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MODELING HYDROLOGICAL DYNAMICS IN EGIRDIR LAKE (TÜRKIYE) BASIN USING SWAT: ADDRESSING WATER LEVEL DECLINE

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Abstract. Egirdir Lake, located in the “Lakes Region” of southwestern Türkiye, is the second largest freshwater reservoir for drinking water. With a large surface area and shallow depth, the lake's water balance is mainly controlled by direct precipitation and evaporation. Water from Egirdir Lake is used for irrigation in irrigation schemes and is also abstracted for domestic water supply. The catchment is characterized by intensive agricultural activity, 70% of which consists of high-water-demand fruit farming. In recent years, the lake has been increasingly affected by the adverse effects of climate change and excessive water withdrawals for irrigation. These pressures have led to a continuous decline in water levels. Projections indicate that lake levels could continue to decline in the future. High diffuse nutrient loads from agriculture and untreated wastewater discharges could also cause water quality issues. To address these interconnected hydrological and ecological challenges, in this study, we aim to develop a semi-distributed hydrological model using the Soil and Water Assessment Tool (SWAT) for the Egirdir Lake Basin. The model was created using the ArcSWAT interface and consisted of 14 subbasins and 274 hydrologic response units (HRUs). It was calibrated using naturalized streamflows with the SWAT-CUP software. Overall, reasonable agreement was obtained based on performance indicators such as the coefficient of determination (R^2), Nash-Sutcliffe Efficiency (NSE), and percent bias (PBIAS). The comparisons of simulated naturalized streamflows with observed streamflows showed that streamflows were significantly reduced in the basin due to anthropogenic impacts, and the effect is getting stronger in more recent years. The developed SWAT model will be used to assess the impacts of climate change and agricultural water use in the future.
Keywords: Hydrologic Modelling, Climate Change, Anthropogenic Impacts, SWAT, Egirdir Lake Basin

1 INTRODUCTION

Egirdir Lake is located in southwestern Türkiye, in the "Lakes Region" within the province of Isparta, between 37° 50' and 38° 16' North latitudes and 30° 57' and 30° 44' East longitudes. It is Türkiye's second-largest drinking water source. The minimum operating level for the lake, as determined by the State Hydraulic Works (DSI), is 914.62 m, with a corresponding lake volume of 2099 hm^3. The maximum operating level is 918.96 m, with a corresponding lake volume of 4001 hm^3 (Kacikoc et al., 2025). Due to its shallowness and large surface area (approximately 460 km^2), the lake's most significant water budget components are precipitation and evaporation. Besides these, the primary sources feeding the lake are Hoyran (A.Tırtar) Stream, Çay Stream, Gelendost Stream, and Pupa Stream. Diversion from the Köprüçay Lower Basin also transfers water to the lake.

The Boğazova, Hoyran, Barla, Gelendost, Senirkent, and Atabey Plains irrigation schemes (located within the Burdur Lake Basin boundaries) are irrigated with water drawn from Eğirdir Lake for agricultural purposes. Additionally, there are DSİ-operated dams, ponds, and reservoirs for irrigation purposes within the lake's drainage area. In addition to agricultural water withdrawals, water is also drawn from the lake for drinking water.

Intensive agricultural activities are carried out in the lake basin. Fruit farming, which has high water requirements, covers about 70% of agricultural areas. In recent years, a continuous decline in the lake's water level has been observed (Kacikoc et al., 2025). Decreases in water level, changes in the lake's transport mechanisms, increases in water temperatures, etc., have made the lake vulnerable to eutrophication and accelerated the process, which is already under pressure from excessive diffuse nutrient loads originating from intensive agricultural activities and untreated wastewater from settlements.

This study aims to understand the hydrological dynamics of the Eğirdir Lake basin. The main objective is to model the basin's hydrological processes and quantify historical and projected changes in water inflows to Egirdir Lake using the Soil and Water Assessment Tool (SWAT).

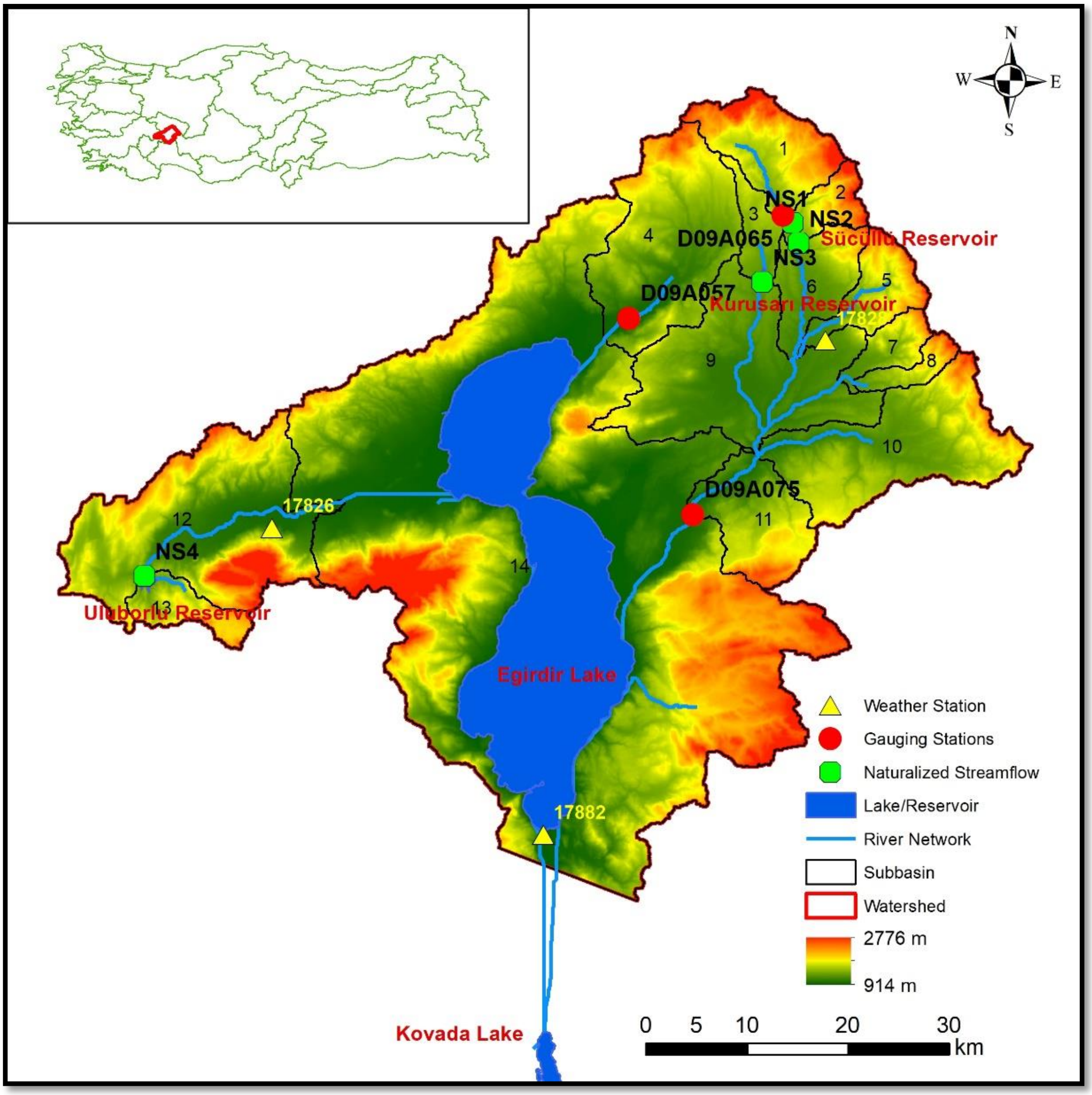

Figure 2. Location and Physical Characteristics of the Egirdir Lake Basin

2 METHODS

This study used SWAT to simulate hydrologic conditions in the Egirdir Lake Basin. SWAT is a conceptual model that operates on the daily time scale and simulates the quality and quantity of surface and ground water and estimates impacts of the land management practices on water resources (Arnold et al., 1998).

To set up the SWAT model, digital elevation model (DEM), land use/cover (LULC), soil, weather, and hydrology databases needed to be prepared as input. In this study, a 30 m×30 m Shuttle Radar Topography Mission (SRTM) digital elevation map was obtained from the United States Geological Survey (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. The soil data was acquired from the World Soil Map, provided by the Food and Agriculture Organization of the United Nations. We obtained maximum and minimum temperature, precipitation, relative humidity, solar radiation, and wind speed data from the State Meteorology Service for three stations, 17826, 17828, and 17882 (Figure 1) in the Egirdir Lake Basin. Streamflow measurements were available at three gauging stations (D09A057, D09A065, D09A075) for the 1990-2000 period. We did not use the streamflow data from these gauging stations for model calibration and validation, as anthropogenic activities heavily influence the recorded flows and do not represent natural hydrological conditions. However, these data were utilized to assess the extent and nature of human impacts on streamflow in the basin.

The GIS interface program ARCSWAT was used to set up the SWAT model. The basin was divided into 14 subbasins and 274 hydrological response units (HRUs) based on soil, LULC, and slope information. SUFI-2 algorithm, available in the SWAT-CUP (Abbaspour, 2015), was used for calibration and validation of the model for naturalized streamflow at four locations (NS1, NS2, NS3, NS4). Naturalized streamflow refers to the estimated flow in a river or stream that would occur under natural conditions, without the influence of human activities such as reservoir operations, water withdrawals, or land use changes. DSI prepared naturalized streamflow data for the 1990-2014 period. We used data from two stations for calibration, and data from two other gauging stations for the same period were used for validation. Twelve parameters were used for model calibration (Table 1).

Table 1. Parameters and initial ranges used in the model calibration and final best parameter values obtained with the SUFI-2 algorithm

Parameter	Description	Initial Range	Selected Value
CN2.mgt	Runoff curve number, antecedent moisture condition II, for land use	-0.15-0.1	-0.033188
ALPHA_BF.gw	Base flow alpha factor, lower number means a slower response (days)	0.05-0.3	0.294688
GW_DELAY.gw	Time required for water leaving the bottom of the root zone to reach the shallow layer aquifer (days)	1-15	2.872500
GWQMN.gw	Threshold water depth in shallow aquifer for return to reach to occur (mm)	0-500	55.625000
RCHRG_DP.gw	Deep Aquifer percolation fraction	0.3-0.7	0.486500
SURLAG.hru	Surface lag coefficient; controls the fraction of water entering the reach in one day (Surface runoff lag time)	1-4	3.666250
SOL_K(1).sol	Soil saturated hydraulic conductivity (mm/h) hr)	30-150	133.650009
SFTMP.bsn	Snowfall temperature (ºC)	3-10	9.203750
SMTMP.bsn	Snowmelt base temperature (ºC)	1-5	3.417500

SMFMX.bsn	Maximum melt rate for snow during the year	3-10	3.481250
SMFMN.bsn	Minimum melt rate for snow during the year (occurs on winter solstice) On June 21 (mm/C_day)	0-5	0.181250
TIMP.bsn	Snow pack temperature lag factor	0.2-0.8	0.359750

We estimated model performance by using objective functions, namely determination coefficient (R^2), Nash-Sutcliffe Efficiency (NSE), and percent bias (PBIAS). According to Moriasi et al. (2007), R^2>0.50, NSE>0.50, PBIAS>10 could be considered as satisfactory model performance.

3 RESULTS AND DISCUSSIONS

3.1 The performance of the SWAT model

The SWAT model developed for the Egirdir Lake Basin consisted of 274 HRUs in 14 subbasins. Twelve parameters were selected for calibration (Table 1), and initial ranges were set based on the physical meaning of the parameters, manual calibration, and literature review. CN2.mgt was the parameter reflecting the runoff generation process. Groundwater flows were calibrated based on ALPHA_BF.gw, GW_DELAY.GW, GWQMN.gw, and RCHRG_DP.gw. SOL_K(1).sol were related to soil properties. Snow melt parameters, including SFTMP.bsn, SMTMP.bsn, SMFMX.bsn, SMFMN.bsn, and TIMP.bsn were also considered.

The performance metrics for naturalized flows at all gauging stations are presented in Table 2, and observed and simulated streamflow at all these stations are shown in Figure 2. Streamflow data from stations NS1 and NS4 were used for model calibration, while data from NS2 and NS3 were used for validation. Overall, the simulated and observed streamflow values show reasonable agreement during calibration and validation periods. However, according to the criteria proposed by Moriasi et al. (2007), model performance is considered satisfactory when the Nash-Sutcliffe Efficiency (NSE) and coefficient of determination (R^2) exceed 0.50, and the Percent Bias (PBIAS) is within ±25%. Although the results in this study are close to these values, the criteria were not fully met.

The model's performance was likely affected by several factors. First, the Eğirdir Lake Basin is under significant anthropogenic pressure, such as reservoir operations, irrigation water use, and land use changes. Due to the complexity and limited documentation of human-induced impacts, naturalized streamflow data were used for calibration and validation to represent flows without anthropogenic influences. While this step was necessary, it also introduced uncertainty, as naturalization involves reconstructing natural flow conditions and it may not fully reflect the actual hydrologic responses of the system.

Second, in this study, we used data with low spatial resolution. Soil and land use data were obtained from global datasets with coarse resolutions, which may not sufficiently represent the basin's spatial heterogeneity or capture short-term hydrological variability.

Third, there are temporal inconsistencies between the input data and real-world changes in land and water management practices. According to the EPA (2002), hydrologic models are sensitive to changes in land use and water infrastructure over time. In the Egirdir Basin, agricultural expansion, urban development, and changing irrigation practices have likely altered hydrological processes during the simulation period. However, these dynamics could not be fully included in the model due to data limitations.

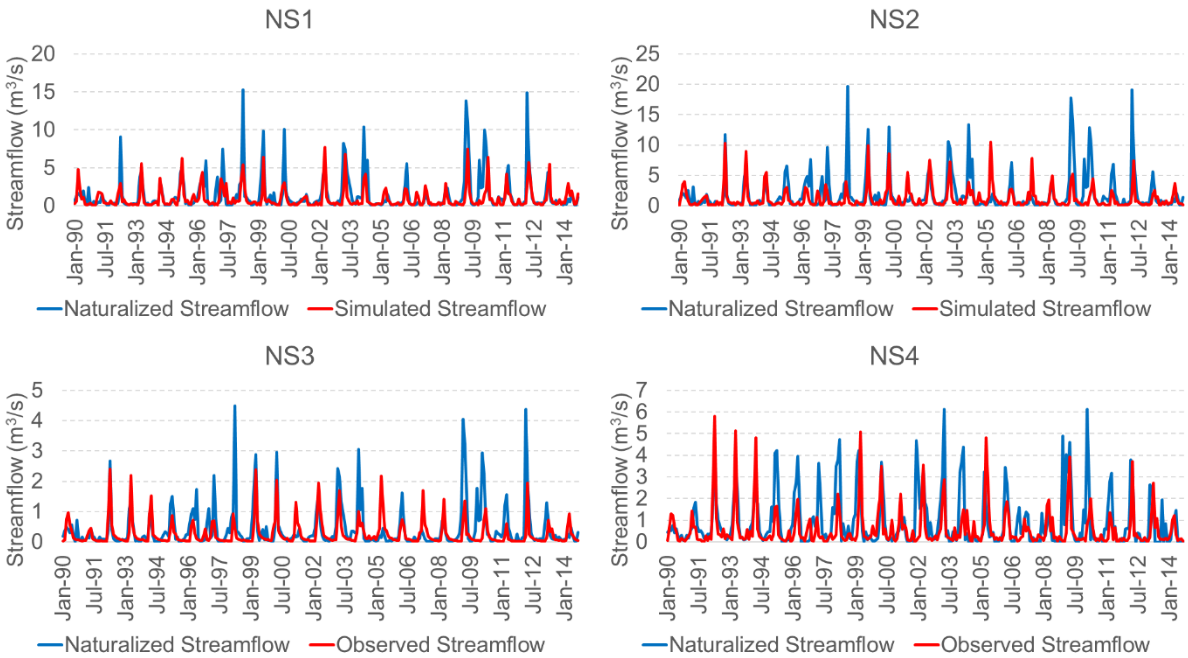

Figure 2. Simulated and naturalized streamflow at Egirdir Lake Basin during calibration and validation periods

Table 1. Statistical metrics for the calibration and validation periods

Period	Variable	R^2	NS	PBIAS
Calibration	Streamflow at NS1	0.49	0.42	37.7
	Streamflow at NS4	0.47	0.38	40.9
Validation	Streamflow at NS2	0.51	0.46	32.1
	Streamflow at NS3	0.46	0.42	34

In summary, the combined effects of anthropogenic alterations, limitations in data quality and resolution, and the inability to fully represent temporal changes in land and water use have caused observed performance limitations. Despite these challenges, the model still provides useful insights into the hydrological behavior of the basin and can serve as a basis for future improvements as better data become available.

3.2. Effects of Irrigation on Streamflow in the Egirdir Lake Basin

Figure 3 compares observed streamflow and simulated naturalized streamflow at three gauging stations (D09A057, D09A065, and D09A075) within the study area. The naturalized streamflow, simulated using the calibrated SWAT model, excludes anthropogenic influences such as reservoir operations, diversions, and abstractions. At all stations, the observed streamflow is lower than the simulated naturalized streamflow, particularly during peak flow periods.

For the 2000–2020 period, the average observed streamflows at gauging stations D09A057, D09A065, and D09A075 were 0.19 m^3/s, 0.52 m^3/s, and 1.25 m^3/s, respectively. The simulated naturalized streamflows were significantly higher: 1.99 m^3/s, 0.93 m^3/s, and 7.89 m^3/s for the same stations. These values indicate significant flow reductions of approximately 90%, 44%, and 84% at D09A057, D09A065, and D09A075, respectively. This difference highlights the strong anthropogenic influence on streamflow in the basin.

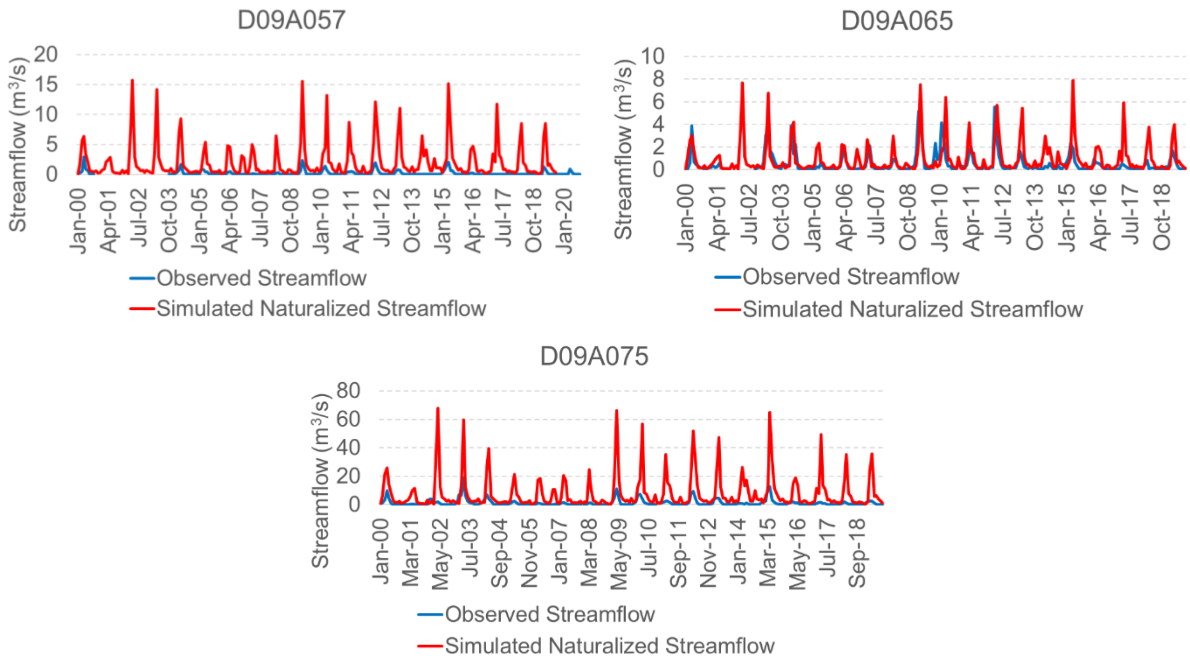

Figure 2. Observed and naturalized streamflow at Egirdir Lake Basin for the 2000-2020 period

The extent of human impact on streamflow seems to vary over time, as shown by the observed changes between the first (2000–2004) and last (2016–2020) five-year periods of the study. During the 2016-2020 period, the average observed streamflows at gauging stations D09A057, D09A065, and D09A075 were 0.08 m³/s, 0.27 m³/s, and 0.60 m³/s, respectively. In contrast, the streamflows were significantly higher for the 2000-2004 period, 0.35 m³/s, 0.62 m³/s, and 1.72 m³/s. This points to a downward trend in observed streamflows over the two decades. However, when we compare the simulated naturalized streamflows for the same periods, we detected no consistent decreasing trend. This suggests that the decline in observed streamflows is not only due to climatic or natural hydrological variability. Increased anthropogenic pressures in the basin, such as increased water withdrawals, reservoir operations, and land use changes, could be responsible for these changes.

4 CONCLUSIONS

In this study, we developed a SWAT model for the Eğirdir Lake Basin to evaluate the effects of anthropogenic impacts on watershed hydrology. The SWAT model was calibrated and validated with naturalized streamflows to reveal the natural hydrological regime of the basin. By comparing observed and simulated naturalized streamflows at three gauging stations over the 2000-2020 period, we showed significant reductions in observed flows, in the range of 44% to 90%, compared to naturalized conditions. We also showed that naturalized streamflows remained relatively stable over time, while a clear downward trend was apparent in observed flows, particularly in the last five years. This result shows that the pressure on the hydrological system is growing, most probably due to water abstractions and reservoir operations. In the future, we plan to explore water quality issues in the basin and provide predictions about lake status under climatic changes.

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