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Assessing lake vulnerability to climate change using the coupled MIKE SHE/MIKE 11 model: Case study of Lake Zazari in Greece

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Introduction

If the worst predictions of general circulation models (GCMs) about climate change become true, then lakes will hardly manage to maintain their current conditions (Zhang et al. 2016) especially in regions, which have been identified as climate change hot spots such as the countries of Mediterranean Basin (Loizidou et al. 2016) from which Greece is of special interest since it has 54 lakes/reservoirs of 0.5 km^2 minimum size.

The hydrological models are important tools for assessing the water balance components of lakes and for supporting the design of water management strategies. Depending on the modelling purposes and the specific attributes of a lake, different types of models and different levels of model complexities can be selected, starting from complex models such as MIKE SHE (Abbott et al. 1986), WATLAC (Zhang 2011) or using simpler methods (Yang et al. 2018). The MIKE model is among the most integrated models and has been used in the past for similar cases (Singh et al. 2010), while in combination with the future climate projections of general circulation models (GCMs), can be used to investigate lake conditions under future climate scenarios. The aim of this study is to present an application for analyzing the vulnerability of a lake to climate change using the MIKE SHE/11 model using as a case study the Lake Zazari in Greece.

Materials and methods

The study area is the sub-basin of Lake Zazari, which is located in the north-western Greece. The maximum allowed lake surface elevation (LSE) is at 602 m above sea level (a.s.l.) and the maximum lake depth is at 6 m regulated by a sluice gate. MIKE SHE coupled with MIKE 11 model for better delineation of channels and lake hydraulic attributes was calibrated based on the current conditions (1/1/2012-31/4/2017). The observed data used for calibration were the variation of lake surface elevation (LSE) and the daily temperature and precipitation data from the Amyntaion and Limnochori meteorological stations for the aforementioned period. The digital elevation model was obtained by the EU-DEM v1.1 database with a spatial resolution of 25 m in which lake bathymetry was incorporated. The land uses were obtained from Corine Land Cover 2012 database and the general soil properties from the ESDB-ESDAC soil database (Hiederer 2013). Soil hydraulic properties were estimated using the pedotransfer functions of Saxton and Rawls (2006). Potential evapotranspiration was calculated based on the Hargreaves and Samani (1982) equation considering the local revised coefficients provided by Aschonitis et al. (2017) for achieving equivalent estimations of FAO-56/ASCE reference crop evapotranspiration ET_o for short grass (Allen et al., 1998). The calibrated model was applied for analyzing the hydroclimatic conditions of the lake under climate change considering the predictions of 4 GCMs (GFDL-CM3, MIROC-ESM-CHEM, MIROC-ESM, IPSL-CM5A-LR) for the worst scenario of highest greenhouse gas emissions RCP8.5 (mean conditions of 2061-2080). These 4 GCMs were selected among 19 GCMs provided by the WorldClim database (Fick and Hijmans 2017) because they represented the worst conditions in terms of rainfall reduction and temperature increase compared to the current conditions at the position of the lake.

Results and concluding remarks

The mean annual lake surface elevation (LSE), basin precipitation (PCP), basin reference evapotranspiration (ET_o) and surface discharge outside the basin (Q_d) for the current conditions (2012-

2017) and for the future conditions according to the 4 GCMs (GFDL-CM3, MIROC-ESM-CHEM, MIROC-ESM, IPSL-CM5A-LR) for the RCP8.5 scenario are given in Table 1.

Table 1. Mean annual values of LSE, PCP, ET_o, Q_d for the current conditions and for the future conditions according to the four GCMs of the RCP8.5

Parameter	**2012-2017**	**Future scenarios according to RCP8.5 for 2061-2080**			
(mean annual values)	**Current**	**GFDL-CM3**	**MIROC-ESM-CHEM**	**MIROC-ESM**	**IPSL-CM5A-LR**
LSE (m.a.s.l.)	599.27	598.84	599.09	599.03	599.06
PCP (mm)	731	405	475	544	520
ET_o (mm)	970	1152	1067	1110	1133
Q_d (m^3)	9.51E+06	0.46E+06	2.89E+06	1.93E+06	2.20E+06

Taking into account Table 1, it is observed that the four climate projections will lead to significant changes in the hydrologic features of the lake. The most important changes are the extreme reduction of Q_d (70 up to 95%) and the LSE reduction (18 up to 43 cm lower water level). This indicates a severe disturbance in the downstream system that consists of another three interconnected lakes (Chimaditida, Petron, Vegoritida). The downstream lakes will face more severe problems not only due to the reduction of upstream flows but also due to the same climatic change within their sub-basins.

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