An Integrated Hydrology-Hydrodynamics-Water Quality Modelling Approach for Assessing the Impacts of Changing Catchment and Climate Conditions on an Urban Freshwater Wetland

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Abstract

Urban wetlands have undergone severe degradation globally over the last few decades, mainly due to various anthropogenic stresses or climate change, making effective wetland conservation and management strategies a necessity. Deepor Beel, a Ramsar site, located in the southern banks of the transboundary river Brahmaputra in northeast India is considered as a representative urban wetland in this study. This wetland, being a home to different endangered species of flora and fauna, is ecologically-sensitive and has undergone severe degradation evident from satellite imageries and multiple field visits. This thesis makes use of numerical modelling and machine learning tools to evaluate water quality dynamics and ecosystem health of the wetland. Of the three broad objectives, the first involves the spatio-temporal assessment of water quality in the wetland using remote sensing-based data and field data, applying artificial neural network (ANN) and random forest (RF), for past three decades (1990-2020) as well as current times (2021-2023). This part of the work also involves the establishment of the primary data inventory comprising of water quality, geo-spatial, hydro-meteorological and physical data collected over the period of six seasons spanning from 2021 to 2023. The second objective comprises of the development and validation of an integrated 1D-2D catchment-river-wetland system using the integrated modelling platform, MIKE+ and MIKE 21, and utilising the six seasons' data collected in the first objective. The coupled model includes a rainfall-runoff model for the Basistha channel catchment, integrated with a 1D hydrodynamic and water quality model of the Basistha channel and a 2D hydrodynamic and water quality model of the wetland. The water quality models of the inlet channel and the wetland include five water quality parameters i.e. chlorophyll-a (Chl-a), biological oxygen demand (BOD), dissolved oxygen (DO), nitrate and phosphate. The third, and final objective applies the integrated model to assess future climate change impacts (2050) and to identify eutrophication drivers and hotspots in the wetland. The remote sensing-based assessment was able to establish a strong correlation between remotely sensed data and field-observed data, highlighting the usefulness of the designed framework for water quality assessment in data-poor and inaccessible regions. The coupled 1D-2D model performed well, with R^2 values ranging between 0.61 (BOD) to 0.68 (Nitrate) for predicting all the five water quality parameters with acceptable RMSE values and PBIAS values less than 25%. The low-flow velocity zones are found to be more prone to eutrophication in the wetland with nitrate and phosphate being the major eutrophication drivers, especially during non-monsoon periods. Future projections indicate increasing spread of poor water quality regions and eutrophic zones, indicating possible loss of bio-remediation capacity of the wetland. The findings of this study emphasize the urgent need for remediation and management interventions such as use of control structures or on-site water treatment in the wetland in order to conserve its ecological stability and overall environmental health.

Keywords: Wetland Degradation, Urban Wetlands, Rainfall-Runoff Modelling, Hydrodynamic Modelling, Water Quality Modelling, Remote Sensing-Based Assessment, Climate Change.