomjin river basins by using SWAT Inlet function and reservoir parameter. The Yeongsan river basin was calibrated at 2 multi-functional weirs (Seungchon and Juksan) with 6 years (2012~2017) daily streamflow and 2 water level gauging stations (Nampyeong and Mareuk) with 13 years (2005~2017) daily streamflow data. The Nash-Sutcliffe model efficiencies (NSE) were 0.45~0.70 respectively. The Seomjin river basin was calibrated for 13 years (2005~2017) at 2 multipurpose dams (Seomjin and Juam) and 2 water level gauging stations (Gokseong and Gurye2) with NSE of 0.45~0.74 respectively. After SWAT setup for 2 river basins, the streamflows of 2 river basins by adjusting water transfer amount from Seomjin to Yeongsan were evaluated to fulfill both the minimum flow (Q355) of Seomjin river even during drought condition and the agricultural water requirements of Yeongsan river.

Acknowledgements

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Keywords

Yeongsan River Basin, Seomjin River Basin, Water conveyance, Inlet function, Reservoir parameter

Is returning farmland to forest an effective measure across spatial scales?

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Abstract

Although it is a typical land use change, the mechanism of returning farmland to forests (RFF) on nonpoint source pollution (NPS) is not clear, especially at multiple spatial scales. In this study, by using the Soil and Water Assessment Tool (SWAT), the changes in several flow-related and NPS-related indicators across several nested catchments were quantified and compared in the Three Gorges Reservoir Area, China. The results indicated that RFF could reduce the total flow and NPS pollution, which are higher in the dry season (41% and 79%, respectively) than in the wet season (21% and 47%, respectively). In comparison, RFF has a larger impact on the baseflow index during the wet season (367.02%) than during the dry season (166.54%). The results also indicated that a spatial scaling effect did exist, while the reduction in NPS increased from 24.57% to 48.46% as the drainage area increased. Specific thresholds of RFF efficiency were also observed (approximately 2000 km^2 for the study area). It is suggested that other source control measures could supplement RFF by stabilizing the efficiency of RFF across different spatial scales. The results of this study could provide valuable suggestions for land use development and water quality protection, especially for large, complex watersheds.

Keywords

Nonpoint Source Pollution; Land Use Change; Returning Farmland to Forests; Scale Effect; Flow; Total phosphorus

Evaluation of stream flow and water quality behavior by weir operation in Nakdong river basin using SWAT

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Abstract

The purpose of this study is to evaluate the stream flow and water quality (SS, T-N, and T-P) behavior of Nakdong river basin (23,609.3 km^2) by simulating the dam and weir operation scenarios using SWAT (Soil and Water Assessment Tool). The operation scenario are the simultaneous release for all dam and weirs (scenario 1), simultaneous release for all weirs (scenario 2), sequential release for the weirs with one month interval from upstream weirs (scenario 3), and no release condition (scenario 4) . Before evaluation, the SWAT was calibrated and validated using 11 years (2005-2015) daily multi-purpose dam inflow at 5 locations (ADD, IHD, HCD, MKD, and MYD), multi-function weir inflow at 7 locations (SHW, GMW, CGW, GJW, DSW, HCW, and HAW), and monthly water quality monitoring data at 6 locations (AD-4, SJ-2, EG, HC, MK-4, and MG). For the two dam inflow and dam storage, the Nash-Sutcliffe efficiency (NSE) was 0.56~0.79, and the coefficient of determination (R^2) was 0.68~0.90. For water quality, the R^2 of SS, T-N, and T-P was 0.64~0.79, 0.51~0.74, and 0.53~0.72 respectively. For the three scenarios of dam and weir release combination suggested by the ministry of environment, the scenario 1 and 3 operations were improved the stream water quality (for T-N and T-P) within the 3 months since the time of release, but it showed the negative effect for 3 months after compared to scenario 2.

Acknowledgements

This work was supported by Korea Environment Industry & Technology Institute (KEITI) through Advanced Water Management Research Program, funded by Korea Ministry of Environment (MOE) (Grant. 83089)

Keywords

SWAT, dam and weir release, release scenario, stream water quality

Watersheds Modeling of Mindanao River Basin in the Philippines using the Soil and Water Assessment Tool (SWAT) for Water Resources Management

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Abstract

The Philippines has an average of 20 typhoons yearly that cause floods. Hence, the country has a total of 18 major river basins and the Mindanao River basin (MRB) is the second largest river basin with a total area of 21,503 km^2, a huge water resources for hydropower development. In past decades the power demand in the Mindanao is increasing by an average of 3.8%. Therefore, this study aims to simulate the watershed of the MRB to enhance water resources management for hydropower applications. Thus, the watershed assessment for MRB is needed to carry out to evaluate the potential sustainability of water resources for future development of hydropower. The SWAT model were used, and the inputs are geospatial datasets and weather records of four meteorological stations of DOST-PAGASA. Subsequently, the quality of the observed precipitation from the four stations were investigated by comparing with the global gridded precipitation datasets of NCDC-CPC and GPCC. The correlation coefficients are 0.46 and 0.78 at General Santos, 0.90 and 0.83 at Cotabato, 0.95 and 0.63 at Davao, and 0.92 and 0.53 at Malaybalay stations. The simulated discharge of the models was calibrated from three river stations in Nituan, Libungan and Pulangi Rivers with the coefficient of determinants (R^2) of 0.61, 0.50 and 0.42 for DOST-PAGASA, 0.66, 0.49 and 0.55 for NCDC-CPC, and 0.62, 0.49 and 0.27 for GPCC. Then, the models were also validated by use of proxy basin at the same river stations and period with $R^2$of 0.61, 0.50 and 0.33 for DOST-PAGASA, 0.64, 0.46 and 0.40 for NCDC-CPC, and 0.57, 0.48 and 0.21 for GPCC. These results indicate the model performances with respect to the current situation of available records of river discharges.

Keywords

Mindanao Island, discharge, watershed modeling, hydropower, precipitation, proxy basin

Assessing SWAT model performance using gridded SAFRAN/ CFSR and conventional weather station datasets at different hydro-meteorological spatial and temporal resolutions - A case study on the 10,000 km² Charente river basin S-W France

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Abstract

Forcing variables relating to the hydrologic response of rainfall runoff modeling are known to play a major role in accuracy of predictions made. In this study, three hydro-climatic daily time step datasets were tested: conventional weather stations, the 8km gridded SAFRAN, and the 0.5° CFSR included in the 10,550km² Charente river basin, South-Western France.

Estimation of discharge and uncertainty analysis for stream flow estimation was carried out using the Soil and Water Assessment Tool (SWAT). Multi-site calibration and parameter uncertainty analysis were performed with the Sequential Uncertainty domain parameter FItting algorithm (SUFI-2). The model was calibrated and validated by means of observed discharge data for the periods 1999 – 2008 and 2009 – 2018, respectively. The performance of the SWAT model regarding stream flows is evaluated based on five criteria: determination coefficient R^2, Nash-Sutcliffe efficiency (NSE), per cent bias (PBIAS), p-factor, and r-factor (calculated on a daily basis). During calibration, the values of R^2 and N SE were found to be 0.73 and 0.71. When validated, they were found to be 0.54 and 0.52. These findings, which are currently undergoing final analysis, show that calibration and validation performance were at their best with conventional weather station datasets for the gauged sub-basins, and that observed and simulated daily stream flows were not much different at 95PPU (95% level of prediction uncertainty).

Keywords

Time series analysis; meteorology; CFSR; SAFRAN: weather stations; SWAT; SUFI2; multi-site calibration; multi-site validation; sensitivity analysis; uncertainty; Charente river basin; model performance; discharge

Water quality modelling at continental scale using the SWAT model

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Abstract

Water contamination caused by the presence of excessive amounts of nitrates can be catastrophic for aquatic ecosystems and for human health. Due to these high risks, a great deal of emphasis has been placed on finding effective measures to reduce nutrient emissions to safe levels both in rivers and aquifers. In this context, eco-hydrological models are essential tools for assessing the impact of management strategies and identifying optimum water quality targets. In this context we applied and calibrated the Soil and Water Assessment Tool (SWAT) at European continental scale using as inputs the latest and best available global datasets. A grid-based version of SWAT was developed performing landscape simulation on a regular grid of 5 arc-minutes of resolution (about 10 x 10 km at the equator) taking advantage that typical global spatial inputs (i.e. digital elevation model, land use and soils) are usually available in gridded raster format. The grid-cell discretization accounted also for a routing network developed based on the Double Maximum Method which processes fine-resolution DEMs to determine the flow patterns in a coarser scale. Different components of the water cycle, water quality and crop yields were simulated at monthly time step in each Hydrological Response Unit (HRU) level inside the grid-cells. The calibration of SWAT was performed following a cascade modelling approach that starts by crop yields, then streamflow and finally nutrient concentrations. Finally, management scenarios of nutrient reduction were developed providing effective strategies to reduce nitrate leaching and nutrient emissions. The proposed modelling approach provides a powerful instrument for addressing synergistic and antagonistic effects of agriculture management on food and water security and environmental condition. This approach can serve a modelling framework for an efficient implementation of the EU Nitrates Directive.

Keywords

SWAT model, nitrates, nutrients, water quality, best management practices, large scale, Europe

Modelling the Spatiotemporal Patterns of Hydrology Processes and Non-point Source Pollution with SWAT in the Three Gorges Reservoir Area, China

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Abstract

It is challenging and difficult to high-precisely simulate the non-point source (NPS) pollution in the Three Gorges Reservoir area (TGRA) at a whole-basin scale for its large scale and significant spatial heterogeneity. In this study, the whole TGRA were divided into 23 watersheds with 1840 subbasins based on the confluences on the banks of Yangtze River. Every watershed has been calibrated and validated separately to simulate the stream flow and NPS pollutant load with soil and water assessment tool (SWAT). The calibrated and validated results indicated that the SWAT model has good applicability for the runoff and NPS pollution simulation in the TGRA. The total amount of runoff and NPS load in the whole TGRA, as well as the contribution rate of every watershed, was calculated from 2010 to 2013. The simulation results demonstrated that low elevation regions near the dam, watersheds in the left bank and the agricultural land will produce higher runoff. The NPS pollution exhibited apparent tempo-spatial heterogeneity in the TGRA. The NPS load was higher in the left bank than the right bank and the nutrient export was higher in cultivated areas, where soil erosion was serious. The amount of the monthly nutrient loads showed seasonal characteristics, which increased significantly from March to April and peaked in May due to over-fertilization during the cultivation period and heavy rainfall. It is believed that the method, dividing large scale basins to watersheds and simulated separately, is available and accurate for NPS assessment. The results of this study have implications for watershed management to control the NPS pollution in the TGRA.

Keywords

Hydrology processes; Non-point source pollution; Three Gorges Reservoir Area; SWAT model; distribution

SWAT to model the the ecosystem services in the small agricultural Lebna watershed (Cap Bon, Tunisia).

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Abstract

The Soil & Water Assessment Tool, (SWAT) is a river basin scale model developed to quantify the impact of land management practices in large, complex watersheds. This model is used worldwide and is continuously under development. A close match with flow does however not mean that the spatially distributed hydrological processes are properly understood and simulated. In this paper, we used swat-cup and numerous spatio-temporal field observations inside the Lebna watershed to properly evaluate the ability of the highly parameterized SWAT model to predict the hydrologic response, sediment and crop production in agricultural catchment. Measurements under the common cereals/legumes/pasture cropping systems within the watershed were used to adjust land management, crop and soil parameters to the different local land use practices.Such calibrated distributed eco-hydrological models can be used for appraising land use and climate change scenarios impacts.

Keywords

Agricultural catchment, biomass production, soil erosion, land use scenarios, climate change.

Application of SWAT Model in Eco-hydrological Assessment of the Clariano River

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Abstract

Water resource challenges are increasing as a result of environmental deterioration. The degradation of ecosystems by human activities such as agriculture, deforestation and urbanization is a major threat today which puts pressures on water resources. Among various water related issues, the deterioration of water quality is a serious worldwide challenge. Pollutants from cities and factories, sediments resulting from farming, the clearance of forests and building roads, sewage and runoff from farmlands as well as wastewater treatment plants (WWTPs) effluents can contain nutrients and toxic chemicals which have negative impacts on aquatic ecosystems. Unfortunately, it is still difficult to quantitatively determine the impacts of water quality changes on aquatic communities. The present research activity aims to investigate aquatic ecosystem responses to water quality deterioration using the Clariano River (Spain) as case study. The Clariano River, which is located in the Jucar River Basin in Valencia, suffers from various sources of pollution including WWTPs, agriculture, livestock and industrial activities as well as septic tanks and cesspits. As a consequence and according to available data, the river faces low water quality and the loss of biodiversity in some parts. In the present study, hydrological modeling of the Clariano River Basin was performed using the Soil and Water Assessment Tool (SWAT). SWAT-CUP was also used to calibrate and validate the SWAT model. The simulation was performed for the years 2002 to 2017, of which the first three years were considered for warming up the model. The 8-year period (2005-2012) was selected as calibration period, and the 5-year period (2013-2017) was considered as validation period. The results indicate a very good performance of SWAT model in streamflow simulation with R^2 and NSE values of higher than 0.8 for both calibration and validation periods. In the following step, nutrients movement along the river will be simulated using the SWAT model to assess if SWAT model is a suitable tool for simulation of nutrients transportation along the Clariano River, as well. Finally, the results of SWAT simulation will be evaluated to have a better understanding of possible relations between river streamflow, nutrients and biodiversity.

Keywords

Eco-hydrology, water quality, aquatic ecosystem, water resources management, SWAT, Clariano River

Simulation of green and blue water impacts on rainfed sugarcane under different management regimes in Salí-Dulce catchment, northern Argentina

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Abstract

Rainfed sugarcane together with subtropical rainforest form the major land cover of the upper part of the Salí-Dulce catchment in northern Argentina. Along with citrus plantations, sugarcane is an important source of income for the regional economy. Last few years even more with growing interest in sugarcane for biofuel. In order to assure sustainable sugarcane production and acquire spatial knowledge about green and blue water availability, the different management types must be linked with hydrological models. Today, sugarcane is being produced under different management regimes according on how technically advanced particular farmers are. Roughly, three types of management can be distinguished within this watershed: 1) small, non-capitalized and low-technified farmers, 2) large, highly-capitalized and technified farmers and 3) mix between to two. Therefore, in this study, these different management regimes were integrated with a calibrated hydrological model, Soil and Water Assessment Tool (SWAT) to get insight in blue and green water footprint (WF) to effectively evaluate water resources and agricultural management regimes for sugarcane in upper Salí-Dulce Catchment in northern Argentina. Multi-site model calibration approaches indicated Nash Sutcliffe Efficiency (NSE) and Coefficient of Determination (R2) as 0.70 and 0.71 for calibration (1995–2005), and 0.68 and 0.69 for validation (2006–2016), respectively. Outcomes showed results with a high spatial resolution and an overall insight in spatial heterogeneity of water footprint according to management practices. SWAT proved to be a valuable tool for interprovincial water resource planning in order to collectively safeguard this vital resource for future generations.

Keywords

Green water; Blue water; SWAT Model; Hydrological modelling; Water resource planning; Management regimes; Sucarcane;

The effects of land use change on non-point source pollution simulation using SWAT model

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Abstract

Nowadays, non-point source pollution (NPS) has received much focus because it is more difficult than point-source pollution to be controlled and has much uncertainty. Models have been widely used to simulate the NPS pollution in a watershed scale. The common characteristic of these models is that they need a large amount of input data, including spatial and attribute data. Land use data is one of the most input data of these models, which may have great effects on the NPS pollution discharge and transportation. When simulating the future scenario, the quality of predicted future land use data directly affects the model performance. In addition, land use change should not be ignored when the simulation period is long. Thus, how to accurately represent the land use pattern and simulate the land use change in NPS pollution model need to be further studied.

In our study, firstly, the impacts of different land use input conditions on the model performance were studied based on the SWAT model in Xiangxi river watershed. Four years of land use data within the simulation period were obtained (2000, 2005, 2010 and 2015). The simulation period was from 2000 to 2015. Seven different land use input conditions were established, including four static land use input (JY2000, JY2005, JY2010 and JY2015). SWAT model was calibrated independently based on these seven different land use input conditions. Then the calibration results and model outputs were analyzed and compared. Secondly, we used the CLUE-S model coupled with Markov chain model and genetic algorithm (GA) to achieve the future land use pattern based on different scenarios. Markov chain was used to predict the area of different land use categories based on the historical change trend. While GA was used to design optimized land use area in future in order to reduce the NPS pollution discharge in the watershed. CLUE-S model was used to predict the land use pattern based on the results of Markov chain model and GA.

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. The land use prediction results showed that under the historical scenario, the area of cultivated land will increase in the future, leading to the increase of NPS pollution discharge. In the opposite, some areas of cultivated land will be changed to forest area under the optimized land use scenario, which will effectively control the NPS pollution discharge.

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Keywords

non-point source pollution; SWAT model; land use change; dynamic input; land use prediction

The evaluation of propagation from meteorological drought to hydrological and agricultural drought under climate change using SWAT model

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Abstract

Drought is one of the most frequent and costly disasters in arid and semi-arid areas. It can be classified into four categories, including meteorological drought (MD, below normal precipitation), agricultural drought (AD, below normal soil water levels), hydrological drought (HD, below normal river flow) and socioeconomic drought (SD, causing social and economic losses). HD and AD follow MD and are mainly caused by the continuation of the MD,which developed very quickly. It is important to investigate the propagation time from MD to AD and HD, for the purpose of predicting and preventing of drought. The propagation time would be influenced by the climate change. And due to the missing monitoring data of soil moisture and stream flow, drought propagation became difficult in watershed scale. However, processes based hydrological simulation has proven to be useful for drought assessment. In this paper, SWAT was used to reproduce hydrological cycles and the simulation results were used to evaluate droughts in Luanhe River Basin (LRB) from 1959 to 2017. The corrected model had high accuracy (NS were 0.83 and 0.86 in simulation and observation periods), and was suitable for the simulation of drought transmission processes. The Standardized Precipitation Index (SPI), the Standardized Soil Moisture Index (SMI) and the Standardized Runoff Index (SRI) were adopted to characterize meteorological, hydrological and agricultural droughts, respectively. The propagation time from MD to AD and HD was investigated in dry and rainy seasons, separately. The results indicated noticeably seasonal and spatial characteristics of drought propagation time: (1) In the rainy season, propagation time from MD to AD was 1-3 months (decreasing from the south to the north). And propagation from MD to HD was 2 months in most of the sub-basins, while only 1 month in the southern area. (2) Propagation was longer in dry seasons than rainy seasons. In dry seasons, propagation from MD to AD would last for 4-7 months, which was shorter than that from MD to HD (7-9months). The propagation showed an increasing pattern from south to north in dry seasons. (3) Under the climate change from 1959 to 2017, which was a warm-dry period, the propagation time of drought tended to shorten, especially in rainy seasons. SWAT model was applied in the study to assess the hydrological process and to evaluate drought propagation from MD to AD and HD. Results will be helpful for the development of improved drought warning and forecasting system in arid and semi-arid areas.

Keywords

SWAT model; drought propagation; agricultural drought; hydrological drought; climate change

Evaluation of Crop-specialized Multi-objective PSO Auto-Calibration Algorithm in Haean Watershed of South Korea

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Abstract

This study is to evaluate the applicability of Crop-specialized Multi-objective Particle Swarm Optimization (CMPSO) auto-calibration algorithm for SWAT (Soil and Water Assessment Tool) modeling to Haean watershed (62.8 km^2) of South Korea. The CMPSO algorithm based on early developed Hydrological PSO algorithm by Python is applied to crops around rivers. Because of the difficult calibration by uncertain water use data information for paddy rice and upland crops, the CMPSO calls .mgt files and tries to find out optimal SWAT crop irrigation parameters viz. IRR_AMT, IRR_EFM, IRR_SQ, DIVMAX etc. by comparing observed streamflow with simulated streamflow. Before CMPSO application, the watershed was calibrated for streamflow using SWAT hydrological parameters of CN2, ALPHA_BF, GW_DELAY, ESCO etc. After, the CMPSO is applied to crop irrigation parameters optimization to improve the 3 objective functions of coefficient of determination (R^2), Percent Bias (PBIAS), and Nash Sutcliffe model Efficiency (NSE) streamflow calibration result. It is expected that users will be able to make more accurate hydrologic analysis by the corrected irrigation water use through the results of CMPSO algorithm.

Acknowledgements

This work was supported by Korea Environment Industry & Technology Institute(KEITI) through Advanced Water Management Research Program, funded by Korea Ministry of Environment(MOE) (83089).

Keywords

PSO, SWAT, crop and irrigation calibration, multi-objective optimization

Evaluation of 3D soil hydraulic data using the SWAT model on the Zala and Kapos catchments, Hungary

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Abstract

Quantitative information on soil properties is important for hydrological models as soil hydraulic properties and soil moisture conditions control hydrological processes that determine water balance, surface and subsurface runoff. Therefore it is key that the highest quality and resolution available soil data is used for hydrological studies. Several soil data sets are available for hydrological model applications in different scales from small regional to continent wide applications, including SoilGrids database, available from the European Soil Data Centre etc. In the current study the SWAT hydrological model was used to test the performance of different soil maps on the Zala and Kapos catchments, Hungary. River discharge was calculated at 5 different stations on the Zala catchment and 11 station at Kapos catchments using original soil parameter sets without modification of the parameters, then a calibration procedure was delivered using manual calibration and SWAT-CUP SUFI-2 calibration tool to assess the sensitivity of the provided soil parameters and to find a parameter range for the soil parameters with which the measured river flow data can be reconstructed. To support the large scale hydrological modelling, 1dimensional soil profile modelling was carried out at one point of the catchment to describe the variation of available water content. Two sets of soil data maps were used for the analysis as soil hydraulic input data, for both catchments i) the 3D European soil hydraulic maps at 250 m resolution (EU-SoilHydroGrids) was used as reference and for the Zala ii) 100 m resolution regional soil hydraulic maps derived from national datasets (DoSoRemi.hu) with two separate methods. For the Kapos catchment the second soil database used, was the Harmonised World Soil Database v1.2. Based on the soil hydraulic data we derived soil hydrological groups (SHGs) with clustering. SHGs – instead of soil texture classes – than were used to define hydrological response units (HRU). HRUs received the spatial soil information, therefore high resolution soil hydraulic data was supplied to the model. Soil input variables were saturated hydraulic conductivity, available water capacity, moist bulk density, porosity, clay, sand, silt content, organic carbon content and maximum rooting depth. Results show a high sensitivity to some of the soil data, and model calibration leads to a conclusion that the vertical variation of hydraulic conductivity play an important role in the runoff processes that is not well represented by the soil data sets. Interflow seems to be a key process in some of the sub catchments, while a very small direct surface runoff was encountered.

Keywords

SWAT hydrological model, soil hydraulic properties, 3D soil database, sensitivity analysis

Application of SWAT in a mountainous region in Turkey using remote sensing data

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Abstract

Subjects like increasing energy demand and climate change, attract the attention especially for mountainous catchments where snowmelt is dominant. In mountainous eastern part of Turkey, snowmelt runoff constitutes approximately 2/3 in volume of the total yearly runoff during spring and early summer months. Hence, monitoring the snow potential in the accumulation season and modeling during the depletion period is of great importance for optimum reservoir planning and management especially in the transboundary Euphrates Basin.

In this study, two headwater basins of the Euphrates River, ranging in elevation between 1500-3500 m are selected as the application area. The necessary digital data are analyzed using ArcSWAT in order to formulate the HRUs. Besides streamflow, both in-situ snow measurements and remotely sensed data of snow covered area (SCA) using daily cloud-free MODIS images are utilized to incorporate in SWAT. Although point measurements show a varying correspondence to the model elevation bands, areal SCA have a noteworthy agreement with the SWAT output. Daily (model) SWE-SCA (satellite) relations are derived for each snow season with a high consistency.

SWAT-CUP is employed for a more detailed hydrologic modeling application. 13 years of hydro-meteorological data is divided into 3 years of warm-up (1999-2001), 6 years of calibration (2002-2007) and 4 years of validation (2008-2011). According to the results, model discharge performance using Nash-Sutcliffe efficiencies for calibration are 0.66-0.76 daily and 0.75-0.87 monthly, and for validation 0.73-0.82 daily and 0.82-0.89 monthly values are achieved. A sensitivity and uncertainty study is also undertaken for model parameters. Future studies will concentrate on climate change scenarios and their effects on snow and runoff variations till the end of the century.

Keywords

Snow, hydrologic modeling, MODIS, SWAT-CUP, Turkey

Assessment of Stream Flow Variability in Pursat River Basin of Cambodia using SWAT Model

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Abstract

Cambodia is a seasonal disaster-prone country in Southeast Asia. Reliability of water resources is fluctuated due to the significant change in rainfall distribution throughout the year. In Pursat River Basin, one of the sub-catchments of Tonle Sap Bain, water resources have been under pressure because of increasing demand between agriculture and other sectors, and variability of water resources has been reported to increase recently. The help of hydrological modeling is required to provide an understanding of the variation in stream flow which is crucial for water resource development and planning. The Soil and Water Assessment Tool (SWAT), a physically based distributed hydrological model, has been known for its capability to simulate hydrological processes in agricultural watersheds. With the aims of assessing stream flow variability of the river basin and evaluating the performance of SWAT model, a two-decade simulation duration was conducted in both daily and monthly time steps. The model was calibrated and validated within the period of 1995-2006 and 2007-2015, respectively using SWAT-CUP with SUFI-2 algorithm, and its performance was then evaluated using the coefficient of determination (R2), the Nash-Sutcliffe (NS), and the percent bias (PBIAS). For the daily time step, the model could not produce an agreeable simulation result, giving unsatisfactory values of R2 and NS, except for PBIAS. The monthly result, on the other hand, showed a good performance of the model with R2 and NS over 0.7, and PBIAS below 15% for both calibration and validation. Based on the suggestion that monthly simulation is preferable, the simulated monthly stream flow was further analyzed and it indicated a variable change with a declining trend during this past twenty years. The calibrated model can be used to further evaluate flood and drought situations for future management and planning.

Keywords

Water resource variability, SWAT model, Pursat river basin

Assessing the potential impact of natural small water retention measures on in-stream siltation risk and habitat conditions with an integrated modeling cascade

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Abstract

Riverine landscapes are threatened by factors acting at different spatial scales, for example, climate change, land use change, as well as agricultural and forestry practices. Natural small water retention measures (NSWRMs) are receiving increasing attention because of the multiple ecosystem services they can provide, ranging from flow regulation, nutrients and sediment control to habitat improvement. However, impacts on in-stream habitat and siltation risk are less investigated because of the coarse resolution that is provided by the catchment scale ecohydrological models. Recently proposed, ecohydrological modelling cascades can provide a useful tool to downscale the ecohydrological catchment response to the microscale (1 – 10 m^2), suitable to assess habitat conditions and siltation risk.

Thus, an integrated modelling cascade is proposed that links the ecohydrological model, Soil and Water Assessment Tool (SWAT), for catchment scale hydrology, the 1D Hec River Analysis System (Hec-RAS) for reach scale hydraulics, a siltation risk module, and a generalized linear model to assess species distribution. The models have been calibrated and validated for the pre-alpine Aist catchment in Austria (650 km^2) with the aim of predicting the in-stream, catchment scale distribution of the sessile macroinvertebrate species the Freshwater Pearl Mussel (FPM, *Margaritifera margaritifera*), the siltation risk and assessing the potential NSWRMs effectiveness for improving river habitat. The modelling cascade performs well in predicting catchment hydrology, reach hydraulics, siltation risk, and spatial distribution of the target organism in the river network of the study area. Well known NSWRMs, namely sediment retention ponds, no-till agriculture, vegetated buffer strips, and in-stream hydromorphological modification were implemented in SWAT scenarios.

Preliminary results show that the proposed model cascade is sensitive enough for downscaling the SWAT scenarios. A reduction of the siltation risk and an increase in the habitat availability for the target organism is observed for all the modeled NSWRMs; first results also show that the most effective practices are sediment ponds where bottom seepage is allowed, with an increase in available habitat of 10 % compared to the baseline scenario.

Keywords

Ecohydrological Modeling Cascade, Natural Small Water Retention Measures, Freshwater Pearl Mussel

Evaluating the performance of conservation practices under climate change scenarios in the Miyun Reservoir Watershed, China

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Abstract

Climate change is one of the major challenges in watershed management systems. Rising air temperatures, increasing precipitation in winter, and decreasing precipitation in summer as well as increases in extreme weather events have increased flooding and droughts and further affected water quality in the Miyun Reservoir Watershed (MRW). This study used the Soil and Water Assessment Tool (SWAT) model with five downscaled general circulation models (GCMs) to quantify the impact of climate change on hydrology, soil erosion, nutrient cycling, and the performance of Best Management Practices (BMPs) at watershed scale, driven by RCPs 2.6, 4.5, and 8.5. Compared with the baseline scenario, the results indicated that climate variability, especially precipitation and temperature, had great effects on surface runoff, sediment yields, and nutrient losses and further significantly affected BMP efficiency, although the magnitudes of change differed among the RCPs. Monthly sediment and nutrient loads increased substantially in all climate change scenarios, especially in flood season, due to the increase in precipitation intensity. Although BMPs were identified to be not appreciably effective in controlling water balance, they were effective in reducing sediment and nutrient losses. Based on this case, a simulation-optimization framework was applied to develop future watershed management strategies with BMP configurations because of their climate adaptation benefits, water improvement targets, and economical cost. The results indicated that the discrepancy among different climate scenarios was reflected by the number and types of BMPs and their spatial distributions at sub-basin scale, especially structural BMPs. This study suggests that the increasing frequency of rainfall events may decrease the efficiency of BMPs in the MRW, and watershed management should be adjusted according to changing climate in the future.

Keywords

Climate change; SWAT; Best Management Practices; BMP efficiency; BMP optimization; Miyun Reservoir Watershed.

A climate-based prognostic LAI modeling in SWAT+ for tropics and subtropical region

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Abstract

The growth of plants exhibits a key role in characterizing a watershed on water, carbon and nutrient balances. Therefore, it is crucial to accurately represent the dynamics of vegetation growth in a watershed eco-hydrologic simulation. This study proposes a novel approach for simulating plant growth in the Soil and Water Assessment Tool (SWAT+) model. Specifically, we propose a non-conventional approach for simulating Leaf Area Index (LAI) for tropical and subtropical regions, by relating plant growth to two climatic variables: precipitation and evapotranspiration. In our approach, the heat unit-based approach for simulating plant growth is fully replaced by a climatic soil moisture index to better reflect the growth conditions driving plant phenology in tropical and sub-tropical regions. The new modeling approach was applied to forest, grassland, tea and shrub lands in the Mara River Basin which is located at the border of Kenya and Tanzania. Simulated LAI and biomass were evaluated using MODIS remote sensing products at 8-day and monthly temporal resolutions, respectively. Results indicate that simulated LAI not only reproduces local seasonality in plant growth but also compares well with MODIS LAI for all tested land uses with less than 5% bias. Also, simulated biomass production is comparable to remote-sensed MODIS gross primary productivity. Overall, the climate-based soil moisture index method is demonstrated to be suitable for modeling LAI in regions where moisture availability is the predominant factor that controls vegetation growth.

Assessment of the Impact of climate change on groundwater recharge in Lahore, Pakistan using modeling approach

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Abstract

Groundwater is an important component of water supply chain. There are a number of factors that can affect groundwater recharge including climate change. However, a very little is known about the impact of climate change on groundwater resources. Therefore, this study attempts to quantify the impact of future climate change on groundwater recharge in Lahore city, using the Soil and Water Assessment Tool. The future climate data for four Regional Climate Models (RCM) under two Representative Concentration Pathways (RCP); RCP4.5 and RCP8.5 were obtained from CORDEX-South Asia project. A quantile mapping technique was used to correct the biases of regional climate models and paired t-test was used for trend detection. The bias corrected climate data was input into the calibrated and validated SWAT model to simulate corresponding changes in groundwater recharge. The results showed increase in annual rainfall by 16% and 24% under RCP4.5 and RCP8.5 respectively and increase in average annual temperature by 0.98 ℃ and 2.6 ℃ under RCP 4.5 and RCP8.5 respectively. Consequently, the recharge will increase by 4% and 21% under RCP4.5 and RCP8.5 respectively. In conclusion, the changing climate will have profound impact on groundwater recharge in the study area, however effect of other factors also needs to be investigated to comprehend more realistic picture of the groundwater resources in future.

Keywords

Climate change; Groundwater recharge; Trend analysis; Calibration; SWAT

SWAT-based Integrated Water Management Model for Selected Watersheds of BIS Countries Under Climate Change Scenarios

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Abstract

Climate change and extreme events will affect the hydrological cycle resulting in substantial impacts on many sectors of water resources systems including water availability, agriculture and water quality. The water stress is particularly high especially in developing countries, such as Brazil, India, and South Africa (hereafter called BIS countries), which are three of the country partners in BRICS. In these countries climate change exerts even more challenges to water resources management. Hence, a multilateral research project is planned to assess the impact of climate change and extremes on quantitative and qualitative aspects of water resources in selected watersheds of these three BRICS countries. The final outcome of the project is the integrated water management model as an adaptation approach to cope with the climate change in these three countries. In the overall project, Soil and Water Assessment Tool (SWAT) is the core hydrological model.

In this paper, a framework and methodology for the integrated water management model for Brazil, India and South Africa are presented. The role of SWAT model in the project implementation, watersheds selection and database creation is also given. The overall methodology is divided into five modules. Module 1 involves creation and compilation of hydro-climatological and geospatial databases for each of the selected watersheds for the three countries. Module 2 is an analysis of long-term climate change anomalies and climate extremes, which cause droughts and floods. Module 3 is the assessment of climate change impacts on quantitative and qualitative aspects of water resources in the selected watersheds using the hydrological models. Module 4 is the evaluation of different adaptation strategies of water resources management including assessing responses to climate change and extremes through several iterations of calibration, sensitivity analysis and validation. Module 5 is the collation of all the climate databases, analysis methods, and integrated water management model into a common geospatial and computational framework. Final policy recommendations will be arrived for the three selected watersheds with the involvement of all teams and support of the specialist team from the developers of the SWAT platform.

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Keywords

BIS, Climate Change, IWMM, SWAT, Framework, Watershed

Modeling the impact of climate change on streamflow of an Iranian Wadi

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Abstract

Climate change has important implications for streamflow and water resources, especially in arid regions such as in the Wadis of Iran. Therefore, to provide reasonable strategies and plans for a better management of limited water resources in these regions, considering the effect of climate change on streamflow is necessary. This study aims at assessing the impacts of climate change on streamflow of the Halilrood basin (7224 km^2). To this end, projections for the emission scenarios RCP4.5 and RCP8.5 from 17 global and regional climate models (GCM and RCM) are used. Two bias correction methods - distribution mapping and linear scaling - are applied, to derive bias corrected input data for hydrologic model runs. We used the hydrological model SWAT that represents the daily streamflow in the study area with reasonable accuracy (NSE: 0.76, PBIAS: 4.7, KGE: 0.87). Hydrological changes were assessed by comparing the simulations for the projected future (2020-2099) climate conditions with the observed monthly mean streamflow of the past (1979-2011). Projected changes in future seasonal streamflow show an increase in January and a considerable decrease in March. In April, the median of all bias-corrected climate model simulations show a decrease of streamflow of 147%, whereas no pronounced changes are projected in May and June. No significant changes in streamflow are expected in summer and autumn, when the lowest monthly runoff is simulated (in September) and a strong change (+493%) is projected for December. While all climate models show similar predictions for the summer season, there is an uncertainty associated with the winter predictions indicated by a wider range of the ensemble predictions. Overall, an increase for high and very high flow and no remarkable changes for middle, low and very low flow is estimated for the 21st century.

Keywords

Climate change, Streamflow, Wadi

Climate Change impact on Surface water and Groundwater resources in Northern Thailand

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Abstract

Over the past few decades, the climate change impact has increased its intensity due to the rising of global temperature. This causes a natural disasters around the world. Most phenomena are influenced by the change of hydrologic process, which relative to the surface water and groundwater regimes. The surface water and groundwater have changed their characteristic due to a fluctuation of weather condition. It is generally known that the surface water and groundwater affect to an occurrence of several natural disasters directly such as flood and drought. In Northern Thailand, flood and drought have always occurred because of the climate change impact and non-systematic management in the conjunctive use of both sources of water. Therefore, this study aims to assessing the impact of climate change on the surface water and groundwater in Yom and Nan River basins, located in Northern Thailand. The surface water and groundwater regimes is simulated by using a fully coupled of the SWAT-MODFLOW model. In addition, Nash-Sutcliffe model Efficiency (NSE) and Root-Mean-Square-Error (RMSE) are used for model performance investigation. In future scenario analysis, the Coupled Model Intercomparison Project Phase 5 (CMIP5) is applied with consideration on the Representative Concentration Pathway (RCP) 2.6 and 8.5, to mainly focus on the different of minimum and maximum issues of global annual GHG emissions. The amount of surface water and groundwater during the present (2007-2016) and near future (2021-2030) periods are compared for investigating their change influenced by climate change. The results show that the air temperature and rainfall in the near future are not different from the present period under scenario RCP 2.6. This produces an amount of surface water and groundwater between both periods are quite similar. However, there is an upward trend in the air temperature and rainfall under scenario RCP8.5 and affect to the amount of runoff and groundwater significantly. Furthermore, the change of amount of water from both sources directly impact to the water availability, when evaluating alongside with the water demand for consumption, industry and agriculture. These results are very useful and can be applied as primary information for sustainable water management in the near future.

Keywords

Climate change impact/ Surface runoff/ Ground water/ SWAT-MODFLOW/ CMIP5

Evaluating the efficiency of using global actual evapotranspiration data from remote sensing in constraining hydrological model parameters for streamflow simulation at a catchment scale in West Africa

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Abstract

The prevalent situation of lack of up-to-date observed streamflow data and gradual decline in the number of hydrological stations in many tropical catchments makes it unrealistic to anticipate more streamflow observations becoming available in the near future. However, advancements in remote sensing have enabled the calibration of hydrological models which can be used as a significant support tool for sustainable water resources management. For example, using global satellite-retrieved actual evapotranspiration (AET) products can be used for calibrating a hydrological model to simulate hydrologic variables in data-sparse/ungauged catchments. The main aim of this study was to evaluate the reliability of using remotely-sensed actual evapotranspiration data from Global Land Evaporation Amsterdam Model (GLEAM_v3.0a) in calibrating/validating the Soil and Water Assessment Tool (SWAT) model for streamflow simulation in a West African catchment.

Firstly, in this modelling framework, three potential evapotranspiration (PET) equations (Penman-Monteith, Priestley-Taylor and Hargreaves) were used for the SWAT simulation of AET at a monthly time-step for the Queme River Basin (48 292 km^2) located in Benin Republic, West Africa. The sequential uncertainty fitting technique (SUFI-2) was used for the SWAT model uncertainty analysis, sensitivity analysis, calibration and validation. Three calibrations (1998-2001) and validations (2002-2005) using different PET equations in SWAT to simulate AET and three reference simulations using the SWAT model with the default parameters were assessed. The simulated AET's were compared to GLEAM_v3.0a AET. Secondly, the simulated streamflows of the calibrated SWAT model were compared with observed streamflow at two gauges within the Queme River Basin.

The results of SWAT model calibrations and validations of the three AET simulations show an average KGE > 0.5 for the entire Queme River Basin. The preliminary results of the calibrated SWAT simulated streamflows when compared with the observed streamflows within the catchment agrees with earlier studies conducted on remote sensing data application in assessing water resources at sites in West Africa and less satisfactory with previous calibrations and validations using observed streamflow at Queme River Basin. Hence, the research is still ongoing, and the final results will be evaluated and presented.

This study will ascertain the level of reliability in the method of using solely actual evapotranspiration product in calibrating and validating the eco-hydrological model SWAT to simulate streamflow at a catchment scale in a data-sparse tropical region.

Keywords

Remote sensing, actual evapotranspiration, SWAT calibration, streamflow, West Africa

Satellite Based Climate Data for Water Resource assessment in scale of range of watersheds by Using SWAT, Upper Blue Nile Basin

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Abstract

Data scarcity has been a huge problem for water resource assessment in the Blue Nile basin, Ethiopia. Currently there is an emerging approach to utilize the satellite-based climate data for water resource assessment. This study presents applications of the satellite-based data in data scarce regions of Upper Blue Nile basin in the range of size of watersheds for water resource assessment by using Soil Water Assessment Tool (SWAT). The satellite-based data used were Multi-source Weight Ensemble Precipitation (MSWEP), Tropical Rainfall Measuring Mission (TRMM) and Climate Forecast System Reanalysis (CFSR). Bias correction was carried out for both precipitation and temperature with Linear Scaling (LS) approach. Soil and Water Assessment Tool (SWAT) was used for predicting discharge by using the station climate data and bias corrected satellite-based data. SWAT predicted discharge with observed data observed station weather data performed very good performance. However, SWAT modelling resulted unsatisfactory before correcting the bias from MSWEP, TRMM and CFSR. Bias corrected TRMM, MSWEP and CFSR climate data also performed reasonably for the three watersheds with the Nash Sutcliffe efficiency, NS (0.55, 0.61,0.45; 0.55, 0.64, 0.51 and 0.66, 0.64, 0.71) and coefficient of determination, R^2 (0.70, 0.69; 0.62, 0.71, 0.72, 61 and 0.65, 0.62, 0.68) for Guder, MainBeles and Anjeni watersheds respectively. Overall results indicated that predictions of discharge with observed climate data performed relatively closer with the bias correct satellite-based climate data. In fact, the bias corrected climate-based data could be used for water resource assessment, planning and developing in Ethiopia. Where currently stakes working in water resources for improving livelihood and food security could benefit from resource assessment by using bias corrected satellite data and SWAT.

Keywords

MSWEP, TRMM, CFSR, Blue Nile

A multi-criteria framework to prioritize subbasins for adaptive water resources management in data scarce semi-arid regions

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Abstract

Several regions of Iran are prone to extended droughts; however, recently they have witnessed unexpected floods and soil erosion threatening drinking water facilities, agricultural lands, and other valuable infrastructure.The Latiyan watershed, located in the middle part of the Alborz Mountains with a drainage area of approximately 701 km^2, was selected as a representative river basin in a mountainous cold semi-arid climate. There is a multipurpose dam (Latiyan) at the outlet of this watershed, which supplies 25 percent of the drinking water of Tehran and is a source of hydropower and irrigation water for the agricultural lands. A novel framework, based on hydrology, morphometric characteristics, and topographic indices was designed to prioritize subbasins to efficiently manage disturbances, such as floods and erosions. The Soil and Water Assessment Tool (SWAT) was applied to simulate hydrologic metrics on a subbasin level. Morphometric characteristics were utilized to assess the risk of erosion and peak discharge and its spatiotemporal dynamics. Topographical indices were also applied to assess the potential of sediment transport. In this framework, the Weighted Sum Analysis (WSA) technique was used to rank morphometric and topographic parameters. Multi-Criteria Evaluation (MCE) and Fuzzy set theory were used to rank 56 subbasins and to classify them into very high, high, medium, low and poor priority zones. The results illustrated that 10% of the subbasins are in the very high critical zones considering erosion and runoff yields. These areas are mostly under bare lands and sparse vegetation surfaces. The topo-hydrologic and morphometric criteria were useful to identify critical areas in the ungauged data-scarce region. Afforestation initiatives with indigenous species adapted to environmental and ecological characteristics of the area are suggested as a natural conservation strategy, which can help to decrease the erosion and flood risk and sustaining the Latiyan reservoir storage capacity.

Keywords

Weighted sum analysis technique, SWAT model, Topo-hydrologic parameters, Morphometric characteristics, Fuzzy theory.

Soil Erosion Models at Regional and Watershed Scale Comparing SWAT, AnnAGNPS, PESERA, and RUSLE2015

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Abstract

In this study, the simulations generated by two of the most used hydrological watershed-scale models, the Soil and Water Assessment Tool (SWAT) and the Annualized Agricultural Non-Point Source (AnnAGNPS), were compared in a Mediterranean watershed, the Carapelle, located in Apulia, Southern Italy.

Firstly, the models were built up using the same dataset. Afterward, they were calibrated and validated for runoff and sediment load at monthly scale, using a daily measured dataset (from January 2007 to December 2011). Three statistical indices (NSE, PBIAS, and R^2) were used to evaluate model performance. Both models showed from satisfactory to very good correlation between observed and simulated streamflow and sediment load data.

In the driest year, the specific measured sediment load at the outlet was 0.89 t ha^{-1} yr^{-1}, while the simulated values were 0.83 t ha^{-1} yr^{-1} and 1.99 t ha^{-1} yr^{-1} for SWAT and AnnAGNPS, respectively. In the wettest year, the specific measured sediment load was 7.45 t ha^{-1} yr^{-1}, and the simulated values were 8.27 t ha^{-1} yr^{-1} and 6.23 t ha^{-1} yr^{-1} for SWAT and AnnAGNPS, respectively. The study of the sediment source areas revealed that most of the basin is under moderate (1.4–10 t ha^{-1} yr^{-1}) and high erosion risk (> 10 t ha^{-1} yr^{-1}).

The sediment yield predicted by the SWAT and AnnAGNPS models were compared with soil erosion estimates from the European scale models PESERA and RUSLE2015. The average gross erosion estimated by the RUSLE2015 model resulted comparable with the average specific sediment yield estimated by SWAT and AnnAGNPS, while the average soil erosion estimated by PESERA was lower than the other estimates. The methodology here applied could be considered an indirect method to calibrate or validate models applied at different scales, thus giving a measure of the uncertainty affecting the results.

Keywords

SWAT; AnnAGNPS; PESERA; RUSLE2015; Soil erosion

Assessment of sediment inflow to a reservoir using the SWAT model for Changing Landuse conditions: A case study for Vaigai Reservoir, Tamilnadu, India

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Abstract

Soil erosion and sedimentation are one of the most serious environmental hazards worldwide. This sediment deposition leads to loss of storages in reservoirs, and eutrophication becomes crucial for the operation of reservoirs. Vaigai reservoir in concerned in this study due to the rapid increase in soil erosion rate over the past decades. The average annual silting rate for the years 1976, 2000, and 2012 are 8.519%, 14.504%, and 16.512% respectively. This could be significantly mitigated by controlling the rate of sediment loss across a watershed. This study aims to demonstrate that the SWAT model can be used to predict discharge and sediment yield to identify critical subwatershed. The assessment method utilizes the Soil and Water Assessment Tool (SWAT) and the Modified Universal Sediment Loss Equation (MUSLE) to quantify sediment losses in the upstream of Vaigai reservoir, Tamilnadu, India. The SWAT model was applied to simulate the total suspended solids at the watershed outlet. The model performance was evaluated using SWAT-CUP by SUFI-2 methods. The model was calibrated for the period 1999-2008 and validated for the period 2009-2015 using observed runoff and sediment yield. The successfully validated model is used to identify the critical sub-watershed and prioritize the total of 32 sub-watersheds of the catchment based on its severity on sediment loss. The goodness-of-fit analyses suggested a realistic representation of the watershed behavior and satisfactory values of Nash-Sutcliffe Efficiency were obtained during the calibration and validation stages (0.53 and 0.52). Different management options were considered in all watersheds of the catchment to study the effects in controlling the reservoir sedimentation rate and thus to enhance the useful life of reservoirs.

Keywords

ArcSWAT, SWAT-CUP, Sedimentation, land-use change, and Vaigai reservoir

Estimating nutrient loss from a typical dairy farming catchment in New Zealand using SWAT

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Abstract

Dairy farming is a significantly important industry in New Zealand. However, water quality deterioration has been observed in dairy farming areas as consequences of high grazing intensity and extensive landscape modifications. The Soil and Water Assessment Tool (SWAT) is one of the most common catchment models that has been applied across a wide range of catchment scales and conditions to assess hydrological and environmental issues. Moreover, SWAT has been developed particularly for agricultural catchments, thus, is possibly a suitable modelling tool for intensively agricultural region like New Zealand where there is still limited number of SWAT applications. This study tests the ability of the SWAT model to simulate water quantity and nutrient load and concentration for a typical dairy farming catchment in New Zealand. The chosen case study is the Toenepi catchment in the Waikato Region of the upper North Island of New Zealand. Long term observations for both water quantity and water quality and knowledge from previous research studies in this catchment were used to evaluate the model performance. The preliminary results showed that the SWAT model could predict discharge very well with daily Nash Sutcliffe Efficiencies (NSE) of 0.82 and 0.78 in the calibration and validation periods, respectively. The model performance was better at the monthly time step with NSE of 0.93 and 0.92 in the two periods. The flow variation was very well captured, however, flow at storm events were underestimated. SWAT also produced reasonable estimates and seasonal variation for nitrogen yield and concentration. Subsurface drainage is the main contribution to streamflow, and consequently is the dominant pathway for nitrogen transport to the streams.

Keywords

Dairy farming, SWAT, nutrients, SWAT in New Zealand

Modelling of Discharge and Sediment Transport in Terrace Paddy Fields Through the SWAT model. a Case study: Keduang sub-watershed, Wonogiri Regency, Central Java, Indonesia.

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Abstract

Keduang Sub-Watershed is the greatest sediment producer into Gajah Mungkur Reservoir. One of the ways to reduce sedimentation is applying soil and water conservation in the mountainous area, i.e. applying terrace paddy fields. There are so many advantages of utilizing terrace paddy fields for the sustainability of the environment due to its capability to retain water and reduce surface run-off. The objective of this study is to simulate the discharge and sedimentation process of the watershed (Keduang Sub-Watershed) containing terrace paddy fields using the Soil and Water Assessment Tool (SWAT) model that integrated with Geographic Information Systems (ArcSWAT version 2012.10.4.21). Model calibration and validation were performed for monthly periods using Sequential Uncertainty Fitting 2 (SUFI-2) within SWAT-CUP that was using observed streamflow data at catchment outlet. Model performance indicator used in this research were Nash-Sutcliffe Efficiency (NSE) and the coefficient of determination (R2). The calibration and validation outputs for monthly simulation showed good performances for discharges. From the simulation of the SWAT model, terrace paddy fields can reduce sedimentation around 37.96 % compared with the result of simulation without applying terrace paddy. It indicated that terrace paddy fields have a significant role in environmental issues, especially in the mountainous area.

Keywords

Terrace; SWAT; SWAT-CUP; Discharge; Sedimentation.

A guideline for consistent water quality modeling

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Abstract

In recent years, the need for consistency in hydrological modeling was claimed in several studies. Hereby, consistency means that all relevant hydrological processes are accurately represented in space and time in accordance with catchment observations. In this study, we transfer the concept of model consistency to water quality. Based on our recent studies, we propose a guideline for consistency in water quality modeling, which includes following criteria:

1. Model input: Spatial distributed representation of nutrient inputs in the catchments, e.g. dependent on agricultural crops, density of live-stock or biogas plants.

2. Crop development: Accuracy check for crop-related criteria in their annual cycle such as fertilizer application, nutrient uptake, crop growth, biomass and yields.

3. Model parameters: Derivation of the temporal variability of dominant model components and model parameters by temporally resolved parameter sensitivity analyses for a better understanding of how a model is controlling nutrient cycles and related water quality processes.

4. Model performance: Multi-metric model calibration by a set of contrasting performance criteria and signature measures that are jointly evaluated for discharge and water quality variables.

5. Scenario simulations: Dynamic update of spatial land use patterns during model simulations induced by changes of agro-economic conditions in the catchment.

6. Best management practices: Analyses of how a combination of different management options change the water quality conditions using a reliable model.

In this way, we demonstrate how diagnostic tools can be transferred from quantitative hydrology to water quality modeling to achieve more consistent model results and more reliable simulation of scenarios.

Keywords

Nitrate modelling, Sensitivity analysis, Model calibration, Land use scenario simulations

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