Water quality and macrophyte changes monitoring using three spaceborne hyperspectral missions

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Lakes contribute to essential ecological functions by being hotspots of biodiversity, yet continuous human pressures and climate change are now threatening these vital ecosystems. In this scenario, hyperspectral remote sensing is emerging as a valuable tool for monitoring the status of waterbodies worldwide. The present study builds on 13 hyperspectral reflectance standard products of Lake Trasimeno (Italy) provided by PRISMA, DESIS and EnMAP missions. The dataset covers the summer periods from 2019 to 2022 (from early June to mid-October) to assess changes in water quality parameters (Chlorophyll-a (Chl-a), Phycocyanin (PC), Total Suspended Matter (TSM)) and aquatic vegetation coverage and type. To the aim, the use of three different data sources with similar spatial and spectral resolutions and complementary temporal resolutions allowed for a more comprehensive picture of the lake's conditions, supporting the analysis with various environmental parameters to discuss spatio-temporal changes. Water levels, air temperature and precipitation data were provided by the hydrographic service of the Umbria region, while water temperature and turbidity were obtained from the Lakes Climate Change Initiative (CCI) project. The bio-optical model BOMBER parameterized with the intrinsic optical properties specific for Lake Trasimeno [1] was run to simultaneously retrieve Chl-a and TSM concentrations and the coverage of submerged macrophytes (SM), while the WAVI index [2] was calculated to map the coverage of emergent macrophytes (EM). PC concentration maps were generated through the Mixture Density Network, a machine learning algorithm tested on Lake Trasimeno imagery data in [3]. Reference in situ measurements were provided by the WISPStation, a fixed-position radiometer that collects continuous reflectance measurements, from which an estimate of bio-geophysical parameters can be derived. The results of the spatio-temporal analysis showing the areas of highest variability of optically active water quality parameters (Chl-a, PC, TSM), fractional coverage of SM and density of EM are presented in Figure 1.

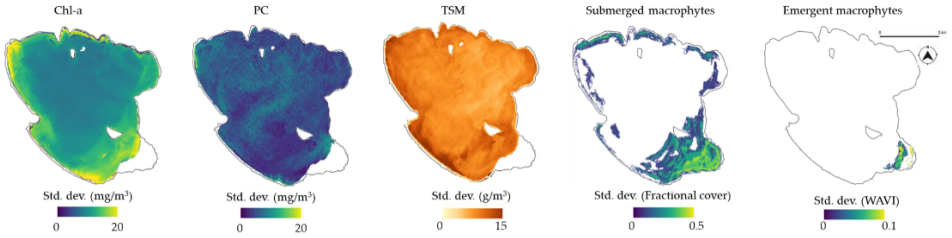

Fig. 1 From left to right, standard deviation maps of Chl-a, PC, TSM, fractional coverage of SM and density of EM (from [4]).

The portions of the lake that show greatest variability in terms of Chl-a are the areas closer to the littoral zones (up to 20 mg/m^3), in terms of PC the open water (up to 17 mg/m^3) and regarding TSM the south-western part of the lake, near the tributary inflow (up to 15 g/m^3). In the south-eastern part of the lake, where the aquatic vegetation is well established, macrophytes' coverage and density show higher variability (up to 50% and 0.1 of WAVI index value). These results highlight the significant degree of changes in the primary producers and aquatic vegetation in Lake Trasimeno, mainly due to the sharp drop in lake levels, accompanied by a reduction in total annual rainfall (-20% compared to 2021). It has been shown that the water level is a fundamental factor in conditioning the lake biodiversity and the complex trophic relations that govern the management of these ecosystems. This study can support the future synergetic use of operational missions, such as CHIME and SBG, for water quality routine monitoring.

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