

## Abstract

Morocco hosts more than 325 estuaries distributed along the Atlantic Ocean and the Mediterranean Sea, forming dynamic transitional ecosystems of high ecological and socio-economic importance. Despite their significance, these environments remain insufficiently characterized at the national scale due to fragmented data and limited field-based studies. This study aims to provide a preliminary classification of Moroccan estuarine wetlands using an approach based on remote sensing and Geographic Information Systems (GIS), enabling large-scale and consistent analysis.

The methodology relies on a set of physiographical descriptors integrating both watershed and local estuarine characteristics. These include watershed area, slope, altitude, geological composition, and rainfall, as well as estuarine dimensions, hydrological regime, sea connection, tidal influence, and coastal exposure. The dataset is analyzed using multivariate statistical methods and clustering techniques to identify patterns and classify estuaries into homogeneous groups.

The results reveal several distinct estuarine types, primarily structured by catchment-related factors such as watershed size, geomorphology, and dominant lithology. These parameters strongly influence sediment transport, freshwater input, and estuarine morphology. Marine factors, including tidal dynamics and sea exposure, also contribute to the differentiation of estuaries, although their influence appears secondary compared to watershed controls.

The study highlights the dominant role of catchment processes in shaping estuarine systems in Morocco, reflecting long-term interactions between geological structure, climate variability, and hydrological dynamics. A significant proportion of estuaries exhibit seasonal or intermittent hydrological regimes, particularly in semi-arid regions, where water availability is highly variable and increasingly affected by human activities such as dam construction and water abstraction.

Furthermore, the research demonstrates the effectiveness of remote sensing and GIS-based methods for the classification and inventory of estuarine ecosystems, especially in contexts where field data are limited or difficult to obtain. While certain limitations remain particularly regarding detailed hydrological and ecological parameters this approach provides a robust framework for large-scale assessment.

This work establishes a foundational basis for improving the understanding, management, and conservation of Moroccan estuaries. It also offers a reference framework for future research integrating additional hydrological, ecological, and anthropogenic variables to refine estuarine classification and support sustainable coastal management strategies.