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Long-term seasonal dynamics of seagrass extent in a Mediterranean Lagoon (Venice, Italy) from public satellite data

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Seagrass meadows are globally distributed ecosystems found on coastal shelves, where they typically occupy the intertidal and shallow subtidal zones. Their sensitivity to environmental changes and proximity to human activities puts them at risk of degradation; as highly valuable marine habitats and potent carbon sequestration agents, they are therefore the target of numerous conservation programmes.

The presence of seagrass strongly influences both wave and current propagation as well as sediment mobility, affecting the morphodynamics of entire estuarine systems. However, quantifying this influence is difficult, because our knowledge of seagrass cover is limited by its dynamic nature. Sensitivity to environmental factors such as nutrient load, available sunlight (mediated by turbidity) and temperature makes seagrass meadows prone to widespread changes in extent and density. Further degradation may occur stochastically through fishing and aquaculture. Conversely, seasonal cycles of high productivity allow meadows to recover and colonize new grounds through clonal and sexual reproduction.

We propose a novel and cost-effective method to monitor seagrass cover in shallow waters across its seasonal and interannual variations. Combining machine learning and simple numerical modelling, we create a dense time-series of seagrass extent using over 100 LandSat scenes covering a 20-year-long period in the Venice Lagoon, Italy. Based on an expert-lead ecological survey (2004), we train one binary Random Forest Classifier in each of 5 environmentally-homogeneous geographical subzones, using spectral reflectance in the blue, green, red and near-infrared bands of the corresponding LandSat scene as recognition features. We then predict seagrass presence probability for LandSat scenes spanning the 1999-2019 period. Such predictions are made unstable by their sensitivity to sediment plumes as well as algal or gelbstoff blooms. Classification is therefore constrained by a simple numerical model that simulates clonal and sexual reproduction, regional die-off and punctual degradation. The model examines the potential areas colonised or degraded with respect to previous scenes, iteratively building stabilised maps of seagrass cover over time.

Results are verified using further expert-lead estival surveys of the lagoon (2009, 2010, 2017) and of the inlets of Lido, Malamocco and Chioggia (2006 to 2015), as well as 10 digitised seagrass patches for a subsample of 20 invernal scenes. Accuracy metrics improve on the raw predictions (>80% to >85%), and scene-to-scene variability is reduced(>50% to <5%). These results show that public satellite data can be used to map seagrass cover and monitor its seasonal variations. In the future, cover maps may be used to estimate carbon storage, improve sediment transport models in shallow coastal areas, or identify drivers of change in seagrass meadows.