EVALUATION OF CHEMICAL AND BIOLOGICAL STATUS OF STREAMS IN THE ALBAIDA VALLEY, SPAIN

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KEY POINTS:

- Rivers are experiencing a rapid biodiversity loss due to water quality degradation.
- Computer models are capable of guiding water management decisions.
- Modeling enables the spatio-temporal assessment of water quantity and quality in streams.

1 INTRODUCTION

Anthropogenic activities are strongly associated with the deterioration of freshwater ecosystems. Studies nowadays benefit from computer models to simulate hydrology, water quality, and different complex processes in watersheds in order to study the response of freshwater resources and ecosystems to several environmental stressors (Li et al., 2017; Park et al., 2013; Boongaling et al., 2018). Molina-Navarro et al., 2014, for instance, discussed that changes in climate and land use could impact both water availability and quality in the Pareja Limno-reservoir. A study conducted in South Africa indicates that poor sewage treatments have the potential to considerably change the trophic status of reservoirs in the upper Olifants Watershed (Dabrowski, 2014). Guse et al. (2015) also predicted that the habitat suitability of species in the Treene River, Germany, will be influenced by changes in climate and land use. In another study, Schmalz et al. (2015) suggested that the species richness would be affected by deforestation in the Changjiang River Watershed, China. Using the Soil and Water Assessment Tool (SWAT), the present study aims to develop an eco-hydrological model of the Albaida Valley, Spain, for evaluating the status of chemical and biological water quality of streams. For this purpose, nitrate, ammonium, total phosphorus, and macroinvertebrates are used as indicators of stream health. Concentrations of nutrients simulated with SWAT are used for chemical water quality assessments. Biological water quality is also modeled by using correlations between observed nutrients concentrations and macroinvertebrate-based metrics and coupling them with concentrations simulated with SWAT.

2 MATERIALS AND METHODS

2.1 STUDY AREA AND DATA

In the present work, a shrubland and agricultural dominated part of the Albaida Valley (Valencia Province, Spain) with an approximate area of 320 km2 is studied (figure 1). The valley which is characterized by a semi-arid Mediterranean climate consists of the Clariano and Albaida River Watersheds. The Clariano River is the main tributary of Albaida River. The behavior of the Albaida River differs at upstream and downstream of the confluence with the Clariano River as it receives important contributions from the Clariano River. High values of nutrients compounds from point and nonpoint sources have led to water quality degradation and the loss of biodiversity in these rivers. A diversity of information is used in this work to describe the study area, including a Digital Terrain Model, a land use and crop map of Spain, the Harmonized World Soil Database version 1.21, meteorological data, hydrological and water quality data, data of WWTPs, chemical and biological observations of rivers, and information about agricultural management operations.

2.2 SWAT MODEL SETUP AND CALIBRATION

SWAT (Arnold et al., 1998), one of the most powerful watershed modeling tools, is used to model processes taking place in the Albaida Valley. To setup the model, several information of topography, land-use, soil, climate, WWTP effluents and agricultural management operations are entered into the model. 14 representative points (figure 1) are also defined for farther analyses of changes in chemical and biological status of Rivers. Daily simulations are performed from 2002 to 2017. The first three years (2002-2004) are used for warming up the model and are excluded from analyses. The rest of simulations are used for model calibration (2005-2011) and validation (2012-2017). In the current work, the semi-automated SUFI-2 algorithm provided in SWAT-CUP program (Abbaspour et al., 2007) is used for model calibration. To quantify the fit between simulation results (95PPU: 95% prediction uncertainty) and observed data, values of P-factor (the percentage of observed data enveloped by the 95PPU) and R-factor (the thickness of the 95PPU envelope) are used. A P-factor value of larger than 0.7 and a R-factor value of less than 1.2 would be acceptable for discharge modeling, while P-factor values of larger than 0.55, 0.45, and 0.4 and R-factor values of less than 1.8, 2.4, and 2.8 are recommended for simulating nitrate, suspended solids, and phosphorus, respectively (Abbaspour, 2020). Data of Montaverner Station (figure 1) including river discharge and loads of suspended solids, nitrate, and total phosphorus are used in this study for model calibration and validation.

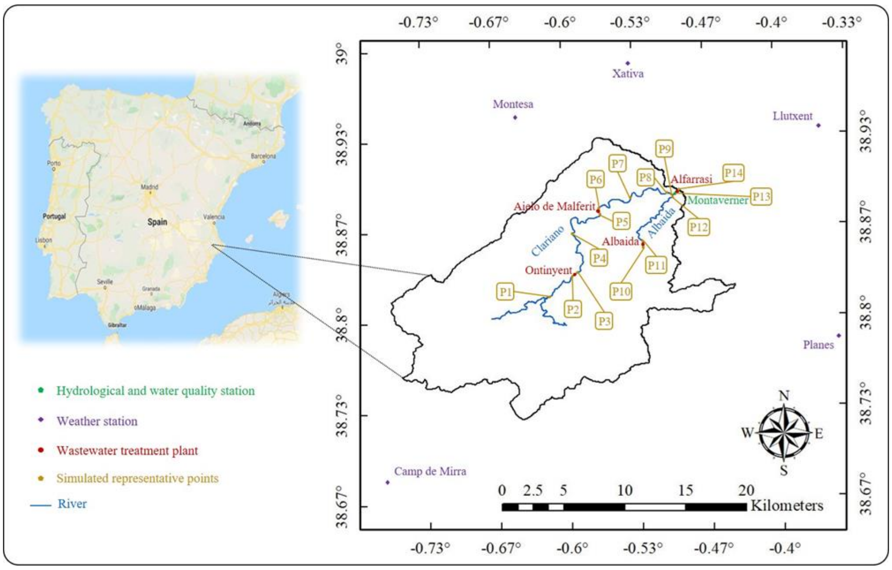

Figure 1. Location of the study area, hydrological, water quality and meteorological stations, WWTPs, and representative points simulated with SWAT

2.3 CHEMICAL AND BIOLOGICAL WATER QUALITY

Chemical status of streams is simply assessed based on time series of concentrations of nutrients generated with SWAT. To model biological water quality, Pearson's correlation and linear regression analyses are first done to evaluate possible relationships between observed concentrations of nutrients and values of macroinvertebrate-based metrics of six sampling sites (points 1, 3, 4, 7, 8, and 14; figure 1). The results of these analyses are then coupled to concentrations generated with SWAT to produce time series of macroinvertebrate-based metrics at 14 predefined points, enabling the assessment of changes in biological status along the rivers.

3 RESULTS AND DISCUSSION

3.1 SWAT MODEL PERFORMANCE

The obtained values of P-factor and R-factor (table 1) indicates that SWAT simulates discharge and water quality variables satisfactorily, hence confirming the use of model outputs for evaluating chemical and biological conditions of streams in the Albaida Valley.

Variable	calibration (2005-2011)		validation (2012-2017)	
	P-factor	R-factor	P-factor	R-factor
Discharge	0.89	0.61	0.81	0.20
Nitrate	0.56	0.79	0.70	1.27
Suspended solids	0.82	0.43	0.74	1.92
Total phosphorus	0.52	0.80	0.37	1.68

Table 1. Values of P-factor and R-factor obtained for discharge, nitrate, suspended solids, and total phosphorus

3.2 CHEMICAL STATUS OF STREAMS

Figure 2 indicates that the chemical water quality of Clariano and Albaida Rivers considerably varies over the river network. The figure also shows that predicted ranges of nutrient concentrations are in agreement with values observed at six sampling points (P1, P3, P4, P7, P8, P14).

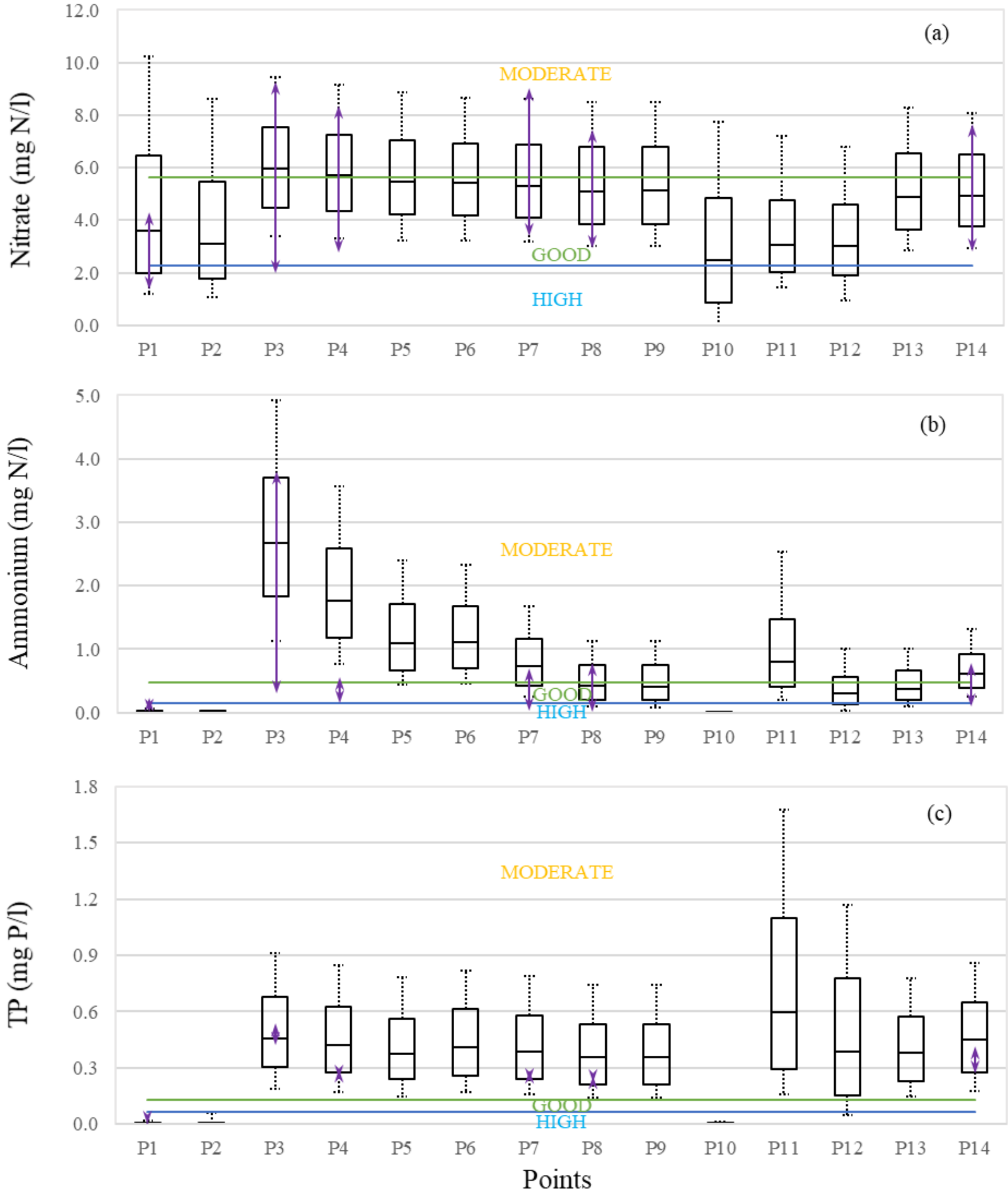

Figure 2. Predicted chemical water quality status at different points of the study area (expressed by concentrations of nitrate (a), ammonium (b), and total phosphorus (c)). The reported box plots reflect both the temporal variability and the model prediction uncertainty. The purple arrows show the range of observed concentrations at six sampling sites. Blue and green horizontal lines indicate the thresholds of nutrients concentrations (Royal Decree 817, 2015).

3.3 BIOLOGICAL STATUS OF STREAMS

Figure 3 indicates that the predicted ranges of IBMWP (Iberian Biological Monitoring Working Party) agree very well with values observed at six sampling points, hence confirming the good performance of the model. In particular, the predicted ranges of IBMWP are in agreement with the classification of the Clariano River as scarce (Martínez Mas et al., 2004).

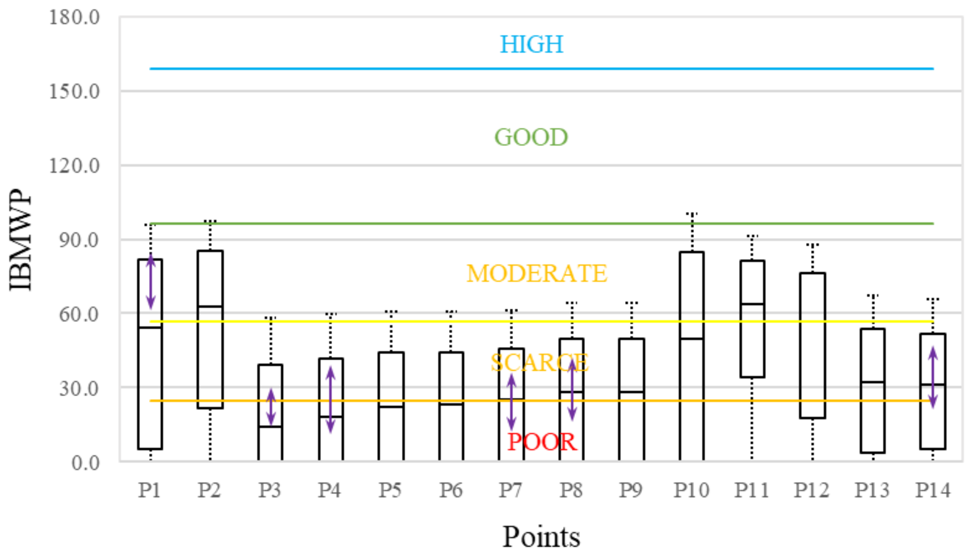

Figure 3. Predicted Biological water quality status (expressed by IBMWP) at different points of the study area. The reported box plots reflect both the temporal variability and the model prediction uncertainty. The purple arrows show the range of observed concentrations at six sampling sites. Blue, green, yellow, and orange horizontal lines indicate the thresholds of IBMWP values (Royal Decree 817, 2015).

4 CONCLUSIONS

Computer models are beneficial for guiding and evaluating management policies for conservation of freshwater environments as they are capable of simulating nearly all processes taking place in watersheds in an efficient way. This research demonstrated the potential of modeling as a complementary technique for sampling programs in rivers of the Albaida Valley. Overall, the study provides an eco-hydrological modeling approach for assessing temporal and spatial patterns of quantity and quality of water resources in river networks. Moreover, this approach can be further used to investigate possible impacts of changes in climate, land use, and local management policies on availability and quality of water, and biodiversity.

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