Interactions between vegetation and aeolian sediment transport in coastal dune systems, a modelling approach

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1. INTRODUCTION

Coastal beach and dune systems are the most effective natural line of defense against coastal flooding in low elevation coastal zones, such as the Belgian Coast. Maintaining, enlarging and creating dunes have been suggested as one of the effective approaches considering nature based solutions in climate adaption projects (e.g. Vlaamse Regering, (2017)).

Restoration, maintenance or the creation of these systems require understanding of aeolian sediment transport. Understanding this process and estimating the amount of sediment transported by the wind will help in predicting beach and dune evolution on short (storm) and long (decadal) timescales and enable in designing better and more efficient maintenance, adaptation and dune design plans to ensure the resiliency of the dunes (Strypsteen *et al*., 2019).

In this paper we assess the aeolian transport along the Belgian coast by first comparing two numerical models and thereafter the influence of vegetation.

2. METHODOLOGY AND RESULTS

The first step of this study is to compare the two most commonly used (open-source) numerical models for simulating Aeolian transport: Duna (Roelvink and Costas, 2019) and Aeolis (Hoonhout and Vries, 2016). Both models are designed to simulate aeolian sediment transport and subsequently model the evolution of dunes in situations where supply constraints are important, such as in coastal environment. The models calculate and update the distribution of cross-shore wind speed, velocity thresholds of sand movement, the interaction with vegetation and sediment transport.

In order to compare the models, a test profile that consists of a constant slope with a schematic dune at the top (top panels of Figure 1) was analyzed. For the comparison, the same boundary conditions and dune vegetation characteristics are applied to both models, simulating a constant wind speed of U_{10} = 13 m/s (i.e. 10 m above the refence level) over 3 hours. The vegetation is modelled using a vegetation factor that accounts for the height and density of vegetation, starting at +7 m TAW (i.e. the dune toe) with a low density factor for the pioneering species to a higher value (reaching up to 0.3) on the top and landward side of the dune for the intermediate vegetation species.

As shown in Figure 1 (bottom panels), differences emerge in the modelled sediment transport (mainly) on the seaward slope of the dune. As both models use the same sediment transport model, wind model and supply constraints the difference emerges from the difference in numerical schemes. The implicit upwind scheme in Duna results in a smoothened sediment transport distribution, whereas the implicit Euler backward scheme in Aeolis results in a more oscillating distribution. The analysis shows that both models can be used for calculating aeolian sediment transport, but since Aeolis can eventually be used in 2D situations we have decided to proceed with Aeolis.

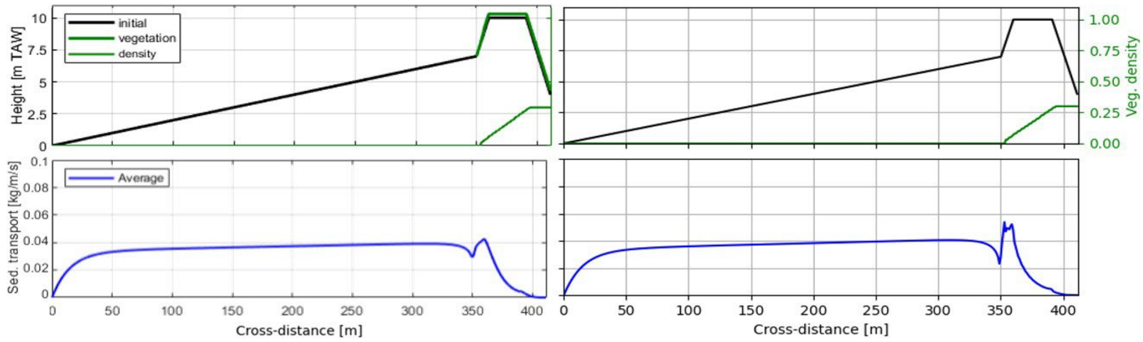

Figure 1: The comparison between Duna (left) and Aeolis (right). Cross-shore profile elevation and vegetation density (upper panels), modelled aeolian sediment transport (bottom panels)

For the second step of this study, we have assessed a representative profile for the Belgian coast and used Aeolis to simulate the effect of dune vegetation on the annual rate of aeolian sediment transport. To have a first estimate of the influence of vegetation on the annual sediment transport, the representative profile with typical vegetation coverage is compared with the same profile without vegetation (Figure 2). The estimated annual rate of aeolian transport is based on the probability of occurrence of different wind conditions (using Oostende wind measurement data from 2012 to 2019) and rainy days for which it is assumed that there is no aeolian sediment transport.

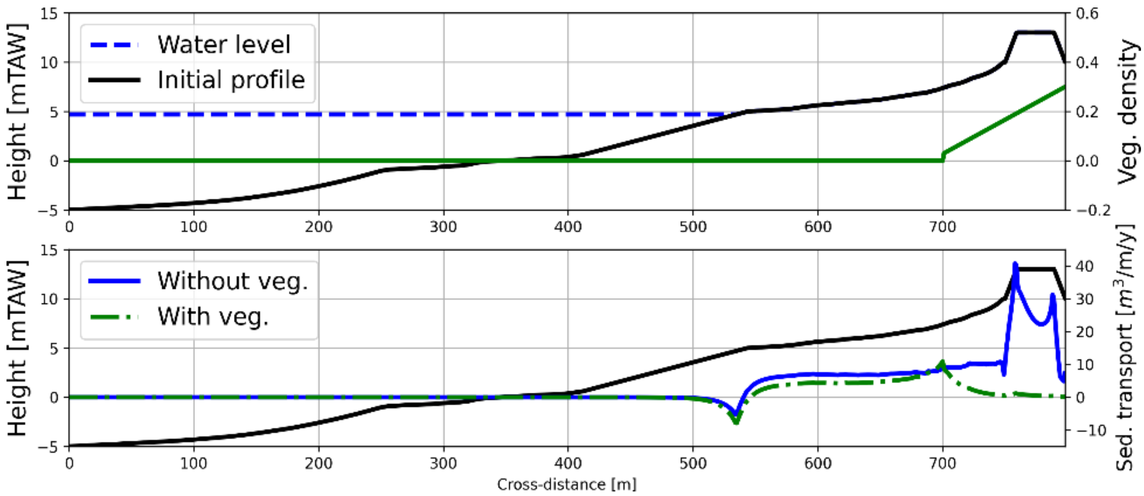

Figure 2: Annual aeolian sediment transport for a typical cross-shore profile along the Belgian coast for a scenario with vegetation and a scenario without vegetation

The most pronounced differences are found around the dune area. In the case of vegetation, transport rates decline rapidly in landward direction, whereas without vegetation transport rates reach their peak at the landward tip of the dune. Hence, it is clear that vegetation has a considerable impact on aeolian transport rates along the profile. The dampening effect and therewith the decline of transport rate towards the dune can imply sedimentation in the dune area. The scenario without vegetation shows on the other hand an increase of transport rates on at seaward slope of the dune, implying that this area is prone to erosion. Eventually it means that vegetation can keep the dunes in place and prevent dunes from migrating landward.

3. CONCLUSION

We observed that two commonly used numerical aeolian sediment transport models (i.e. Aeolis and Duna) are largely similar when looking at sediment transport rates along a schematized profile.

Moreover, when using Aeolis to simulate aeolian sediment transport along a coastal profile it was found that vegetation has a considerable impact on the transport rates. In the case of vegetation we observed a decrease in transport rates, potentially leading to sedimentation in the area of vegetation. For the case without vegetation an increase in aeolian sediment transport at the dune area was found, leading to potential erosion of the dune area.

4. ACKNOWLEDGEMENT

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