Building with nature: Aeolian sediment input to engineered dunes

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Coastal managers are getting convinced of building with nature concepts, such as engineered dunes in front of traditional dikes, for coastal protection and as sand mitigation measure. For an optimal design of these marram grass planted dunes, a fundamental knowledge of the morphological changes of dune development is required. Hence, the characterization and prediction of aeolian sediment supply from the beach to the dune is a key component in the development of comprehensive models for beach and dune interactions. Observations of aeolian transport in coastal areas have largely focused on short-term experiments because of limitations imposed by instrumentation. This research uses a unique case study of the 120x20m² dune-in-front-of-a-dike pilot site in Oosteroever, Oostende, Belgium, to analyze how frequently and with which magnitude aeolian transport occurs at the beach over a complete year of measurements by using continuous records of wind from an erected monitoring station and weekly topographic RTK-GPS measurements and monthly high-resolution drone surveys. Occasionally, during storm events a camera setup was used to determine shoreline position, fetch distances, and possible storm erosion. The analysis of a set of 12 months at an hourly basis, for a total of 8784 hours, shows that the wind was above the threshold of transport (i.e., 6 m/s) 20.4% of the time (1793 hours), and approached the dune from a longshore to onshore direction 47.7% (4193 hours) of the time. Prevailing winds were from northeast, whereas the strongest winds were from west and southwest. The combined effect of both an appropriate wind speed and angle of wind approach for potential aeolian transport towards the dune resulted in a total of 1607 hours; this is 18.3% of the total time throughout the year. Transport rates varied between 0 and 300 kg m-1 h-1 with the majority (i.e., 67.7%) below 100 kg m-1 h-1 for moderate wind speeds between 8 and 10 m s-1. During winter period, there were a few occasions where strong winds occurred in combination with (spring) high tide inundating the beach hampering any aeolian sediment transport towards the dune and thus limiting dune growth. This supports the idea that potential aeolian transport is less than 18.3% of the year. The local wind speed measurements differ from the regional wind speed measurements suggesting that wind speed transformation is necessary when predicting aeolian sediment at the beach/dune interface. During longshore winds, wind speed at the beach is generally 1.1 to 1.35 times higher than in the landward dunes. Rainfall occurred 9.4% (825 hours) of the time with a cumulative total of 625mm but did not significantly influence aeolian sediment transport processes according to model predictions. The total volume of sand in the dune has increased significantly since the plantation of the marram grass (i.e., January 2021). In total 14 m³ m-1 of sand has been added due to the aeolian processes translating into a vertical elevation increase of 1 m. Moreover, the dune suffered from erosion where cliffs at the dune toe were formed up to 1.5 m exposing the underlying roots of the marram grass. Nearly 1.5 m³ m-1 of sand was eroded in a couple of hours. However, the dune proofs to be rather resilient as already new sand from the beach is getting deposited at the dune toe. Initial vegetation patterns in the dune disappeared giving the dune a more natural and dynamic behavior. Vegetation growth and density varied throughout the year and thus its sand trapping efficiency. Although there is less than one-fifth of the year for potential aeolian sediment transport at the beach, the results show a significant dune growth in the dune-in-front-of-a-dike pilot site which is encouraging for coastal protection. Marram grass proves to be a good mitigation measure to keep the sand on the beach. However, dune growth is influenced by supply limitations, vegetation characteristics, and sediment erosion by wind and storm events.

Keywords: Aeolian sediment transport; Dune development; Case study; Remote sensing; Beach/dune interaction