EGU23-8409, updated on 05 Jun 2023
https://doi.org/10.5194/egusphere-egu23-8409
EGU General Assembly 2023

Evaluation of lagoon eutrophication potential under climate change conditions: A novel water quality machine learning and biogeochemical-based framework.

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Lagoons are highly valued coastal environments providing unique ecosystem services. However, they are fragile and vulnerable to natural processes and anthropogenic activities. Concurrently, climate change pressures, are likely to lead to severe ecological impacts on lagoon ecosystems. Among these, direct effects are mainly through changes in temperature and associated physico-chemical alterations, whereas indirect ones, mediated through processes such as extreme weather events in the catchment, include the alteration of nutrient loading patterns among others that can, in turn, modify the trophic states leading to depletion or to eutrophication. This phenomenon can lead, under certain circumstances, to harmful algal blooms events, anoxia, and mortality of aquatic flora and fauna, or to the reduction of primary production, with cascading effects on the whole trophic web with dramatic consequences for aquaculture, fishery, and recreational activities. The complexity of eutrophication processes, characterized by compounding and interconnected pressures, highlights the importance of adequate sophisticated methods to estimate future ecological impacts on fragile lagoon environments. In this context, a novel framework combining Machine Learning (ML) and biogeochemical models is proposed, leveraging the potential offered by both approaches to unravel and modelling environmental systems featured by compounding pressures. Multi-Layer Perceptron (MLP) and Random Forest (RF) models are used (trained, validated, and tested) within the Venice Lagoon case study to assimilate historical heterogenous WQ data (i.e., water temperature, salinity, and dissolved oxygen) and spatio-temporal information (i.e., monitoring station location and month), and to predict changes in chlorophyll-a (Chl-a) conditions. Then, projections from the biogeochemical model SHYFEM-BFM for 2049, and 2099 timeframes under RCP 8.5 are integrated to evaluate Chl-a variations under future bio-geochemical conditions forced by climate change projections. Annual and seasonal Chl-a predictions were performed out by classes based on two classification modes established on the descriptive statistics computed on baseline data: *i)* binary classification of Chl-a values under and over the median value, *ii)* multi-class classification defined by Chl-a quartiles. Results from the case study showed as the RF successfully classifies Chl-a under the baseline scenario with an overall model accuracy of about 80% for the median classification mode, and 61% for the quartile classification mode. Overall, a decreasing trend for the lowest Chl-a values (below the first quartile, i.e. 0.85 μg/l) can be observed, with an opposite rising fashion for the highest Chl-a values (above the fourth quartile, i.e. 2.78 μg/l). On the seasonal level, summer remains the season with the highest Chl-a values in all scenarios, although in 2099 a strong increase in Chl-a is also expected during the spring one. The proposed novel framework represents a valuable approach to strengthen both eutrophication modelling and scenarios analysis, by placing artificial intelligence-based models alongside biogeochemical models.