Simulating Nutrient Loads in an Intensively Cultivated Mediterranean Watershed under Current and Projected Climate Conditions

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Abstract
On the global scale, agriculture constitutes the most significant non-point pollution source for surface water bodies, especially in terms of nitrogen and phosphorus. Located in northeastern Greece, Vistonis basin, in which agricultural activities are widely developed, constitutes the area that discharges into Vistonis estuarine system, which is very significant both from the environmental and economic perspective. SWAT model was used in order to quantify discharge, nitrogen and phosphorus loads for the period 2003-2014, after calibration and validation. Simulation results indicated significant variation in nutrient loads, while their contribution on a massive fish kill event that took place on summer 2014 was found to be potentially significant. Nutrient loads variation were further investigated using projected, bias-corrected climate data from 3 Regional Climate Models (RCMs) for the periods 2021-2040 and 2061-2080. The results demonstrated decreasing trend in nutrient loads due to decrease in river discharge driven by precipitation decrease.
Keywords: SWAT model, nutrients, climate change

1. Introduction

Agriculture constitutes the most significant source of non-point pollution and according to Schoumans et al. (2014), Member States of European Union should focus on limiting nutrient discharges from agricultural activities in order to achieve good ecological status of surface water bodies, which is mandatory in the context of Water Framework Directive (2000/60/EC). Surface runoff from agricultural areas has been recognized to directly affect the ecological status and the relevant processes on coastal ecosystems. Beman et al. (2005) indicated that in 80% of the cases, there was a direct connection between phytoplankton blooms and events of irrigation and application of fertilizers in the Gulf of California, USA.

Considering the above, the present study aims to quantify and simulate nutrient loads produced mainly by agricultural activities in Vistonis basin, which are discharging into Vistonis estuarine system. Moreover, the simulation results are used in order to investigate the possible contribution of nutrient loads on a massive fish kill event that took place on summer 2014. Finally, nutrient loads variation was further investigated using projected, bias-corrected climate data from 3 Regional Climate Models (RCMs) for the period 2021-2040 and 2061-2080.

2. Materials & Methods

Vistonis estuarine system is located in northeastern Greece and covers an area of about 44 km^2 (Figure 1). Vistonis is a valuable ecosystem protected by the Ramsar Convention, included in the Natura 2000 network, while it constitutes part of the National Park of East Macedonia & Thrace. Vistonis estuarine system has been classified as eutrophic since 1980's (Gikas et al. 2006). Three rivers are discharging into Vistonis estuarine system (Kosinthos, Kompsatos and Travos) which form a watershed of about 1300 km^2 (Figure 1). More than 200 km^2 of the watershed is covered by crops, the most significant of which are cotton, corn, wheat and tobacco. Nutrient loads were simulated with widely applied Soil and Water Assessment Tool (SWAT) model (Arnold et al. 2012) by combining meteorological and land use data, soil hydraulic parameters, digital elevation model and local cultivation practices. The model was applied for the period 2003-2014 and the calibration was performed based on in river discharge and nurient data for the period 2003-2006. Climate change projection was based on bias-corrected data from the study of Pisinaras (2016).

3. Results

Simulation results indicated that total nutrient loads (nitrogen and phosphorus) during June and July of year 2014 were the highest compared to the corresponding loads for the period 2003-2014, as presented in Figure 2. Especially for phosphorus, it is worth noting that the total phosphorus load for June and July 2014 was 2,900 kg, while the next highest load was 1,800 kg, indicating thus a difference of 61%. Moreover, SWAT model results indicate that 3 days before massive fish kill death observed at 18/07/2014, the daily nutrient load was the maximum simulated for July in the period 2003-2014. More specifically, total nitrogen and phosphorus loads simulated on 15/07/2014 were 2667 kg-N and 459 kg-P, respectively, while the second higher loads were observed

at 17/07/2003 and the corresponding loads were 1.476 kg- N and 177 kg-P.

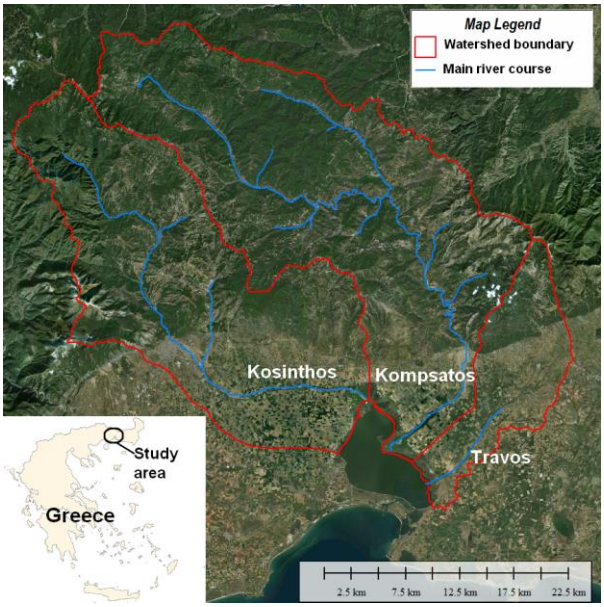

Figure 1. Location map of the study area.

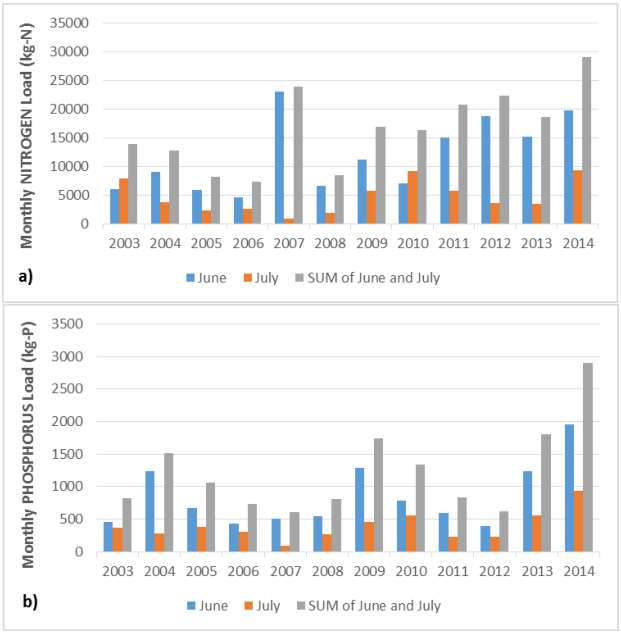

Figure 2. Variation of total monthly loads of a) nitrogen and b) phosphorus for June, July and the sum of the two months, for the period 2003-2014.

The significant reduction in precipitation indicated by projected climate data had a direct impact on simulated surface runoff dischargin in Vistonis. The results of the SWAT model for the 2021-2040 and 2061-2080 periods indicate a decrease in annual inflows of 51% for the period 2021-2040 compared to the period 2003-2014 and a decrease of 55% over the period 2061- 2080. Despite the fact that freshwater inflows are significantly reduced, the possibility of flood occurence, which have a devastating impact on the Vistonis, is quite high, as despite the decreasing trend in rainfall there are still extreme rainfall events occured.

As regards the nutrient loads that discharge in the Vistonis estuarine system, they appear to be reduced in both projected periods 2021-2040 and 2061-2080. This reduction results from the total reduction in surface run-off as a consequence of reduced rainfall. However, for the most part, reductions in nutrient loads were not proportional to reductions in surface runoff, while differences were also noted between the years 2021-2040 and 2061-2080.

4. Discussion & Conclusions

Due to the fact that simulated nutrient loads discharging in Vistonis estuarine system prior the massive fish kill event observed at 18/7/2014 were the highest for the period 2003-2014, it gives strong evidence that nutrient loads may have significantly contributed to this massive fish kill event.

SWAT model was found to be an effective tool for the investigation and assessment of nutrient loads in Vistonis estuarine system, while it also demonstrates significant potential to be used as an operational management tool when combined to other components, such as weather forecast.

The significant reduction in river discharge in the Vistonis estuarine system simulated for the two projected period is likely to result in significant changes in its water renewal rate and salinity. Therefore, climate change constitutes a factor that has to be explicitly considered for the long-term management of both the basin and the estuarine system. Moreover, the decrease in surface runoff simulated for the projected periods was not proportional to the reduction in nutrient load. In fact, it was found that decrease in surface runoff was greater than the reduction in nutrient loads, thus constituting an important conclusion for nutrient management within the basin.

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