Remote Sensing of Urban Stream Eutrophication and Its Implications for Public Health

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Remote Sensing of Urban Stream Eutrophication and Its Implications for Public Health

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Abstract. Integrated environmental health policies, including scalable solutions, must be part of any successful public health strategy in the face of climate change impacts. The literature on algal blooms suggests that they can pose problems for human health, including digestive and respiratory difficulties. A holistic approach involving the systematic collection and analysis of data from hospital records, public health databases and population health surveys can be used to link environmental events such as algal blooms to disease, identify trends early and proactively take countermeasures. This paper presents a framework that combines remote sensing-based environmental monitoring systems with human health monitoring to combat eutrophication and dangerous algal blooms in urban streams, using environmental (NDCI) and morbidity indicators for public health. To demonstrate its utility, we developed an interactive web application using Python's Dash library that allows users to visualize and explore spatiotemporal correlations between NDCI-derived bloom intensity and rates of health incidents rates (synthetic data) in the area of Gazanos and Almyros, Crete.

Keywords: Eutrophication, algal blooms, remote sensing, public health informatics, Dash application

1. Introduction

Eutrophication occurs when additional nutrients enter aquatic habitats. It is often characterised by excessive plant growth, algal growth, hypoxic and anoxic conditions, a decline in biodiversity, and a shift in the dominant biota [1]. The main nutrients causing eutrophication of water bodies are phosphorus (P) and nitrogen (N), which often originate from agricultural, industrial, and urban runoff [2]. As freshwater is essential for human existence and life on Earth [3], it is crucial to monitor the status of these blue

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spaces [4] and observe how their climate-induces depletion and water quality affects human health in order to take proactive measures for public health. In addition to the ecological harm caused by eutrophication and its negative economic effects, it leads to a rapid increase in algae growth, which has been linked to mild skin irritation, gastrointestinal diseases, respiratory problems, liver damage, convulsions, and even death [5]. Environmental monitoring is a crucial component of the framework of comprehensive public health strategies aimed at reducing the damage related to both ecosystems and human health. Combining public health and environmental indicators in a dashboard can help raise awareness in aligning public health and environmental monitoring stimulating investment and volunteering.

2. Methods

2.1. Monitoring of eutrophication in urban streams

Researchers can monitor eutrophication using methods ranging from chemical analysis to remote sensing. The latter involves the use of satellites, airplanes and unmanned aerial vehicles (UAVs) to assess urban stream environments [6]. Remote sensing applications include mapping of suspended solids (SS), colored dissolved organic matter (CDOM), and chlorophyll concentrations [7], but spectral indices derived from multispectral data are proving particularly effective [8]. An exception is the Normalized Difference Chlorophyll Index (NDCI), which, similar to the Normalized Difference Vegetation Index (NDVI) for vegetation, estimates chlorophyll-a in inland, coastal and estuarine waters and detects algal blooms in combination with ground-truth data [9]. We illustrate this with a case study of the Almyros stream in Heraklion, Crete, a UNESCO-protected karstic wetland characterized by high salinity and carbonate rocks that prolong the persistence of pollutants and hinder recovery [10][11]. There, multispectral images acquired with a UAV were processed in QGIS to create a digital NDCI map of the entire wetland (Fig. 1).

2.2. Human health monitoring

Research studies have shown that harmful algal blooms (HABs) are often associated with increased cases of gastroenteritis, respiratory problems, skin irritation and, in severe cases, neurological symptoms due to exposure to cyanotoxins [12]. The combined presentation of public health data with remote sensing indicators such as NDCI can help researchers find temporal and spatial correlations between environmental changes and public health outcomes. For example, the integration of satellite data with field data has been successful in predicting and identifying Harmful Algal Blooms (HABs) and determining some early warning indicators for public health [13]. To establish a link between ecological data and human health data, the data can be accessed via ready-built Application Programming Interfaces (APIs)based on FL7 FHIR [14]. The OneAquaHealth project, invests in establishing processing for assessing and FAIRifying data sets that are FAIR (Findable, Accessible, Interoperable and Reusuable) and in that context HL7 FHIR and Health specific terminologies like the International Codification for Diseases (ICD) and SNOMED play a key role [15].

2.3. Implementation of a Dash-Based Framework for Integrating Public Health Surveillance with Harmful Algal Bloom Monitoring

To operationalize the theoretical framework connecting ecological events to public health outcomes, we developed an interactive web dashboard using Python's Dash library. This dashboard integrates two main data streams: environmental measurements of HAB indicators and community health monitoring metrics [16]. U.S. data from 2019–2022 served as inspiration to create synthetic data sets of HAB events and the number of human case counts, for the area of Herakleion in Crete.

The resulting Dash app (Fig. 1) offers an interactive spatiotemporal interface: A Year Selector dropdown filtered data by year; a Plotly choropleth map visualized Postal Codes shaded by total HAB events, with tooltips showing HAB and human case counts. A State Click Callback triggers a horizontal bar chart comparing HAB events and human cases for the selected state and year. If no state is selected, national totals are shown instead. Although the data presented are synthetic.

This implementation provides a reproducible and extensible informatics tool, directly linking ecological data with public health outcomes.

3. Results and Discussion

The multispectral monitoring of the Almyros wetland via remote sensing revealed that the Almyros stream is mostly eutrophic (green) and hypereutrophic (red) (Fig. 1).

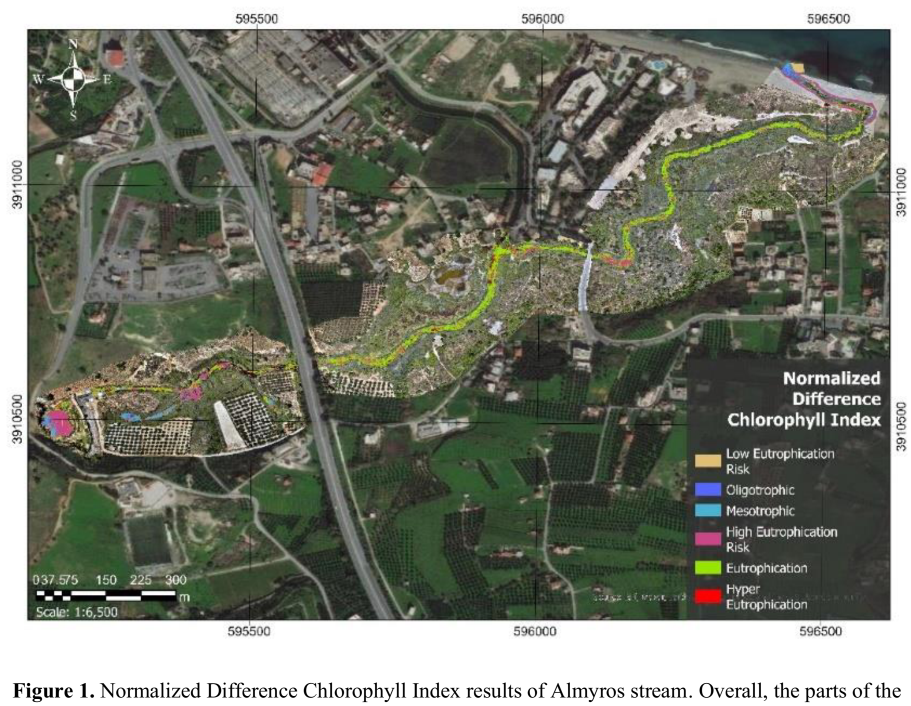

Figure 1. Normalized Difference Chlorophyll Index results of Almyros stream. Overall, the parts of the stream that are not eutrophic are classified as "high eutrophication risk" (pink color).

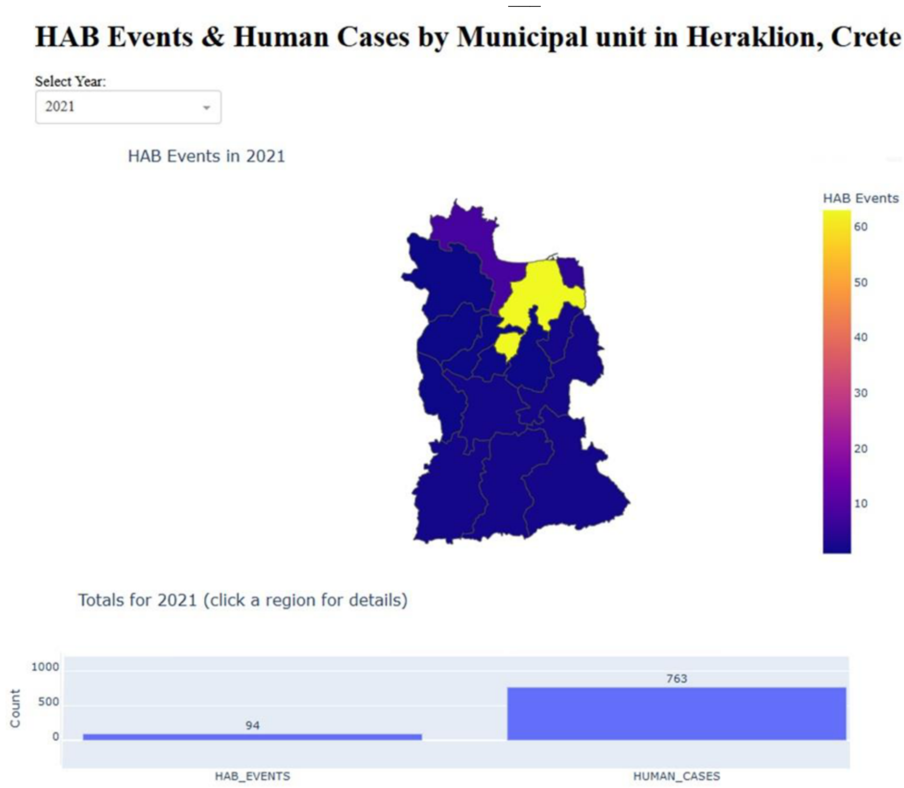

Figure 2. Dashboard showing a choropleth of HAB events by municipality (right) and a linked bar chart of HAB events versus hospital admissions (synthetic data) for the selected municipality (down).

Although this index (Fig. 1) doesn't require in situ measurements to support its estimations [9], it's important to highlight that its accuracy is verified by research done in 2023 that also classified the stream as eutrophic [11]. Although this case study does not currently include any direct human health data from the area surrounding the stream, the dashboard framework (Fig. 2) can ingest the remotely sensed values and present them together with public health data. This combined framework offers a scalable, data-driven early warning system for detecting and mitigating HAB-related health risks.

4. Conclusions

By combining remote sensing data and the normalized difference chlorophyll index to track eutrophication and dangerous algal blooms with a human monitoring framework, the current study demonstrates a realistic strategy for early detection and intervention in public health. With the ultimate goal of maintaining community well-being, future studies should integrate quantitative health data for the study area. Globally, environmental health policy is hindered by insufficient data to facilitate focused and effective decision-making. The proposed tool could significantly contribute in environmental health policy by using FAIR data sets and HL7 FHIR based APIs the proposed work can be extended to serve as dashboard for environmental/public health interventions of municipalities.

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