Freshwater lens monitoring in an artificial dune

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Introduction

Historically, freshwater lenses beneath Belgian dunes have served as a natural barrier against saltwater intrusion (SI), safeguarding the hinterland's freshwater storage and economy. Urbanization and anthropogenic activities have led to a decline in freshwater lenses, heightening the threat of saltwater intrusion. Understanding hydrogeological feedback mechanisms driving freshwater lens development is crucial for predicting growth and implementing effective coastal protection strategies. This is especially pertinent as more coastal managers turn to nature-based solutions, such as engineered or artificial dunes, like the dune-in-front-of-a-dike approach, to counter seawater intrusion. However, there is still a gap in knowledge regarding freshwater lens growth in dynamic environments, particularly in juvenile (artificial) dunes.

Method

Over four years, our study aims to conduct a thorough investigation, monitoring, and modelling of freshwater lens development during the early stages of dune growth at a newly established artificial dune area measuring 750 x 20 m² in Raversijde, Belgium. The study area incorporates a split-plot design for vegetation with diverse spatial distributions and planting densities. Additionally, a portion of the vegetation is enclosed by brushwood fences featuring varying densities. To capture and comprehend these hydrogeological mechanisms comprehensively, we employ a multifaceted approach combining field measurements, advanced data analysis, and numerical modelling. Our methodology has evolved to incorporate the latest advancements and insights into the study. Our initial focus involves regular time-lapse inversion of Electrical Resistivity Tomography (ERT) data, conducted on a weekly or bi-weekly basis. This process facilitates the visualization of subsurface resistivity (salinity) and provides a detailed examination of the evolving freshwater lens. In addition to ERT measurements, continuous monitoring of the water table, tidal response, and salt levels along several transects is carried out using strategically placed well-monitoring points perpendicular and parallel to the dune area. Detailed monthly drone surveys document topographical changes, while Real-Time Kinematic (RTK) measurements, both pre-and post-storm conditions, evaluate the impact of storm surges on groundwater variations and salinity. An enhancement to our methodology includes the installation of a dedicated monitoring station that tracks solar radiation, soil moisture, and precipitation. This addition provides valuable insights into the overall recharge dynamics of the study site.

The initial ERT measurements have validated the existence of a growing freshwater lens beneath the dune. As part of our ongoing optimization efforts, we are refining the data acquisition process. This includes adjusting the measurement regime for ERT, evaluating the influence of electrode placement, and optimizing the installation of monitoring wells. Additionally, soil samples are being collected to provide a comprehensive understanding of the subsurface conditions.

Conclusion

The collected data forms the basis for a combined dataset of forcing factors, topographical changes, and geohydrological responses. This dataset identifies factors influencing dune lens development, serving as boundary conditions for our MODFLOW 6 groundwater model, developed using Model Muse and FLOPY. The model aims to simulate freshwater lens development, saline-freshwater recharge mixing, and maximum storage of fresh groundwater. This comprehensive approach provides valuable insights into freshwater lens dynamics, enhancing our understanding of interactions during the early stages of dune growth. The project's outcomes will be instrumental in addressing scenarios like sea-level rise and coastal management. By combining field measurements, data analysis, and numerical modelling, we unravel feedback mechanisms shaping freshwater lens development.

Keywords

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