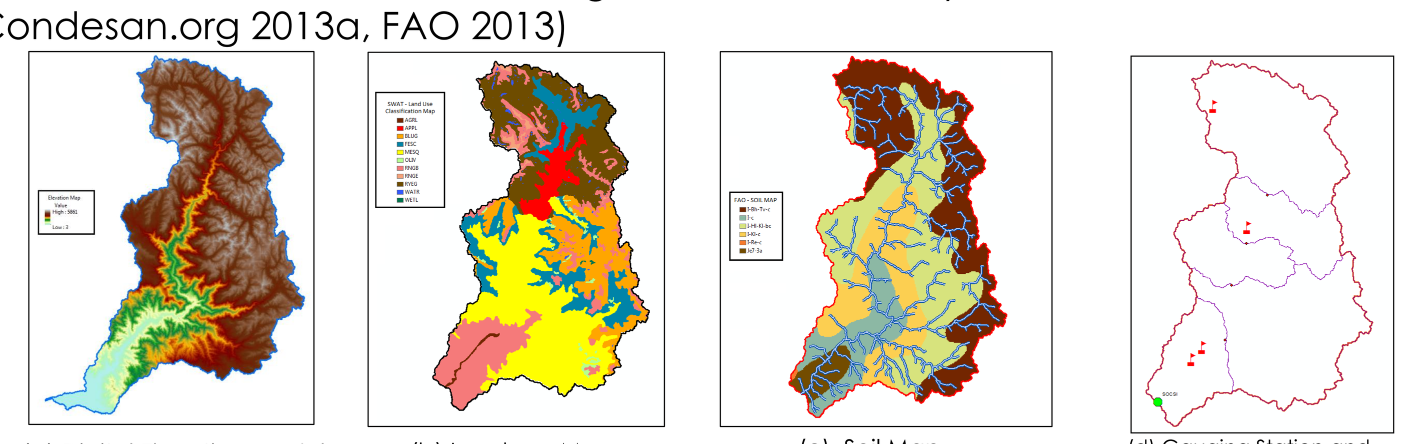
Daily hydrology and sediment yield modeling using SWAT model in the Cañete basin (Peru)

Nilton Fuertes[1,2], Waldo Lavado[1,2] William Santini[3]
José Miguel Sánchez-Pérez[4,5], Sabine Sauvage[4,5]

Scientifical Context : Collecting sediment flow data over a decade and periodic reservoir survey information are some resources demanding methods for estimating sediment yield rates at a catchment level (Silva et al.,2007). The SWAT model (Arnold et al. 1998) was developed for the evaluation of impacts of land use and management practices on hydrology and water quality in large complex watersheds (Neitsch et al. 2011). In principle, their parameters have a physical meaning and can be measured in the field, and therefore model validation can be concluded on the basis of a short field survey and a short time series of meteorological and hydrological data (Bathurst, 2002). Sediment yield is estimated for each HRU using the empirical Modified Universal Soil Loss Equation (MUSLE; Williams 1975) .

Objective : Evaluate the performance and functionality of SWAT model in daily hydrology and predict sediment yield from 2003 to 2009, using daily meteorological, hydrological data and monthly sediment samples data in one station of the Cañete basin (Socsi hydrological station) in Peru.

Study site and data : The Cañete basin (8'543,759~8'676,000N - 345,250~444,750E) UTM is located in the extreme south of the Department of Lima (Peru), in Cañete and Yauyos provinces. It is the only river on the coast of Peru that flows throughout the entire year with an annual average flow of 52 m3/s. (Condesan.org 2013a, FAO 2013)



(a) Digital Elevation Model
Resolution : 90 m
Source of data : SRTM

(b) Land use Map
Resolution : 1:100.000
Source of data : National Geographic Institute (IGN) - PERU

(c) Soil Map
Resolution : 1:100.000
Source of data : FAO

(d) Gauging Station and weather stations
Resolution : 1:100.000
Source of data : SENAMHI - PERU

1 gauging station and 4 four meteorological station
Source of data : SENAMHI - PERU

7 hydrological years for running SWAT (2003 -2009) at daily scale.

Number of HRUs : 382
Number of Subbasins : 5

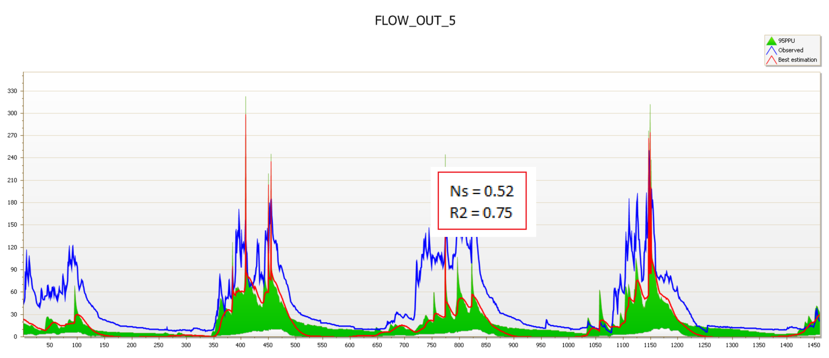
Fig 1. Input Parameters for SWAT (a) Digital Elevation Model ; (b) Land use map; (c) Soil Map and (d) Gauge Station and weather stations

Methodology: SWAT model requires DEM data, soils data, land use and management information, also simulation requires meteorological input data including precipitation, temperature, and solar radiation. Cañete watershed was delineated using a model default parameters as a first scene, which represents the area of a subbasin in the watershed. Subbasins were divided into hydrological response units (HRUs) using a threshold of 2% for land use, 2% for soil type and 2% for slope, getting 382 individual HRUs and 5 subbasins. Finally, all the input files and climate data were set up according to the conditions and objectives of the study. The first results of the simulation were compared with observed river flow data at SOCSI gauging station. SWAT-CUP(SWAT Calibration and Uncertainty Procedures) were used to calibrate the model parameters using time series of flow and sediment load data of 2003 to 2006 and validated with the observed data from years 2006 to 2009.We still working on validation process using statistical (coefficient of determination (R2) and NSE values for the daily runoff by using [SUFI-2] algorithm) and graphical methods to assess the capability of the model in simulating daily stream flow and sediment yield for the study area.

Modelling approach

- Modeling of ungauged basin, prediction of sediment yields and surface runoff with different scenarios such as different land use classification, slopes , or soil maps.
- Understand the physical meaning of each parameter in the simulation, calibration and validation steps.
- The use of weather simulation to generate daily data for rainfall, solar radiation, relative humidity, wind speed and temperature from monthly average variables of these data.

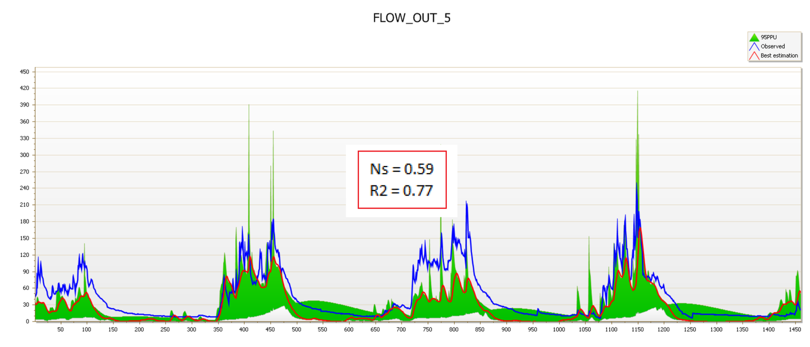
Results : Calibration and Validation



Daily flow simulation

Parameter used to calibrate flow			
Parameter	**Min_value**	**Max_value**	**Fitted_Value**
CN2.mgt	-0.2	0.2	-0.133333
ALPHA_BF.gw	0.0	1.0	0.633333
GW_DELAY.gw	0.0	0.0	0
EVPOT.hru	0.0	0.0	0.00
ESCO.hru	0.8	1.0	0.83
CH_N2.rte	0.0	0.3	0.05
CH_K2.rte	5.0	130.0	92.50
ALPHA_BNK.rte	0.0	1.0	0.37
SFTMP.bsn	-5.0	5.0	4.50
GW_REVAP.gw	0.0	0.2	0.14
SFTMP.bsn	-5.0	5.0	2.00

Fig 2. Daily flow simulation and parameters



Daily flow simulation

Parameter used to calibrate flow			
Parameter	**Min_value**	**Max_value**	**Fitted_Value**
CN2.mgt	-0.2	0.2	-0.17
ALPHA_BF.gw	0.0	1.0	0.23
GW_DELAY.gw	30.0	450.0	67.80
GWQMN.gw	0.0	2.0	0.66
EVPOT.hru	0.0	0.0	0.00
CH_N2.rte	0.0	0.3	0.18
CH_K2.rte	5.0	130.0	61.25
ALPHA_BNK.rte	0.0	1.0	0.89
SFTMP.bsn	-5.0	5.0	4.50
GW_REVAP.gw	0.0	0.2	0.14
SURLAG.bsn	0.0	0.0	0.00

Fig 3. Daily flow simulation with GWQMN parameter

- We used SWAT-CUP (SUFI- 2) algorithm for the calibration, based on physical basin parameters.
- Daily observed flow data (m3/s) is used for calibration , monthly measured samples data for suspended sediments (mg/L) (2008 – 2009) .
- The first graphic represents simulated flow with calibrated parameters, the number of simulations with this new parameters were 50, with 2 objective functions Nash Sutcliff and R2 ,as we can see ,the statistical representation for this simulation are good (Ns = 0.52 & R2 = 0.75)
- For the next simulation we added a new parameter GWQMN. This parameter is defined as "the threshold depth of water in the shallow aquifer required for return flow to occur"(SWAT Input Data,2009).Figure 3 represents simulated flow with calibrated parameters, the number of simulations with this new parameters were 100 , with 2 objective functions Nash Sutcliff and R2,the statistical representation for this simulation are better (Ns = 0.59 & R2 = 0.77).

Results : Simulations

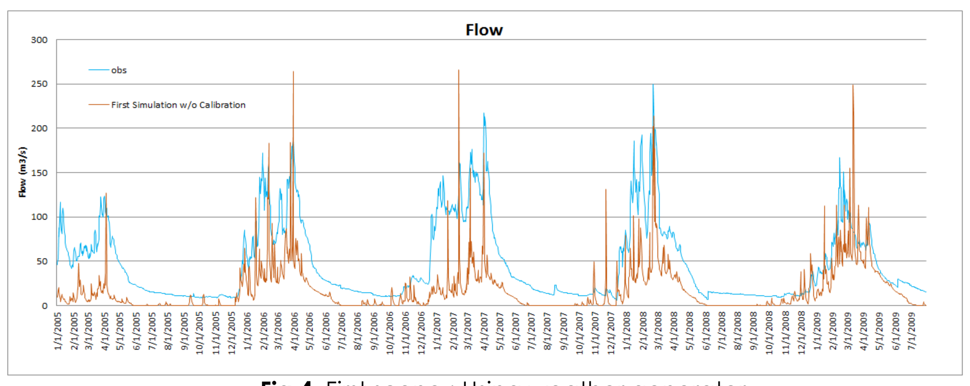


Fig 4. First scene : Using weather generator

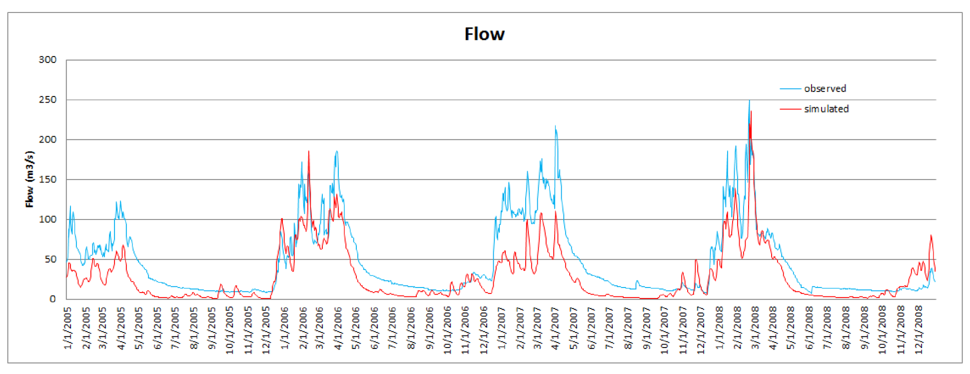


Fig 5. Second scene : Using observed weather data

- The first simulated scene was setup using the weather generator, results has a similar behavior to the observed data, but the flow peaks are high and sub estimated, simulated base flow is lower too.
- The second scene is using observed weather data, simulated daily runoff simulation results daily runoff during calibration showed that the simulated discharge generally followed the trend to observed discharge. However, model predicted peak values with reasonable limits .
- In both scenarios show similar trends, the use of weather generator influence the simulation results and the change in GWQMN provided a more closely matched to the observed river flow data.

Perspective :

- Suspended sediment concentration are not well represented , because we need to calibrated and validated surface runoff first to follow the process and get better results.

Conclusions

- Results from SWAT model at a daily time step have a good behavior even with simulated and observed weather data, the problem with peak values can be reduced using
- Statistical parameters as Nash Sutcliff and R2 are the best indicator for calibration and validation processes .
- Surface run off must be validated and calibrated first to represent a good suspended sediment simulation.
- Slope discretization could affects the sediment prediction.

[1,2] Servicio Nacional de Meteorología e Hidrología. Lima, Perú (SENAMHI).
[3]Institut de Recherche pour le Développement (IRD) , Geosciences Environnement Toulouse (GET).
[4,5]University of Toulouse; INPT, UPS; CNRS ;
[4,5] Laboratoire Ecologie Fonctionnelle et Environnement (EcoLab), France.