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Modelling Hydrological Processes in the Altınapa Reservoir Watershed by SWAT

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ABSTRACT

In this study, we used the Soil and Water Assessment Tool (SWAT) to model hydrological processes in the Altınapa Reservoir Watershed in the Konya province, Turkey. Altınapa Reservoir Watershed is a small semi-arid watershed, which discharges into Altınapa Reservoir, that supplies drinking water to Konya, a city of about 2 million. The modelling process was challenging due to the unavailability of high resolution data about basin characteristics and uncertainties in climatic and hydrologic data. The model was setup using digital elevation model, soil, land use/cover and slope data obtained from global datasets and meteorological data obtained from a local station. The watershed was delineated into 18 subbasins and 159 hydrological response units. The model was run on the monthly time step from 2000 to 2016. Data from the 2000-2004 period was used for model warm-up. The model was calibrated for streamflow for the 2005-2010 period and the 2011-2016 period was used for model validation. For model calibration, we used SWAT-CUP program with the built-in SUFI-2 algorithm and 24 parameters were included in the calibration process. The model performance during the calibration period was satisfactory with Nash-Sutcliffe Efficiency (NSE) value of 0.56 and determination coefficient (R2) of 0.56. During model validation, NSE was calculated as 0.51 and R2 was calculated as 0.54. The physically-based model, SWAT, successfully represented hydrological processes in the Altınapa Reservoir Watershed with scarce data input. The model can be used for simulating water quality and impacts of land use and climatic changes in the future.

Keywords: hydrological modelling, streamflow, SWAT, Altınapa reservoir
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Introduction

Konya Closed Basin is one of the most arid basins in Turkey. The basin has very scarce water resources and they are under the pressure of human- and climate-induced impacts. The water levels and volumes in lakes, wetlands and reservoirs and groundwater levels have declined in the basin in recent decades (Berke and Dıvrak, 2014). In this study, we characterize and analyse hydrological conditions in a small watershed (Altınapa Reservoir Watershed) within the Konya Closed Basin by developing a hydrologic model using the Soil and Water Assessment Tool (SWAT).

Hydrological models can provide various advantages to water managers for understanding hydrological processes/changes and for making predictions regarding future hydrologic conditions (Gassman et al., 2014). However, hydrologic modelling requires background data/information about basin characteristics and climatic conditions, which may not be always available. Calibration and validation of hydrologic models is a challenging process and conceptualization of the physical system, model inputs and parameter selection can create major uncertainties in model predictions (Gupta et al., 2009). SWAT is a semi-distributed hydrological model that can be used to simulate streamflow, sediment and nutrient loadings in small watershed to river-basin scale. SWAT can make successful predictions for ungauged basins where high resolution data about the basin characteristics are not available (Emam et al., 2017).

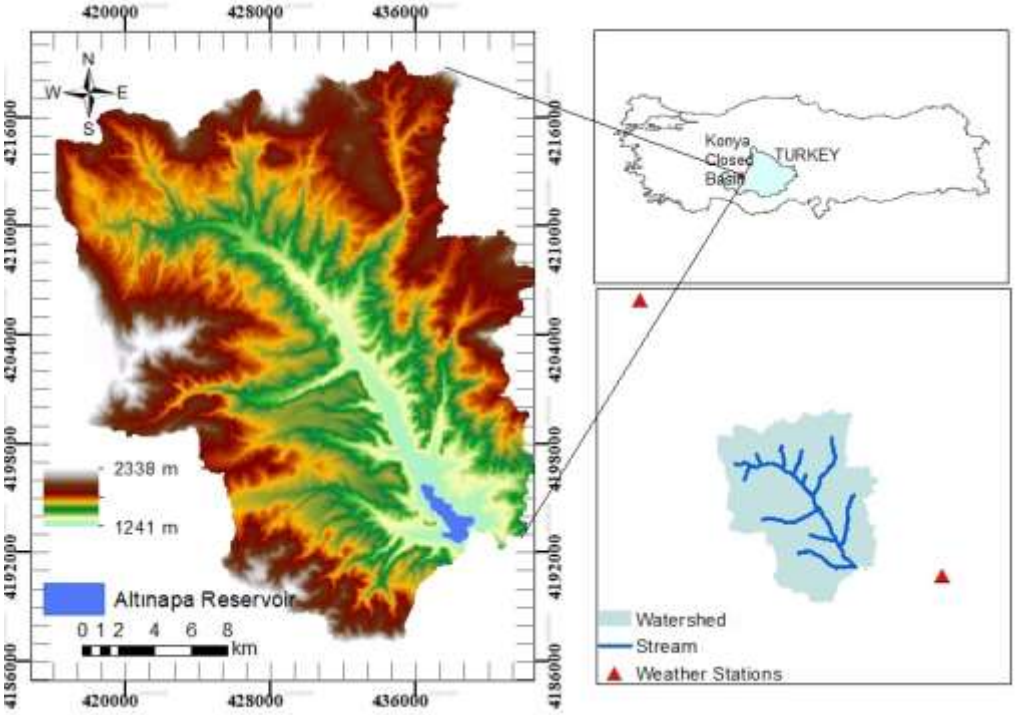
The main goal of this study was to investigate applicability of SWAT for predicting streamflow in the Altınapa Reservoir Watershed. Altınapa Reservoir Watershed is a small basin, which discharges into Altınapa Reservoir, a drinking water reservoir that supplies water to the Konya province with a population of about 2 million.

Materials and Methods

Study Area

Altınapa Reservoir Watershed is located in the western part of Konya Closed Basin, south-central Turkey (Figure 1). The climate is continental in the basin and the average air temperature and precipitation are about 11.6°C and 338 mm, respectively. The average elevation of study area is 1,603 m and the basin covers a 563 km^2 area. The Altınapa Dam and Reservoir were built by the State Hydraulic Works (DSI) in 1967 with the purpose of flood protection and drinking water supply. The main stream, Dolay River, with an average annual flow of 1 m^3/s, feeds the reservoir. Altınapa Reservoir is located at the basin outlet and acts as the final discharge point. The reservoir has an average volume of about 15,000 million m^3 and has surface area of 3.8 km^2. Six small villages are located inside watershed and major crops cultivated are winter wheat, maize, and vegetables, and fruits.

Figure 1. *The Location of the Altınapa Reservoir Watershed*



Data Sets

To set up the SWAT model, digital elevation model (DEM), land use/cover (LULC), soil, weather and hydrology databases were need to be prepared as input. In this study, 30 m×30 m SRTM digital elevation map was obtained from the USGS and has been used as an input for watershed/subbasin delineations and topographic parameterization. The LULC map used for the SWAT model was obtained from the Coordination of Information on the Environment (CORINE) data. According to CORINE 2012 data, the basin is covered by sparsely vegetated areas (29%), mixed agriculture and natural vegetation (23%), and transitional woodland-shrub areas (22%). Rest of the basin is covered with non-irrigated areas, natural grasslands as well as complex cultivation patterns. The soil data was acquired from World Soil Map, provided by Food and Agricultural Organization of the United Nations. According to this map, Altınapa Reservoir Watershed has a uniform soil cover with loamy soil texture. We obtained maximum and minimum temperature, precipitation, relative humidity, solar radiation and wind speed data from the State Meteorology Service. Streamflow measurements were available at a single gauging station. We used these data for model calibration and validation.

SWAT Model Setup, Calibration, and Validation

SWAT is a conceptual model that operates on the daily time scale and simulates the quality and quantity of surface and ground water and estimate

impacts of the land management practices on water resources (Arnold et al., 1998)). In this study, GIS interface program ARCSWAT was used to set up SWAT model. The Altınapa Reservoir Watershed has been divided into 18 subbasins and 159 hydrological response units (HRUs) based on soil, LULC and slope information.

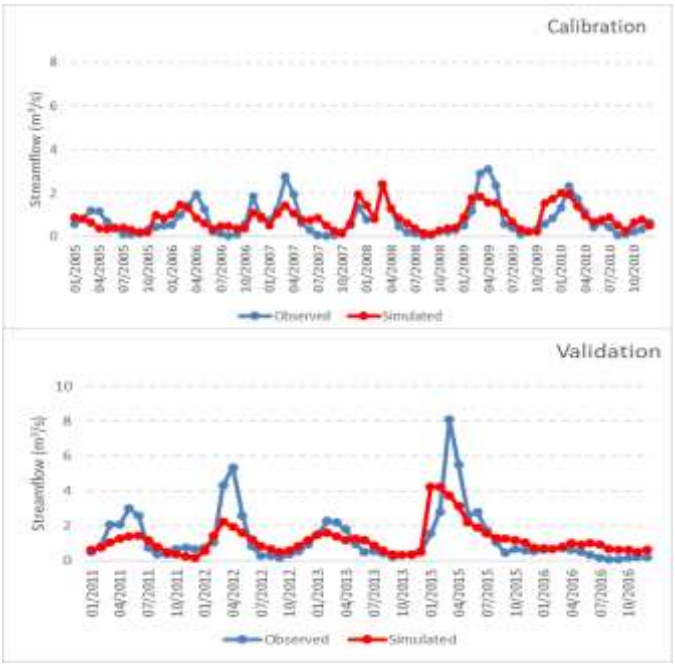
SUFI-2 algorithm, available in the SWAT-CUP (Abbaspout et al., 2004) was used for calibration and validation of the model for streamflow. Twenty-four parameters were selected used for model calibration. Observed streamflow data from the 2005-2010 period were used for calibration and the 2011-2016 data were used for validation. We estimated model performance by using objective functions namely determination coefficient (R2), NSE, percent bias (PBIAS), observations standard deviation ratio (RSR) and Kling-Gupta Efficiency (KGE). According to Moriasi et al. (2007), R2>0.50, NSE>0.50, PBIAS>10, RSR>0.6 and KGE>0.5 could be considered as satisfactory model performance.

Results and Discussion

SWAT model was calibrated for monthly streamflow by comparing simulated values with observed streamflow data at the Dolay River gauging station. The model was run for a period of 17 years (2000-2016) by considering the first 5 years as the warm-up period. The period 2005-2010 was used for calibration, whereas the six years of the dataset 2011-2013 and 2015-2016 periods were used for validation (Figure 2).

During the calibration period, R^2 and NSE values calculated between observed and simulated streamflows were 0.56 and 0.55, respectively, while RSR was 0.67, PBIAS was -7.0, and KGE was 0.61. For the validation period, R^2 was calculated as 0.54 and NSE as 0.51. RSR was 0.70, PBIAS was 8.4 and KGE was 0.49 during validation. It can be clearly seen from Figure 2 that observed and simulated streamflows fit well. We observe some differences in peak streamflow, which can be due to uncertainties in input data or errors in stream flow measurements (Abbaspour et al., 2017, Fontaine et al., 2002)

Figure 2. *Observed and Simulated Streamflows during Calibration and Validation Periods*



The water balance in the basin was estimated based on model outcomes. The annual potential evapotranspiration for the 2005-2016 period was 1198.7 mm and annual evapotranspiration was 255.8 mm. Annual precipitation was very low, compared to potential evapotranspiration; it was 328.3 mm. The total water yield was calculated as 74.4 mm.

Conclusion

In this study, a SWAT model was developed for the Altınapa Reservoir Watershed to simulate streamflows from 2000 to 2016. The model was calibrated and validated for streamflow using the SUFI-2 algorithm. We obtained satisfactory results in calibration and validation although model inputs had some uncertainties. The streamflows simulated by the model matched well with observed values. This study showed that hydrologic models can be used for estimating streamflows in arid basins, with scarce data resources. Hydrologic models can provide valuable information for water resource management and planning. The calibrated and validated models can be used for further studies on sediment, water quality analysis, land use & climate change impacts on watershed.

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