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Hydrological Modelling for Water Balance Components Assessment

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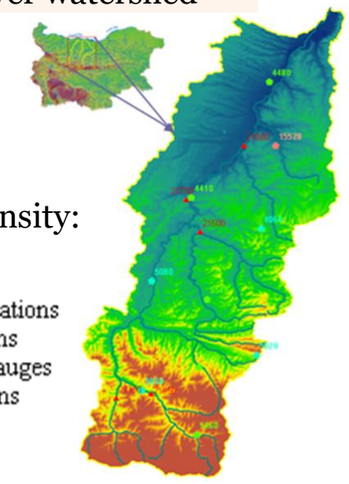
Introduction:

Water balance is a well acknowledged technique for analyzing the hydrology of a watershed. Quantifying the parameters of the hydrological cycle is the first step for estimating water resources and water balance. Due to the complex character of hydrological processes the usage of hydrological models is widely recognized as an effective tool for understanding and representing the relationship between different processes and water balance parameters (Koshinchanov et al., 2014). Hydrological models identify the dominant hydrological processes which influence water balance (Yordanova et al., 2020). Hydrological models delineate the partition of water input to a watershed (mainly rainfall) into hydrological processes – surface run-off, base flow, ET and storage changes. The water balance components that are commonly interpolated for WRA purposes are the characteristics of precipitation and runoff (WMO, 1992a).

In this study SWAT (Soil Water Assessment Tool) hydrological model was applied to Vit river basin to estimate the water balance components of the catchment – surface run off, lateral flow, evapotranspiration,

Study area: Vit river watershed



Methodology:

The study area (Vit river watershed) is located in northern Bulgaria and is part of the Danube river basin. Vit river catchment is elongated with an area of 3225 km2.

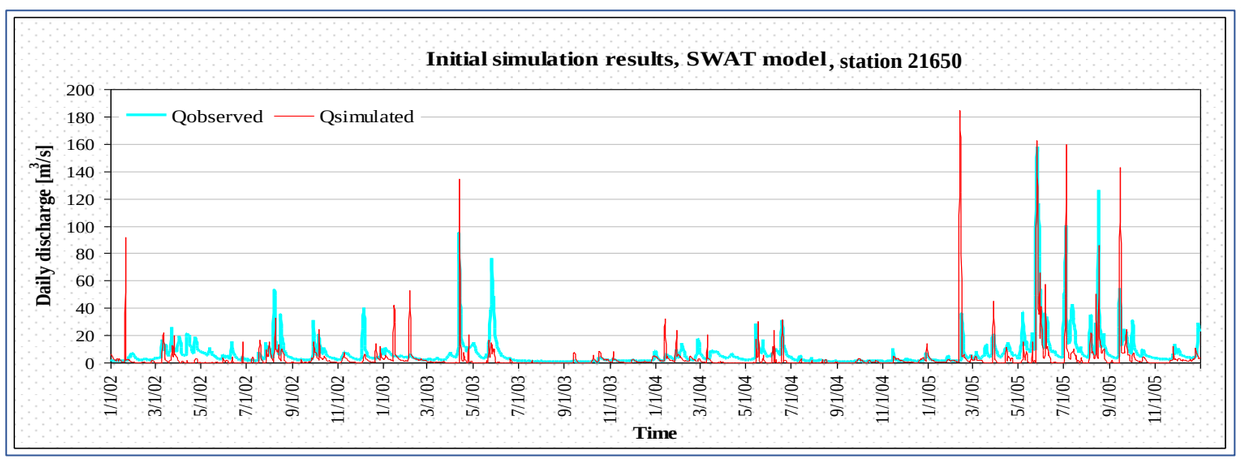
In this study the Soil and Water Assessment Tool was used (Arnold et al., 2012). SWAT is an open source watershed scale, semi-distributed hydrological model. Water balance is the main driving force behind every process in the SWAT model as a result of its effects on plant development and the movement of sediments, nutrients, pesticides, and pathogen within the watershed region (Arnold et al., 2011). It uses physically-based input such as topography, soil properties, land cover and weather data to evaluate temporal and spatial variability of water cycle parameters.

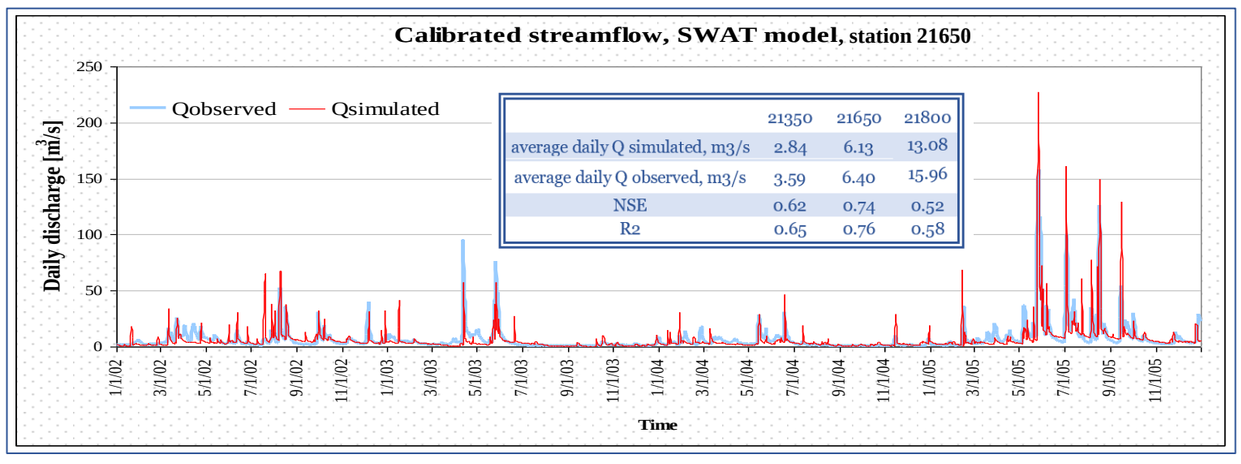
For setting up the model spatial data set was processed including a digital elevation map (DEM), landuse and soil maps. Meteorological data i.e. daily precipitation, maximum and minimum daily temperature, daily relative humidity and daily wind speed from nine rainfall gauges and four meteorological stations was also collected and processed.

Hydrometeorological data sets were provided by the National Institute of Meteorology and Hydrology in Bulgaria.

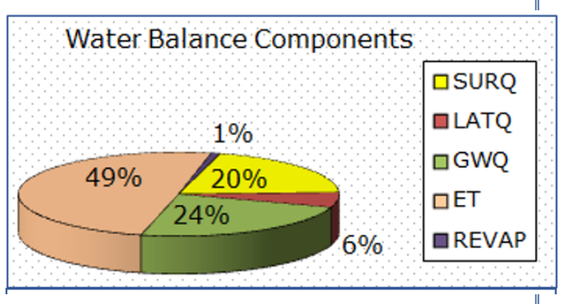
Results:

✓ After the initial SWAT model simulations a sensitivity analysis towards daily discharge records from three* flow gauges was performed prior to model calibration and validation. Further adjustment of selected sensitive parameters was performed for model calibration.
✓ Two quantitative statistics were used to evaluate the goodness of calibration – the Nash-Sutcliffe efficiency (NSE) and the coefficient of determination (R2)
✓ The accuracy of the calibrated model results was evaluated at three* control gauges of the watershed – 21650 and 21350 upstream and 21800 at downstream Vit river.
✓ As seen from the graphs presented the calibrated SWAT model showed a good temporal streamflow representation.
✓ The statistical estimates at the control hydrometric stations presented below show that the overall estimated daily discharges ranged from satisfactory (downstream Vit river basin at station 21800) to good and very good for upstream Vit river basin.





	21350	21650	21800
average daily Q simulated, m3/s	2.84	6.13	13.08
average daily Q observed, m3/s	3.59	6.40	15.96
NSE	0.62	0.74	0.52
R2	0.65	0.76	0.58



Water Balance Components	AMOUNT, [mm]	
Precipitation	796.20	
Surface runoff		157.50
Groundwater flow		183.92
Lateral flow		44.81
Revap		7.16
Recharge of deep Aquifer		10.12
Evapotranspiration		385.30
TOTAL	**796.20**	**788.81**

Results:

✓ The average annual water balance components for the entire Vit Basin were obtained after running the calibrated model.
✓ The watershed receives 796.20 mm precipitation per year (83.90 mm of which is snowfall).
✓ SWAT-based water balance component calculations showed that ET has the highest share of the water balance with a value of 49%. Revap (<1%) has the lowest percentage of all.
✓ Surface runoff is 157.50 mm and subsurface flow is only 6% (44.81 mm) of the total precipitation.
✓ Groundwater (GWQ) contribution to the stream is significant- 183.92 mm (24%).
✓ The amount of water passing from the shallow aquifer and recharging the deep aquifer is 10.12 mm (about 1%).
✓ The sum of the simulated hydrological components is only 7.40 mm less than the total precipitation received by the catchment.

Conclusion:

✓ Spatial and temporal characteristics of the observed daily discharge data were properly represented by SWAT. The high values of the statistical estimates R2 and NSE for calibration period imply that SWAT model is useful in studying hydrology and estimating water balance components in the study watershed.
✓ SWAT-based water balance component calculations show that the model succeeded in preserving the water balance equation for the Vit river watershed.
✓ The results of the water balance study presented in this paper indicate that surface water availability is considerable.
✓ Simulation results however are subject to further validation and further improvements in model performance should be sought.
✓ Additional land cover analysis is required during the available period of rainfall-run-off record to establish a statistically valid link between changes in land cover and hydrological response.