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Revolutionizing Marine Litter spatiotemporal mapping combining UAV – Citizen Science & Machine Learning

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Abstract:

The escalating presence of marine litter (ML) in coastal zones has emerged as a critical global concern, profoundly impacting marine ecosystems, coastal economies, and local communities. Their presence can dramatically affect flora and fauna and lead to severe economic impacts on coastal communities, tourism, and fisheries (Löhr et al., 2017; Morseletto, 2020; Topouzelis et al., 2021; UNEP & Ljubomir Jeftic, Seba Sheavly, 2009). Currently, reporting and mapping marine litter in the coastal zones is carried out using conventional sample field surveys (Cheshire et al., 2009; Rees & Pond, 1995). Existing data collection methods prove to be insufficient either due to spatial and temporal coverage and scale of surveillance or due to the resolution and density of spatial information. Consequently, the data collection approach used nowadays for spatiotemporal mapping and monitoring the ML accumulation relies on in situ campaigns that need effort to be realized. This method is highly limited in scale and time. Thus, it cannot answer fundamental questions regarding the densities and accumulation of ML in the coastal zone and their spatial and temporal dynamics (Papakonstantinou et al., 2021). A growing number of scholars from cartography have demonstrated successfully that GeoAI can accelerate previously complex cartographic tasks and even enable cartographic creativity, production of data, and spatiotemporal mapping in new ways (Kang et al., 2024; Richter & Scheider, 2023). As conventional field surveys for mapping and assessing coastal ML often prove inadequate in capturing comprehensive spatial and temporal data, underscoring the necessity of a new approach that uses a GeoAI relying on state-of-the-art technologies. The Coastal Marine Litter Observatory (CMLO) was created in this direction. CMLO integrates GeoAI with drone data and a citizen participatory protocol to replicate and enhance the conventional method. Thus, combining very high-resolution drone data, citizen science-based data acquisition, geoinformatics, machine learning algorithms, and geovisualization methods forms a new method replicating the traditional one. At this end, CMLO harmonizes spatiotemporal monitoring and mapping of marine pollution accumulation by automatically producing case-specific density maps. More specifically, a citizen science drone data acquisition protocol was created to enhance spatial and geographical scales of data collection. The protocol is formed to adapt the most common use consumer-grade and off-the-self UAS that nonexperienced pilots can fly. By "uploading" the data to the CMLO online platform, pre-processing steps are carried out to ensure data integrity and quality. Drone aerial images are automatically checked, and all necessary metadata such as flight height, resolution, location, sensor type, capture date & time, and other sensor technical parameters are used and stored in the system. As a next step, a specially trained machine learning algorithm automatically detects, quantifies, and spatially positions the ML. These are classified automatically into seven categories according to the OSPAR guidelines. Finally, CMLO automatically creates geovisualizations of classification, positioning, and detection confidence as maps for all marine litter of a coastal zone. Density maps using an ML harmonizing clustering approach that lies in the blue flag criterion. This automated mapping process runs less than 20 minutes for a 500m beach. Harmonized ML density maps and all relative geoinformation are automatically generated and stored in an appropriately configured spatial data cloud infrastructure. CMLO can additionally produce time series data analysis by delivering density maps of differences of ML accumulation. To date, the CMLO mapping approach has been used on four continents, in 6 countries (Greece, Portugal, Israel, Ghana, Argentina, Japan & Finland) in various latitudes and longitudes, making it the largest database of high-resolution aerial photographs worldwide for mapping marine pollution in the coastal zone. It contains data and spatio-temporal imagery from 455 beaches, with 14,558 high-resolution images covering 95 km of coastline. In total, more than 410,043 items have been classified with 85% classification accuracy as ML, with 335,312 of them defined as plastic. The CMLO pipeline transforms and processes

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UAV data by using local projection systems appropriate for each country, and for visualizing the results, ML positions, and density maps, the projected coordinate system ESPG3857 is used.

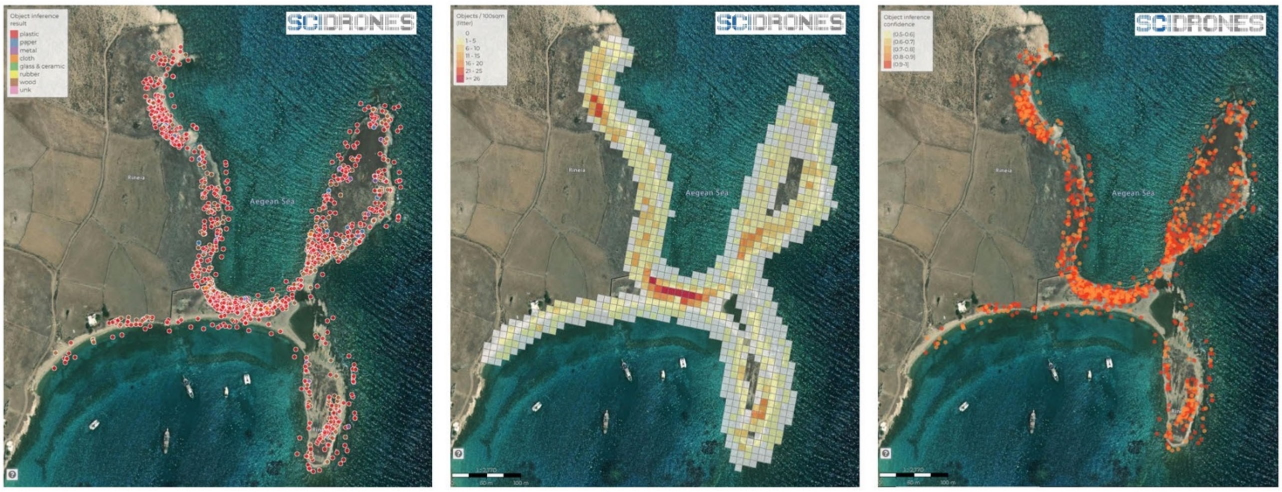

Figure 1. CMLO results in Rineia Island, located in the Aegean Sea close to Mykonos Island, Greece. From left to right, ML positions, ML density map, and detection algorithm confident level map.

CMLO emphasizes the importance of stakeholder engagement and collaboration. The system promotes the involvement of local communities, environmental agencies, policymakers, and researchers in the monitoring, mapping, and management of ML. Through a participatory framework, CMLO fosters collective action, knowledge sharing, and the implementation of effective litter mitigation strategies. By furnishing precise and current data on litter distribution, CMLO empowers decision-makers with invaluable insights for policy formulation and resource allocation. Furthermore, CMLO contributes to scientific inquiry by facilitating data-centric studies on litter origins, trajectories, and impacts, leading to more informed management approaches. The integration of CMLO offers a robust platform for near real-time monitoring and mapping of marine pollution, facilitating standardized data collection and harmonization results to drive efforts and actions crucial for supporting SDG 14.1.1 and EU-MSFD D10C1 indicators.

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