THE ECONET PROJECT: AI BASED SATELLITE AND GROUND SENSOR ANALYSIS FOR SURFACE WATERS PROTECTION

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The long-term conservation of natural capital is currently seriously threatened by unsustainable human activities that can impair water quality, thus interfering with ecosystems by driving habitat and biodiversity losses. The presence of urban settlements can cause contamination of surface waters due to human activities (e.g., peri-urban agriculture). With the introduction of xenobiotic contaminants in surface freshwaters, there is high concern due to their hardly predictable effects on freshwater ecosystem's homeostasis.

For rapid diagnostics, as an early warning system, and for the understanding of complex spatial and temporal alteration in ecosystems, a still little explored approach concerns the use in situ of bio/chemo-sensoristic devices [1] in combination with remote sensoristic technologies.

This possibility is now supported by the EcoNet project (ASI - CNR-ISMN Agreement n. 2022-32-HH.0) which promotes the development and demonstration of an integrated sensor-driven system, managed by artificial intelligence, which integrates sensor data obtained from satellite images with those from terrestrial bio/chemo-sensor devices, for monitoring surface waters on which human settlements insist. In particular, satellite observations undertaken with Sentinel-2 and PRISMA are exploited alongside records from terrestrial devices that include the 'Snoop' prototype, i.e., CNR-ISMN European patent [2] based on the use in the same sensor of one or more biological and inorganic-biological hybrid sensitive materials.

In recent years, remote sensing techniques using multi/hyperspectral imaging technologies have proved their effectiveness as affordable and practical supports for more traditional sensor-based methodologies. The advantage of integrating ground measurements with satellite data mainly stands in the different method of data acquisition, giving to the phenomenon definition an independent characterization based on electromagnetic principles. Another edge lies in the huge range of spatial and temporal resolution than satellite data can provide, making the integration of the two sensors a valuable way for monitoring aquatic status and defining early identifications of hazards and alert procedures.

On the other hand, the contribution of satellite data for water quality monitoring is a consolidated technique [3, 4]. In the range of the electromagnetic spectrum between the visible and thermal infrared bands, the measurements of radiometric quantities are sensitive to water relevant parameters, such as temperature, chlorophyll concentration and total suspended solids [5]. Project activities include use of data from sensor instruments on board the PRISMA, Landsat and Sentinel-2 missions, using then both multispectral and hyperspectral images [6, 7, 8]. Chosen missions can ensure feasible temporal, spatial and spectral resolutions suitable for monitoring inland waters and their alterations. Moreover, to broaden the collection of remote sensing measurements, also drone observations with MAIA camera are being considered.

The promising dialogue that occurs between multi-sensoristic technologies will require the implementation of tools for data handling and analysis. In this context, the Artificial Intelligence (AI) technology-mediated integration of different raw data generated from arrays of multiple types of sensors (chemical, physical, biological sensors) is particularly interesting. This integration opens enormous potential for overcoming the limits of traditional environmental monitoring and diagnostic techniques.

The dataset for the AI model is built simultaneously by matching satellite data from missions archives with ground-based data collections guaranteeing appropriate space-time windows to appreciate waters phenomenon variations due to seasonal effects. Model inputs consist in data from ground measurements combined with satellite ones having as output new environmental indices that can support quality monitoring of surface water bodies and their deviation from standard parameters. Preprocessing standard operations are applied to satellite data and the model is designed and implemented in a Python development environment, using tensorflow and keras packages and keeping open access developing algorithms. Different models of neural networks are being considered both characterized by deep architectures (Deep Neural Networks) and by a limited number of layers (Multi-Layer Perceptron Neural Networks). The proposed methodology can be then compared with experimental measurements that are traditionally carried out for the characterization of water in order to evaluate and improve performances.

Specific test areas have been already identified for the validation of the methodology that will be designed. The test areas selected for carrying out the project activities are environmental sites of the Natura 2000 network (https://ec.europa.eu/environment/nature/natura2000/index_en.html), areas recognized at European community level, hosting rare and threatened species and/or habitats for which it is a priority to ensure long-term survival. The specific test areas for EcoNet projects are: Riserva Naturale Regionale “Selva del Lamone” (Farnese, Viterbo, Italy); Riserva Naturale Regionale “Nazzano Tevere-Farfa” (Nazzano, Roma, Italy); Lago di Piediluco (Piediluco, Terni, Italy). All the test areas share common factors in terms of anthropic pressures deriving from punctual and diffuse sources of pollution: peri-urban productive activities (intensive monocultures, trout farming, intensive livestock productions) and the presence of discharges from wastewater treatment plants.

The EcoNet project also includes specific education sessions leading to build qualified personnel on the topic. The training path involves an e-learning course and an internship on aquatic ecosystems environmental monitoring purposes. In this regard, the project is part of the ASI’s program “Innovation for Downstream Preparation for Science” (I4DP_SCIENCE) aiming, as per the ASI’s roadmap towards scientific downstream [9], to demonstrate the capabilities of consolidated methodologies of Scientific Readiness Level higher than 4 “Proof of concept” to address user-driven applications. Therefore, the present paper will showcase how the integrated sensor-driven system is being demonstrated in the test sites, also via the direct engagement of the local stakeholders and bodies in charge of the protection and management of the natural reserves and their water resources.

REFERENCES

[1] G. Grasso, D. Zane, and R. Dragone, "Field and Remote Sensors for Environmental Health and Food Safety Diagnostics: An Open Challenge", *Biosensors*, MDPI, Switzerland, pp. 1-3, 2022.

[2] R. Dragone, C. Frazzoli, F. Monacelli, "Chemical-physical sensing device for chemical-toxicological diagnostics in real matrices (Snoop)". EU Patent, EP2697628 B1 (2015).

[3] A. Gitelson, G. Garbuzov, F. Szilagyi, K-H. Mittenzwey, A. Karnieli, and A. Kaiser, "Quantitative remote sensing methods for real-time monitoring of inland waters quality", *International Journal of Remote Sensing*, 14:7, pp. 1269-1295, 1993.

[4] M.H. Gholizadeh, A.M. Melesse, and L. Reddi, "A Comprehensive Review on Water Quality Parameters Estimation Using Remote Sensing Techniques", *Sensors*, 16:8, pp. 1298, 2016.

[5] J.C. Ritchie, P.V. Zimba, and J.H. Everitt, "Remote Sensing Techniques to Assess Water Quality", *Photogrammetric Engineering & Remote Sensing*, American Society for Photogrammetry and Remote Sensing, 6:10, pp. 695-704, 2003.

[6] J.P. Verdin, "Monitoring Water Quality Conditions in a Large Western Reservoir with Landsat imagery", *Photogrammetric Engineering & Remote Sensing*, 51:3, pp. 343-353, 1985.

[7] K. Toming, T. Kutser, A. Laas, M. Sepp, B. Paavel, and T. Nõges, "First Experiences in Mapping Lake Water Quality Parameters with Sentinel-2 MSI Imagery", *Remote Sensing*, 8:8, pp. 640, 2016.

[8] M. Niroumand-Jadidi, F. Bovolo, and L. Bruzzone, "Water Quality Retrieval from PRISMA Hyperspectral Images: First Experience in a Turbid Lake and Comparison with Sentinel-2", *Remote Sensing*, 12:23, pp. 3984, 2020.

[9] D. Tapete and A. Coletta, "ASI's roadmap towards scientific downstream applications of satellite data", EGU General Assembly 2022, EGU22-5643, Vienna, 2022.