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A pollution fate and transport model application in a semi-arid region: Is some number better than no number?

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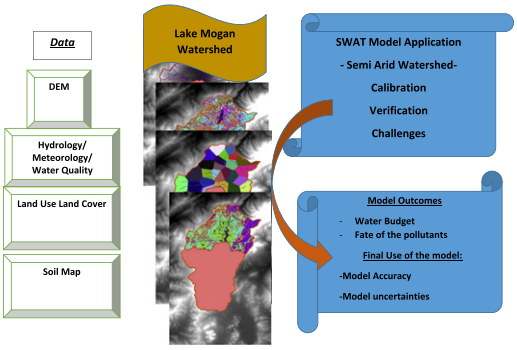
HIGHLIGHTS

- Even with limited input data, SWAT model provides useful results for specific applications.
- Large portion of the precipitation may be lost to evaporation: 50–75% at Lake Mogan Watershed.
- Unit pollution load estimates can be used as model performance evaluation criteria.

GRAPHICAL ABSTRACT



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ABSTRACT

Fate and transport models are powerful tools that aid authorities in making unbiased decisions for developing sustainable management strategies. Application of pollution fate and transport models in semi-arid regions has been challenging because of unique hydrological characteristics and limited data availability. Significant temporal and spatial variability in rainfall events, complex interactions between soil, vegetation and topography, and limited water quality and hydrological data due to insufficient monitoring network make it a difficult task to develop reliable models in semi-arid regions. The performances of these models govern the final use of the outcomes such as policy implementation, screening, economical analysis, etc. In this study, a deterministic distributed fate and transport model, SWAT, is applied in Lake Mogan Watershed, a semi-arid region dominated by dry agricultural practices, to estimate nutrient loads and to develop the water budget of the watershed. To minimize the discrepancy due to limited availability of historical water quality data extensive efforts were placed in collecting site-specific data for model inputs such as soil properties, agricultural practice information and land use. Moreover, calibration parameter ranges suggested in the literature are utilized during calibration in order to obtain more realistic representation of Lake Mogan Watershed in the model. Model performance is evaluated using comparisons of the measured data with 95%CI for the simulated data and comparison of unit pollution load estimations with those provided in the literature for similar catchments, in addition to commonly used evaluation criteria such as Nash-Sutcliffe simulation efficiency, coefficient of determination and percent bias. These evaluations demonstrated that even though the model prediction power is not high according to the commonly

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used model performance criteria, the calibrated model may provide useful information in the comparison of the effects of different management practices on diffuse pollution and water quality in Lake Mogan Watershed.
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1. Introduction

In the arid and semi-arid regions, water resources are susceptible to several stresses such as pollution (point and non-point), urbanization, rise in water demand due to population increase, high agricultural activities and climate change. Since the water resources are limited in the arid and semi-arid regions, sustainable water management that demand utilization of various tools such as modelling, monitoring, risk analysis, economical analysis, etc. is crucial. Application of deterministic models in semi-arid regions is a challenging task. Schneider et al. (2007) mentioned that there can be unexpected challenges in modelling the hydrology of semi-arid watersheds compared to similar efforts made in humid areas. For example, differing precipitation and temperature patterns together with the differences in soil and vegetation properties cause alterations in the distribution of runoff processes (Schneider et al., 2007). Wheater (2008) pointed out that models have been used for decades but majority of them were developed for applications in humid regions and challenges experienced in arid and semi-arid area modelling have received little attention. Pilgrim et al. (1988) identified lack of observed data as the major problem for runoff modelling in arid regions. Similarly, Hughes (2008) stated that a lack of spatial and temporal detail in rainfall data is among the main constraints of modelling in arid and semi-arid regions. Furthermore, data on evapotranspiration, another significant component of water budget, is generally less available compared to rainfall in these regions. According to Croke and Jakeman (2008), poor rain gauge density is another issue limiting the capacity of any rainfall-runoff model to simulate the observed flow. Mirshahi (2010) listed the features of semi-arid and arid regions making hydrological modelling challenging as poor data quality, data paucity, poor rain gauge density, rainfall spatial variability, low frequency of events, highly non-linear relationships between rainfall and runoff, and less documentation for rainfall-runoff modelling in such regions compared to humid watersheds. To summarize, varying hydrological characteristics, complex interaction between soil, vegetation and topography and lack of observed data are the main complications in modelling in semi-arid regions.

In this study, a deterministic distributed fate and transport model is applied in Lake Mogan Watershed, a semi-arid region, to estimate nutrient loads and to develop the water budget of the watershed. Lake Mogan Watershed with a total area of 970 km^2 is mostly covered with agricultural land. Intensive agricultural activities are among the most significant pressures threatening the water quality of the lake. The

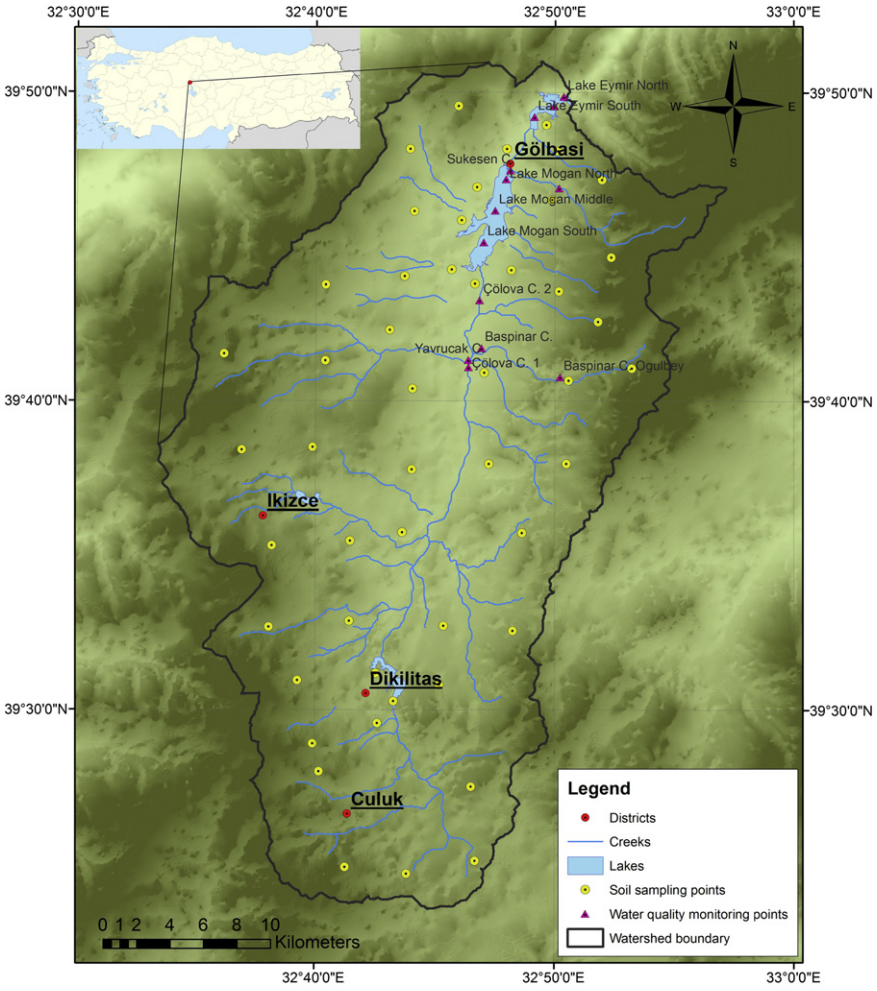

Fig. 1. Lake Mogan Watershed.

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