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DEVELOPING AN EFFICIENT MODELLING FRAMEWORK TO EVALUATE NATURE-BASED SOLUTIONS TO COUNTERACT ESTUARINE SALT INTRUSION

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ABSTRACT

Estuaries connect our rivers and oceans, and support densely populated regions worldwide. These estuaries are increasingly threatened by salt intrusion due to climate change and side effects of human interventions, limiting freshwater availability. Nature-based solutions (NBSs), e.g. sand waves or wetlands, show potential to increase mixing of fresh- and salt water and have shown to be adaptable to a changing climate. Hence, they may provide a resilient way to reduce salt intrusion, while also supporting important ecosystem services. An efficient modelling framework will be developed, that is able to evaluate NBSs to counteract salt intrusion, estuarine wide, including CC. It will be applied to establish a knowledge base around the interactions between estuarine ecomorphology, related to NBSs, and salt intrusion. This way, the proposed research will improve understanding and provide modelling tools on the interaction between NBSs and estuarine wide salt intrusion.

Keywords: estuaries, salt intrusion, ecomorphology, nature-based solutions, numerical model

1 INTRODUCTION

In many and often densely populated regions worldwide, rivers meet with seas. Within these water systems, called estuaries, salt water can intrude far inland during extreme events, such as storm surges and river droughts. During recent periods of drought in the Netherlands (2003, 2011, 2018 & 2019), the intrusion of salt water severely limited freshwater availability, threatening the supply of fresh water for agricultural and industrial use. Moreover, estuarine regions are increasingly threatened by salt intrusion due to climate change (CC) and side effects of human interventions, further threatening freshwater supply in the future.

Due to the difference in density between fresh- and salt water, salt water intrudes inland as a plume over the estuarine bed. Nature-based measures, like artificial sand waves, wetlands or oyster beds, are proposed to reduce this salt intrusion. These measures impose a roughness on the flow of water, due to which they increase the mixing of the stratified fresh- and salt water flows. In addition, these ecosystems have dynamics on their own due to which they can adapt to a changing climate. Consequently, they may provide a resilient way to reduce salt intrusion. However, the various interactions between NBSs and salt intrusion are not yet understood.

Moreover, a modelling framework that is able to evaluate NBSs to counteract salt intrusion, under long-term development, is missing. This framework needs to include processes acting on vast spatial and temporal scales, resulting in substantial computational efforts. Surrogate approaches are available to improve modelling efficiency, e.g. Artificial Neural Networks (Bomers et al., 2019) and multi-fidelity approaches (Berends et al., 2018), but these methods are often novel and not yet applied to study long-term estuarine ecomorphodynamics.

The objective of this research is to develop a computationally efficient modelling framework to evaluate the impacts of NBSs on estuarine salt intrusion under ecomorphological development, on an estuary wide scale, for the present till the next century, taking into account CC,.

2 METHOD

To accomplish the set objective, a modelling framework will be created (within the process-based, numerical modelling software Delft3D-FM) in which the impact of estuarine ecomorphological development, related to NBSs, on salt intrusion can be assessed efficiently. However, when assessing the impact of long-term estuarine development on salt intrusion, various relevant timescales are identified (Figure 1).

To improve efficiency within the framework, the various timescales are separated when modelling. Firstly, an idealized ecomorphological model will be developed to study the impact of NBSs on estuarine development, on an engineering timescale (1 to 10 years). Herein, scenarios will be implemented within the estuary, representing NBSs. E.g., at the estuarine bed, scenarios ranging from flatbed to sand waves of equilibrium height or, at the estuarine sides, wetlands with various sizes and vegetation characteristics are implemented. Subsequently, an idealized salt intrusion model will be developed. Within this model, salt intrusion is studied for extreme scenarios (up to several days), before and after the previously simulated ecomorphological development. Hence, the impact of NBSs on salt intrusion, under estuarine development, can be assessed. For these models, surrogate approaches will be tested and applied to reduce computational efforts, e.g. ANNs or multi-fidelity approaches.

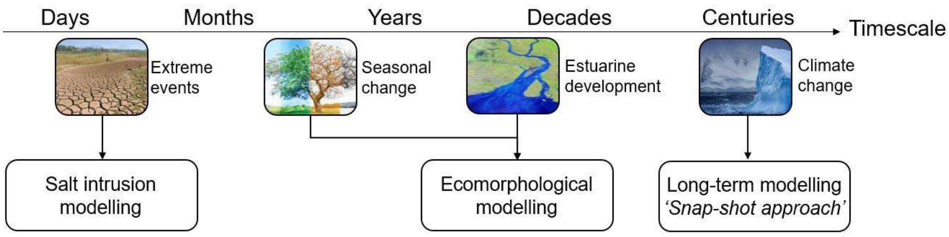

Figure 1. Temporal processes relevant to the study, and the modelling tools applied for these processes.

Next, salt intrusion due to NBSs will be assessed within a real study area of the Rhine-Meuse Delta (RMD), under CC till 2100. However, to study the long-term development due to CC (decadal+ timescale), regular, process-based modelling will lead to infeasible computational efforts. Therefore, the snap-shot approach will be applied, as proposed by (Duong et al., 2016). In addition, surrogate approaches which are successfully applied previously within the idealized models, will be applied within this framework. The complete modelling framework for a real case study, including all temporal scales (Figure 1), will be as follows:

1. Construct and validate a salt intrusion- and ecomorphological model for present day conditions.
2. Perform salt intrusion modelling of extreme events (several days) for present day conditions.
3. Apply the snap-shot approach to create future scenarios at the desired year (e.g. 2050, 2100) from the present day conditions, following (Duong et al., 2018). This is performed for the ecomorphological model and the salt intrusion model.
4. Perform ecomorphological modelling (1 year) of the future scenario created in the previous step.
5. Perform salt intrusion modelling of extreme events (several days) after the simulated future ecomorphological development (step 4). Comparison of these results with those of step 1 will show the impact of long-term estuarine development on salt intrusion.

This framework will be applied to study the impact of CC and its uncertainty within the RMD, by applying different CC scenarios. Also, scenarios representing NBSs are implemented within the framework, similarly as within the idealized models, as mentioned earlier. These NBSs will be implemented in both present and future simulations.

3 EXPECTED RESULTS

By reaching the research objective, an efficient modelling framework is constructed and will successfully be applied to predict the impact of a wide range of predetermined NBSs on estuarine development and salt intrusion within the RMD, under CC up to the next century. Insights will be gained on estuarine wide development due to various NBSs, and understanding on how this development affects salt intrusion will be improved. In addition, various novel surrogate approaches will be tested and successfully applied within the modelling framework to reduce computational restraints.

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