MODELING HYDROLOGY AND WATER QUALITY IN MEDITERRANEAN WATERSHEDS: THE CASE STUDY OF CLARIANO RIVER, SPAIN

MODELING HYDROLOGY AND WATER QUALITY IN MEDITERRANEAN WATERSHEDS: THE CASE STUDY OF CLARIANO RIVER, SPAIN

Hamed Vagheei [1*], Paolo Vezza [1], Guillermo Palau-Salvador [2] & Fulvio Boano [1]

(1) Department of Environment, Land and Infrastructure Engineering, Polytechnic University of Turin
(2) Department of Rural and Agri-food Engineering, Polytechnic University of Valencia
*email: hamed.vagheei@polito.it

KEY POINTS:

- Water quality degradation is a serious worldwide challenge affecting aquatic ecosystem.
- Eco-hydrological models could assess human-caused environmental issues impacts on water quality.
- Possible relations between water quality and biodiversity will be investigated as future steps.

1 INTRODUCTION

Environmental deterioration resulting from anthropogenic activities is a major threat today that may put pressure on global water resources. Among various water related issues, the degradation of water quality is a serious worldwide challenge which have negative impacts on aquatic ecology. In fact, pollutants from cities and factories, sediments resulting from the clearance of forests, runoff from farmlands and urban areas as well as effluent from wastewater treatment plants (WWTPs) affect the freshwater environments. Various studies have been performed to assess the impacts of human-caused environmental issues at the watershed scale (Tu, 2009; Park et al., 2011). Studies, for instance, indicate that climate and land use changes will impact habitat suitability for freshwater organisms by affecting water quantity and quality (Stephenson & Morin, 2009; Dahm et al., 2013; Marzin et al., 2013). In addition to changing the hydrological cycle, land use change contaminates groundwater and rivers by nutrient, pesticides, heavy metals and other contaminants resulting from the conversion of forest to agricultural or urban areas (Abbaspour et al., 2007; Boonkaewwan & Chotpantarat, 2018). Climate change will also alter river streamflow as well as sediment and nutrient loads within the watershed (Li et al., 2011; Alam et al., 2018). Focusing on the Treene River, Guse et al. (2015) indicate that land use and climate changes affect the river discharge, nitrate concentration, hydrodynamics and river ecosystem. Schmalz et al. (2015) also predict the possible changes in hydrology and stream macroinvertebrate distributions in the Changjiang River under different land use scenarios. Hence, the impacts of climate and land use changes on watersheds must be evaluated in order to reduce and manage the vulnerability of aquatic communities.

The objective of the present research activity is to investigate aquatic ecosystem responses to water quality deterioration using a case study of Clariano River, Spain. The Clariano River faces low water quality and the loss of biodiversity in some parts as a result of agricultural, industrial and livestock activities as well as WWTPs effluents entering the river. The Soil and Water Assessment Tool (SWAT), an eco-hydrological model, is used in the present study for the modelling of discharge, sediment and nutrients. SWAT-CUP is also used to calibrate and validate the SWAT model. The results from the calibrated model will then be employed to obtain a better understanding of possible relations between water quality and biodiversity in future studies, when model predictions will be coupled with correlations between stream water quality and macroinvertebrates presence in order to assess the impacts of water quality changes on aquatic life.

2 MATERIALS AND METHODS

2.1 STUDY AREA AND DATA

The Clariano River Watershed is a shrubland and agriculture dominated area in Valencia, Spain. The Clariano River, which originates from Bocairent, forms a part of the Júcar River Watershed. After running nearly 40 kms, the river joins the Albaida River and eventually flows into Bellús Reservoir. This watershed is characterized by a semi-arid climate with a mean annual precipitation about 450 mm. The river suffers from various sources of pollution including WWTPs, agricultural and industrial activities as well as septic tanks. Consequently, the river faces low water quality and the loss of biodiversity in some parts.

In the present study, the climatic data from Valencian Institute for Agricultural Research (IVIA, Spain), the hydrological and water quality data from the Júcar Hydrographic Confederation (CHJ, Spain), the Digital Terrain Model (DTM) from the Spanish National Geographic Institute, the land use and crop map of Spain (MCA 2000-2009) from the Ministry of Agriculture, Fisheries and Food (MAPA, Spain), the data of WWTPs from the Public Entity for Sanitation of Wastewater (EPSAR, Spain), and the Harmonized World Soil Database (HWSD) were used. Figure 1 shows the location of the Clariano River Watershed (the study area: 320 km^2), hydrological, water quality and meteorological stations, and wastewater treatment plants.

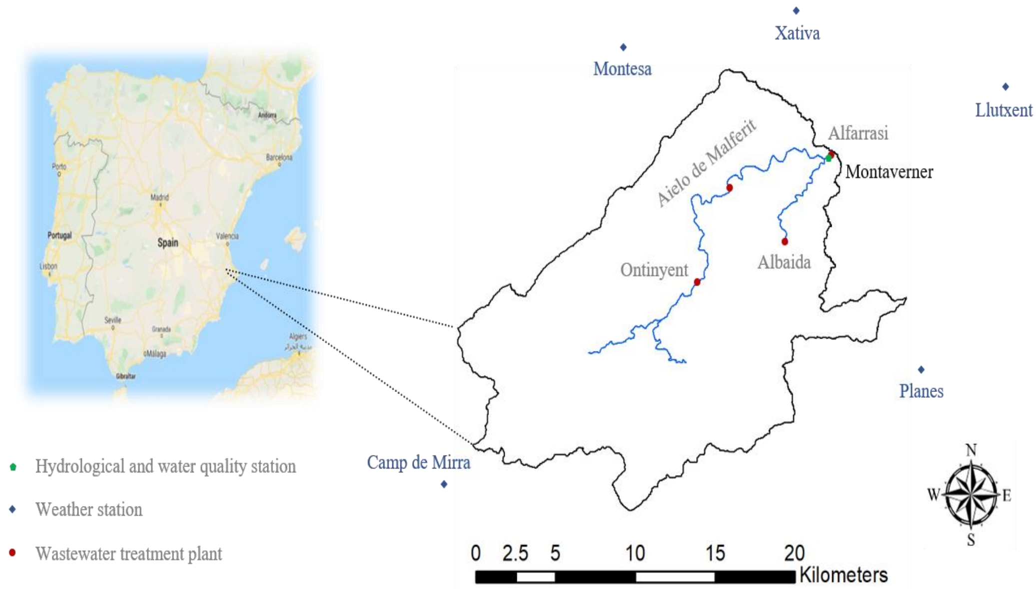

Figure 1. The location of the study area, hydrological, water quality and meteorological stations, and wastewater treatment plants

2.2 SWAT MODEL

SWAT was predicted to be a suitable tool for the modelling of discharge, sediment and nutrients within the Clariano River Watershed. SWAT which was developed by the United States Department of Agriculture, is a comprehensive model that requires a diversity of information including topography and climatic data as well as land use and soil maps in order to run (Arnold et al., 2012). To develop the watershed model, daily precipitation, minimum and maximum air temperature, solar radiation, wind speed and relative humidity of five stations (Planes, Llutxent, Xativa, Montesa and Camp de Mirra), the DTM with a resolution of 25 meters, the land use and crop map of Spain and the HWSD v1.21 were used. Agricultural management operations such as planting, harvesting, fertilization and irrigation have been derived from indications by local farmers and IVIA. As WWTPs effluents affect the hydrology and water quality of the river, effluent and water quality data of four WWTPs (Aielo de Malferit, Albaida, Alfarrasi, and Ontinyent) were also added to the model.

3 RESULTS AND DISCUSSION

The measured streamflow, sediment and nutrients data are required for calibration and validation processes. Hence, the Montaverner Station data including river discharge, and sediment, nitrogen and phosphorus loads were collected for the years 2002 to 2017. Water discharge was measured continuously, but sediment, nitrogen and phosphorus loads were measured irregularly during this period. A 3-year period was considered as warm-up period (2002-2004), a 7-year period was considered as calibration period (2005-2011), and a 6-year period was considered as validation period (2012-2017). The SUFI-2 algorithm in the SWAT-CUP program was used for the model calibration, validation, sensitivity, and uncertainty analysis. P-factor and R-factor were used to quantify the fit between simulation result (95PPU: the 95% Prediction Uncertainty) and observation data (Abbaspour et al., 2007). Table 1 presents the suggested reference values for P-factor and R-factor. R^2 (coefficient of determination) and NSE (Nash & Sutcliffe Efficiency) were also used to further quantify the goodness of fit between the observations and the best simulation. As figures 2 and 3 illustrate, SWAT has an acceptable performance in streamflow, sediment and nutrients modeling of Clariano River Watershed in both calibration and validation periods.

Variable	P-factor	R-factor
Discharge	P-factor > 0.7	R-factor < 1.2
Sediment	P-factor > 0.45	R-factor < 2.4
Nitrate	P-factor > 0.55	R-factor < 1.8
Phosphorus	P-factor > 0.4	R-factor < 2.8

Table 1. Recommended reference values for P-factor and R-factor (Abbaspour, 2020)

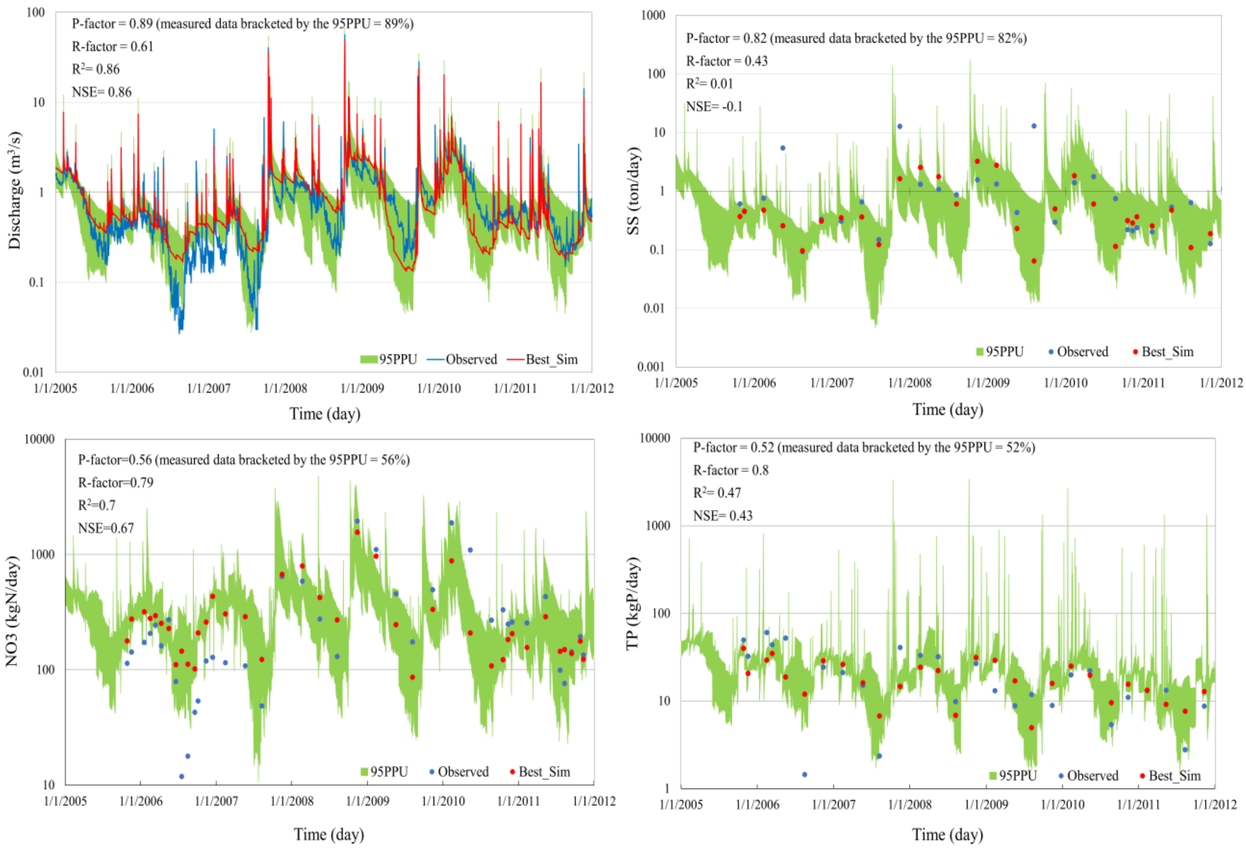

Figure 2. SWAT-CUP outputs showing the observed, the 95PPU and the best simulation for discharge, suspended solids, nitrate and total phosphorus **(calibration period: 2005-2011)**

4 CONCLUSIONS

At present, we were able to reproduce observed loads of total phosphorus, nitrate and suspended solids in our case study. Afterwards, the results from SWAT will be employed to obtain a better understanding of possible relations between water quality and biodiversity. This will be done by using correlations between concentrations of nutrients and biological indicators of stream health (i.e. macroinvertebrates) and coupling them with concentrations simulated with SWAT for different scenarios. Using the analysis of Pearson's correlation and data from the six sampling sites along the Clariano River, relationships between nutrients concentrations and values of macrobenthic metrics (Camargo et al., 2004) are currently being examined. In the following steps, the potential impacts of changes in land use, climate and WWTPs operation on water quality and biodiversity will be evaluated.

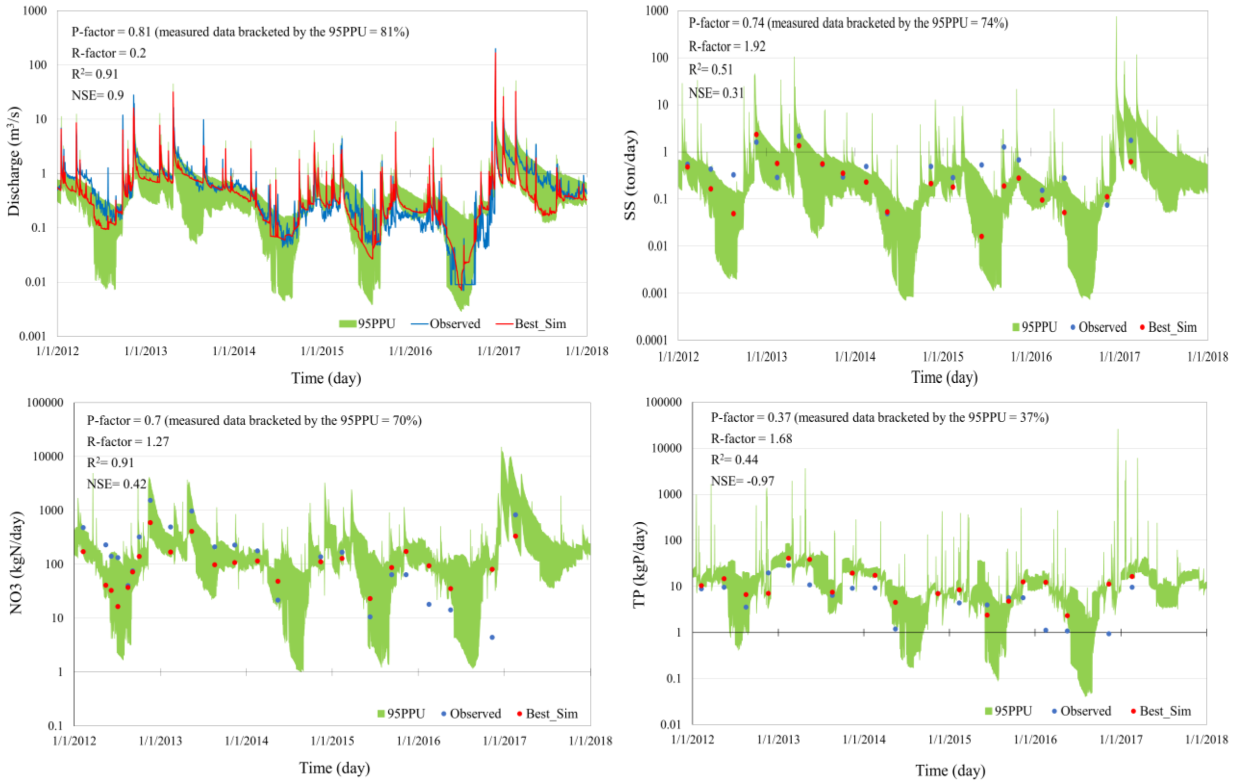

Figure 3. SWAT-CUP outputs showing the observed, the 95PPU and the best simulation for discharge, suspended solids, nitrate and total phosphorus **(validation period: 2012-2017)**

5 REFERENCES

Abbaspour, K.C., Yang, J., Maximov, I., Siber, R., Bogner, K., Mieleitner, J., Zobrist, J. & Srinivasan, R. Modelling hydrology and water quality in the pre-alpine/alpine Thur watershed using SWAT, Journal of Hydrology, 2007.

Abbaspour, K.C. SWAT-CUP Tutorial (2): Introduction to SWAT-CUP program, SPE, www.2w2e.com, 2020.

Alam, M.J., Ercan, M.B., Zahura, F.T. & Goodall, J.L. Using geospatial analysis and hydrologic modeling to estimate climate change impacts on nitrogen export: case study for a forest and pasture dominated watershed in North Carolina, International Journal of Geo-Information, 2018.

Arnold, J.G., Moriasi, D.N., Gassman, P.W., Abbaspour, K.C., White, M.J., Srinivasan, R., Santhi, C., Harmel, R.D., van Griensven, A., Van Liew, M.W., Kannan, N. & Jha, M.K. SWAT: model use, calibration, and validation, Transactions of the ASABE (American Society of Agricultural and Biological Engineers), 2012.

Boonkaewwan, S. & Chotpantarat, S. Impacts of land-use changes on watershed discharge and water quality in a large intensive agricultural area in Thailand, Hydrological Sciences Journal, 2018.

Camargo, J.A., Alonso, A. & De La Puente, M. Multimetric Assessment of Nutrient Enrichment in Impounded Rivers Based on Benthic Macroinvertebrates. Environmental Monitoring and Assessment 96, 2004.

Dahm, V., Hering, D., Nemitz, D., Graf, W., Schmidt-Kloiber, A., Leitner, P., Melcher, A. & Feld, C. Effects of physico-chemistry, land use and hydromorphology on three riverine organism groups: a comparative analysis with monitoring data from Germany and Austria, Hydrobiologia, 2013.

Guse, B., Kail, J., Radinger, J., Schröder, M., Kiesel, J., Hering, D., Wolter, C. & Fohrer, N. Eco-hydrologic model cascades: Simulating land use and climate change impacts on hydrology, hydraulics and habitats for fish and macroinvertebrates, Science of the Total Environment, 2015.

Li, Y., Chen, B.M., Wang, Z.G. & Peng, S.L. Effects of temperature change on water discharge, and sediment and nutrient loading in the lower pearl river basin based on SWAT modelling, Hydrological Sciences Journal, 2011.

Marzin, A., Verdonschot, P. & Pont, D. The relative influence of catchment, riparian corridor, and reach-scale anthropogenic pressures on fish and macroinvertebrate assemblages in French rivers, Hydrobiologia, 2013.

Park, J.Y., Park, M.J., Ahn, S.R., Park, G.A., Yi, J.E., Kim, G.S., Srinivasan, R. & Kim, S.J. Assessment of future climate change impacts on water quantity and quality for a mountainous dam watershed using SWAT, Transactions of the ASABE (American Society of Agricultural and Biological Engineers), 2011.

Schmalz, B., Kuemmerlen, M., Kiesel, J., Cai, Q., Jähnig, S.C. & Fohrer, N. Impacts of land use changes on hydrological components and macroinvertebrate distributions in the Poyang lake area, Ecohydrology, 2015.

Stephenson, J.M. & Morin, A. Covariation of stream community structure and biomass of algae, invertebrates and fish with forest cover at multiple spatial scales, Freshwater Biology, 2009.

Tu, J. Combined impact of climate and land use changes on streamflow and water quality in eastern Massachusetts, USA, Journal of Hydrology, 2009.