Artificial dunes as a solution to saltwater intrusion: A large-scale monitoring and modelling study

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Introduction

Historically, freshwater lenses beneath the Belgian dunes have played an important role in protecting the hinterland from saltwater intrusion (SI). However, urbanization and other human activities have led to a decline in the formation and preservation of these freshwater lenses, putting our freshwater storage and economy at risk of further SI. To address this issue, it is crucial to gain a deeper understanding of the hydrogeological feedback mechanisms that occur during dune development. As more coastal managers turn to nature-based solutions, such as engineered or artificial dunes, for coastal protection, it is especially important to be able to predict the development of freshwater lenses in these dynamic environments. However, current knowledge on how to anticipate freshwater lens growth in juvenile (artificial) dunes is limited. This project aims to fill this gap in knowledge by conducting a detailed investigation of the hydrogeological feedback mechanisms involved in dune development and using this information to design and validate a hydrogeological model that can be used to predict freshwater lens growth in dynamic artificial dune environments.

Method

To better understand, monitor, and model freshwater lens development during early-stage dune growth, we have constructed an artificial dune area of 750 x 20 m² in Raversijde, Belgium. Vegetation has been planted in a split-plot design with varying spatial distributions and planting densities, and part of the vegetation is surrounded by brushwood fences with different densities. To accomplish our objectives, we will use a combination of field measurements, data analysis, and numerical modelling. First, we will conduct regular ERT measurements to visualize subsurface resistivity (salinity) and examine the development of the freshwater lens. We will also continuously monitor the water table, tidal response, and salt levels on several transects using well monitoring perpendicular and parallel to the dune area. To correlate these measurements with dune development, we will conduct monthly drone surveys to monitor topographical changes, as well as additional RTK measurements on pre- and post-storm conditions. This will provide crucial information on the effects of storm surges on groundwater variations and salinity, as well as the time it takes for the groundwater balance to recover. Additionally, we will also obtain data from nearby monitoring wells that contain historical data, a weather station that monitors precipitation, and a nearby artificial dike, monitoring water levels and wave transformations. In the second stage, a combined dataset of forcing factors, topographical changes, and geohydrological responses will be generated through data analysis to better understand the hydrogeological feedback mechanisms at play, and to identify which of these factors could be used as key parameters or boundary conditions. This analysis and the identified parameters will be used to create and validate a hydrogeological SEAWAT model simulating the development of the freshwater lens, the mixing process of saline and freshwater recharge, and the maximum storage of fresh groundwater.

Results

Our model will help us understand how different scenarios of sea level rise and coastal management impact the development of freshwater lenses. To validate the model, we will apply it to case studies along the Belgian coast, and examine how it affects the surrounding area and the availability of freshwater for human use. Additionally, we will investigate whether artificially replenishing the dune with waste or runoff water can improve freshwater lens development. This research will provide a valuable toolkit for understanding and managing freshwater lenses in artificial dune systems, working towards a more climate-resilient coastal area.

Keywords

Early-Stage Dune Development; Nature-Based Solution; Saltwater Intrusion; Hydrogeological Feedback Mechanism; Coastal Protection; Artificial Dunes; Geophysical Surveys