

Valuing Cultural Ecosystem Services of Natural Treatment Systems Using Crowdsourced Data

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Abstract : Natural treatment systems such as constructed wetlands and waste stabilization ponds are increasingly used to treat water and wastewater from a variety of sources, including stormwater and polluted surface water. The provision of ancillary benefits in the form of cultural ecosystem services makes these systems unique among water and wastewater treatment technologies and greatly contributes to determine their potential role in promoting sustainable water management practices. A quantitative analysis of these benefits, however, has been lacking in the literature. Here, a critical assessment of the recreational and educational benefits in natural treatment systems is provided, which combines observed public use from a survey of managers and operators with estimated public use as obtained using geotagged photos from social media as a proxy for visitation rates. Geographic Information Systems (GIS) are used to characterize the spatial boundaries of 273 natural treatment systems worldwide. Such boundaries are used as input for the Application Program Interfaces (APIs) of two popular photo-sharing websites (Flickr and Panoramio) in order to derive the number of photo-user-days, i.e., the number of yearly visits by individual photo users in each site. The adequateness and predictive power of four univariate calibration models using the crowdsourced data as a proxy for visitation are evaluated. A high correlation is found between photo-user-days and observed annual visitors (Pearson's $r = 0.811$; $p\text{-value} < 0.001$; $N = 62$). Standardized Major Axis (SMA) regression is found to outperform Ordinary Least Squares regression and count data models in terms of predictive power insofar as standard verification statistics - such as the root mean square error of prediction (RMSEP), the mean absolute error of prediction (MAEP), the reduction of error (RE), and the coefficient of efficiency (CE) - are concerned. The SMA regression model is used to estimate the intensity of public use in all 273 natural treatment systems. System type, influent water quality, and area are found to statistically affect public use, consistently with a priori expectations. Publicly available information regarding the home location of the sampled visitors is derived from their social media profiles and used to infer the distance they are willing to travel to visit the natural treatment systems in the database. Such information is analyzed using the travel cost method to derive monetary estimates of the recreational benefits of the investigated natural treatment systems. Overall, the findings confirm the opportunities arising from an integrated design and management of natural treatment systems, which combines the objectives of water quality enhancement and provision of cultural ecosystem services through public use in a multi-functional approach and compatibly with the need to protect public health.

Keywords : constructed wetlands, cultural ecosystem services, ecological engineering, waste stabilization ponds

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