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Equitable science for ecosystem monitoring in Aruba

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Abstract:

Tropical coastal ecosystems face immense pressure from the impacts of climate change and human activities. At the same time, they support high levels of biodiversity and ecological resilience, and provide structural protection for populations living near the ocean. Mangrove, coral, and seagrass ecosystems represent a particularly interconnected system.

The island of Aruba, like many coastal communities, has a long and intricate relationship with the ocean, depending on it for quality of life and sustenance. While Aruba's northern coast is relatively uninhabited, its southern coast is home to most of the island's population and economic activity, which are closely linked with mangrove forests, seagrass meadows, and coral. These support biodiversity, provide coastal protection, and enhance resilience to climate change, and contribute to sustainable development efforts on the island.

These coastal ecosystems face physical threats from construction, ocean weather, downstream impacts from pollution, ecological disturbances, and changes in environmental conditions. Continuous monitoring is critical to conservation and restoration efforts. Many global monitoring tools are either slow to update, use generalized models, or have low spatial resolution, with limited use for localized applications. *At present, monitoring of these ecosystems is sporadic and responsive, and improved continuity could support better understanding and management of local threats and impacts.* For islands like Aruba, sustainable development means protecting these ecosystems, which means understanding them, and being able to clearly communicate their state and ongoing changes.

The principles of equitable science provide a framework for the development of up-to-date, accurate mapping of environmental parameters at the scale of small islands. The Civic Laboratory for Environmental Action Research (CLEAR, 2017), outlines design principles for equitable science, recommending that tools should be developed as open source, online, well communicated, accessible to all types of scientists (citizen and professional), affordable (under 50 CAD), using available materials, repairable, and plastic free. These principles inherently support the sustainability of monitoring efforts using these tools, with openness, accessibility and affordability, the barriers to continue are significantly reduced.

In recent years, collaborative efforts among local institutions and expertise have contributed to improvements in ecosystem monitoring using open access tools and data. Initially, these focused on the development of air and water quality monitoring and mapping. A review of physical SDG indicators was done and equitable instruments were developed for Aruba, contributing to the monitoring of three additional previously unmonitored indicators, including fine particulate matter (11.6.2), average marine acidity (14.3.1), and forest area (15.1.1). Six additional indicators were identified that could be physically measured, as candidates for further development.

The Surfside Science project established an automated database using validated, open source tools and methods to produce monthly maps of benthic habitat, shoreline boundary, reef island extent, and mangrove cover. Scripts were written in Javascript and Python using the Google Earth Engine platform, based on open access Sentinel-2 imagery, which can be modified to produce maps for different dates and locations, and to take into account local observations. Maps of shoreline boundary and reef island extent were based on the NDWI spectral index that indicates areas with water, and delineating boundaries between water and land. Basic machine learning models were developed for seafloor (including coral and seagrass) and mangrove mapping, which learn based on user inputs indicating ground-truthed locations of these ecosystems, based on local knowledge.

Another process for seafloor mapping was developed wherein a camera is strapped to a kayak and pointed down, taking timelapse photos of the seafloor, connected to a GPS tracking app in the kayak which was used to geotag the images. The resulting images are then run through a previously trained image classifier and used to produce a map of benthic habitat type. Validation protocols were also developed, used to validate methods, and shared to facilitate validation in other locations or habitat types, or with different equipment or circumstances. Validated data were then shared through the automated database for open access (data.brenchies.com).

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Since the initial project period, these approaches have been used to develop a blue carbon map and estimates for blue carbon sequestration for Aruba, contributing these and additional maps to Aruba's Climate Impact Atlas (aruba.climateimpactatlas.com), and producing surface temperature maps for Aruba and three other islands (Curacao, St. Martin, and Jamaica) in the Feelin Hot project (feelinghot.org). Thesis research was recently conducted to further investigate equitable scientific instruments, meeting criteria of open accessibility and affordability, to map coastal ecosystems, focusing on mangroves as the most visible of the three habitat types. In particular, the study examined the potential of small island cartography derived from satellite data to observe changes in mangrove extent, aiming to help inform conservation efforts.

Assessment of equitable scientific instruments suitable for application at the island scale included a review and analysis of previous research to determine what time and spatial scales are needed to effectively monitor coastal ecosystems, followed by consideration of available tools for classifying mangroves, methods for enhancing resolution, local monitoring applications, and suitable data sources. Tools fitting the design principles of equitable science, especially in terms of affordability, accessibility, and understandability, were tested at a local mangrove site with ongoing impacts.

Spectral indices suitable for threshold-based classification (NDVI, MVI, and EMVI), as well as a classification and regression tree model, were applied to publicly available Sentinel-2 satellite imagery to map mangrove extent in a 1.8 ha study area at Santo Largo, Aruba (Figure 1). Classified high resolution aerial reference imagery was used for validation.

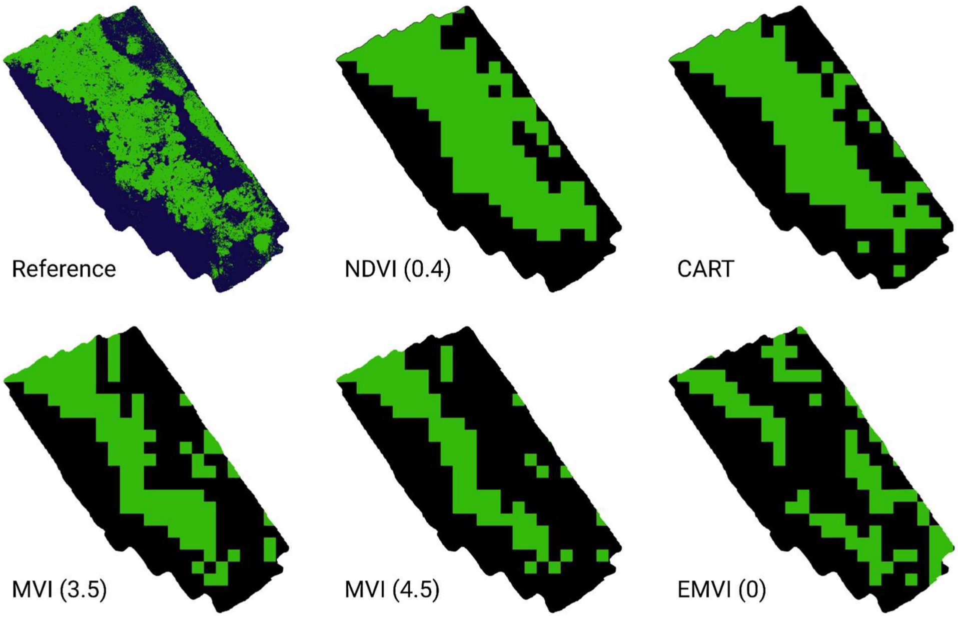

Figure 1. Mangrove classification maps of study area based on selected methods

These findings indicate that in this case, the most equitable methods are also the most accurate. This supports the experience of ongoing progress in the development of simple tools that use open data for ecosystem monitoring on the scale of small islands. These principles of equitable science can contribute to broader efforts to understand and communicate the state of nature, helping us make decisions and take actions that support sustainable development by looking after the ecosystems we depend on.

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