Final Report

Brilliant Marine Research Idea 2021

This report should be submitted **no later than 28 February 2022** via filantropie@vliz.be and consist of the following documents:

- A final report listing the work done and the problems encountered. This report will be made available online. If any of the tasks has not been completely finished, the report should clearly mention this, including a short explanation. **max. 5 pages**
- An overview of all expenditures including invoices.
- A set of five pictures (low resolution in this document). The five High Resolution pictures should be delivered to VLIZ by email to karen.rappe@vliz.be. Pictures should be free from use - to upload on the VLIZ website and to use in VLIZ communications.

Keep in mind that VLIZ should be mentioned in the acknowledgements of publications following the results of this Brilliant Marine Research Idea.

1. General information

Title of the idea	Building with nature: Aeolian sediment input to engineered dunes
Name PhD student	dr. ing. Glenn Strypsteen
Name supervisor	prof. dr. ir. Pieter Rauwoens
Flemish University or Flemish University College	KU Leuven (Bruges Campus)

2. Brilliant Marine Research Idea – Report about the activities

Abstract
Observations of aeolian sediment 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. The type of measurements described here has been specifically designed to acquire information on the dynamics of the beach and dune at high spatial and temporal resolution during long periods of time. The analysis of a set of 12 months at an hourly basis shows that the combined effect of both an appropriate wind speed and angle of wind approach for potential aeolian transport towards the dune is less than one-fifth of the year. Transport rates varied between 0 and 300 kg m^{-1} h^{-1} with the majority

below 100 kg m^{-1} h^{-1} for moderate wind speeds between 8 and 10 m s^{-1}. The results show a significant dune growth of about 14 m^3 m^{-1} or 1 m in vertical direction in the pilot site which is encouraging for coastal protection. The planted marram grass proves to be a good and resilient mitigation measure to keep the sand on the beach. However, long-term dune growth is influenced by supply limitations, vegetation characteristics, and sediment erosion by wind and storm events.

Intro

Coastal managers are getting convinced of building with nature concepts, such as engineered dunes in front of traditional dikes, to strengthen 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 to assess their role in supplying sediment for early-stage dune building. This dune field is planted with marram grass with three different plant densities (6, 9 and 15 plants/m²) and four spatial configurations (gridded, random, clustered, and staggered) providing a unique experimental setup to study dune growth in the early stage. The results obtained from this research idea will help us to set up a field-based model to predict early-stage dune development in engineered dune fields, needed for coastal management.

Material & Methods

A long-term monitoring station at the study site is erected which permits the acquisition of continuous records of wind, and beach and dune characteristics that can be coupled with sand transport measurements over period of months to years. Local wind speed and direction is measured at the seaward side of the dune foot for 9 months with cup anemometers at four different heights above the surface (i.e., 0.21, 0.48, 1.01 and 2.01m with a variation of 4 cm) and a wind vane to extract surface roughness and shear velocities from the vertical wind velocity profiles. Averaged wind data is stored on a Campbell datalogger every 20 seconds. Aeolian sediment transport intensity (impact of sediment transport) is measured at a height of 10 cm above the sand surface every one second with a saltiphone connected to the Campbell datalogger. Data on regional wind data, precipitation, and tidal elevations is accessed from Meetnet Vlaamse Banken at Meteopark Oostende located next to the study site (distance of 315 m).

Besides using the saltiphone, sediment transport and deposition within the 120x20 m² dune field is measured using erosion-deposition (ED) pins. The ED pins consist of metal rods (max. diameter of 6 mm) which is driven vertically into the beach surface. The ED pins are installed in cross-shore transects (two per vegetation zone, 12 in total) where changes in the level of the sand against the rod is measured weekly (Figure 1). Furthermore, topographic elevation changes are measured on a more detailed spatial level with drone flights once every month (except for the summer period) conducted by ATO and Flanders Coastal Division.

Occasionally, during storm events a camera setup was used to determine shoreline position, fetch distances, and possible storm erosion.

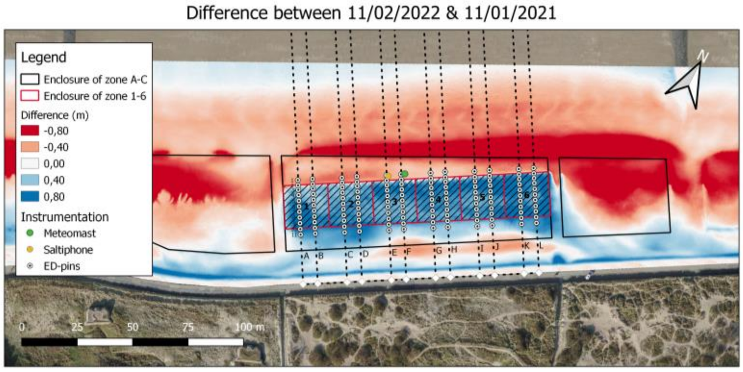

Figure 1. Experimental setup at the planted dune-in-front-of-a-dike pilot site in Oosteroever, Oostende (section 120). Planted zones are 20x20 m² (6 in total). Blue and red colors show deposition and erosion between the drone surveys of 11/02/2022 and 11/01/2021.

Results/Conclusions

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 (see Figure 2). Prevailing winds were from northeast, whereas the strongest winds (gusts up to 30-35 m/s) 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.

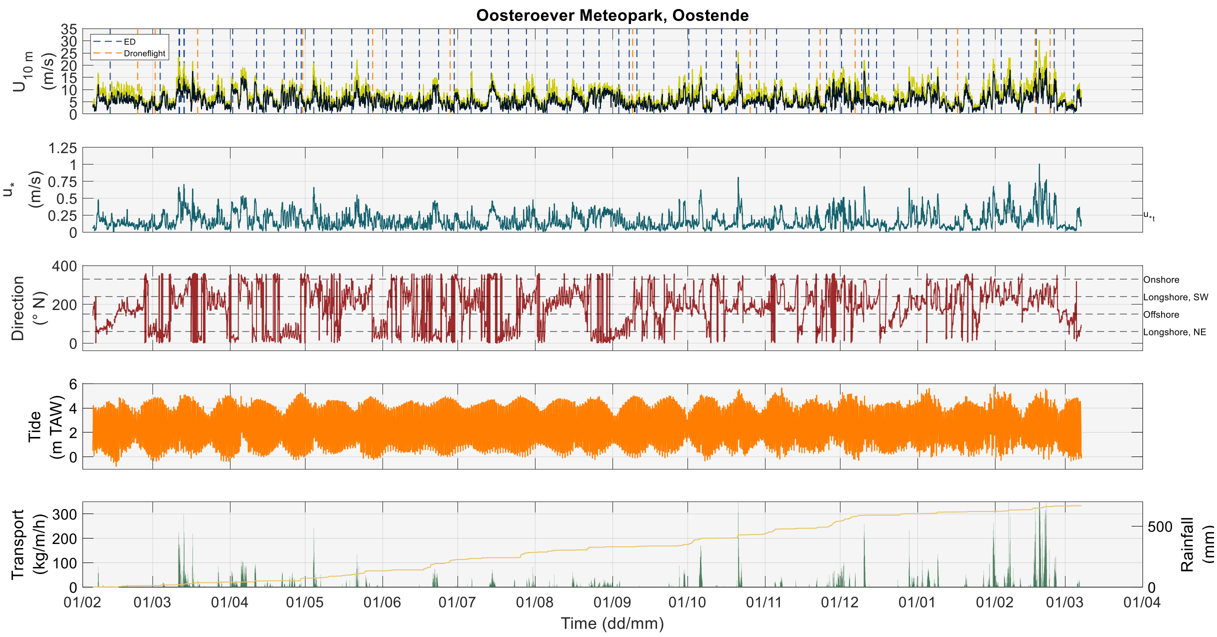

Figure 2. Meteorological conditions and transport events during one year of monitoring.

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., end of 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 (see Figure 3). The months March and April 2021 were responsible for half of the annual dune growth (see Figure 4). The other months delivered a comparable amount of net sediment input to the dune (i.e., approximately 1 m³ m⁻¹) but slowly decreased towards the end of the year. From October 2021 onwards the dune volume remained fairly stable due to a combination of supply limitations and a decrease in vegetation trapping efficiency (mismatch with predictions). However, a large amount of sediment is deposited in the landward area (120x15 m²) of the dune (i.e., 3 m³ m⁻¹). Moreover, the dune suffered from erosion (end of January 2022) 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. Nevertheless, the dune proofs to be rather resilient as new sand from the beach is deposited at the dune toe. Initial vegetation patterns disappeared (after 3 months) giving the dune a more natural and dynamic behavior.

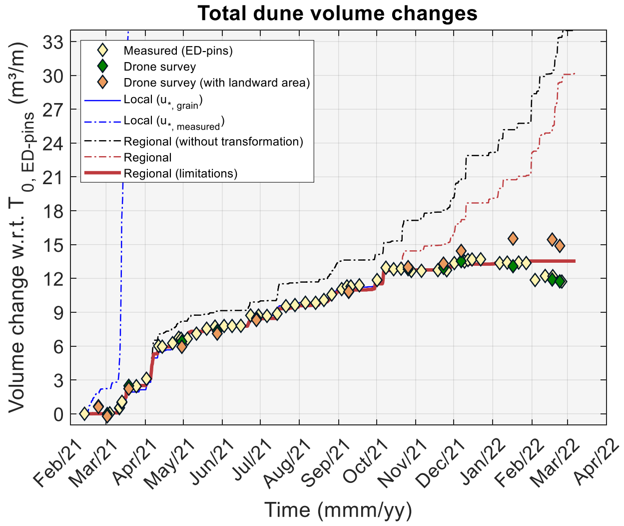

Figure 3. Total sand volume changes in the dune area (120x20m²) with corresponding predictions (with and without supply/vegetation limitations).

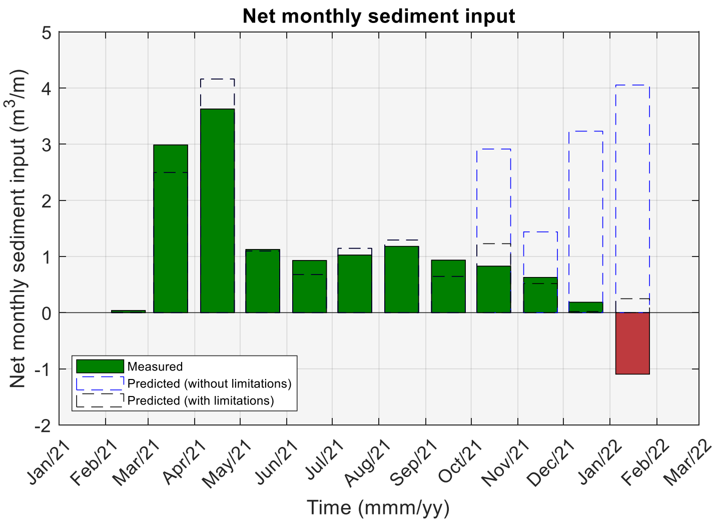

Figure 4. Monthly net sediment input towards the dune showing measured and predicted values.

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, long-term dune growth is influenced by supply limitations, vegetation characteristics, and sediment erosion by wind and storm events.

3. Overview of the expenditures

Describe in detail how the requested fund was spent within the implementation period (1 March 2021 and 28 February 2022). Be as specific as possible.

Since we only made an estimation of possible expenditures in our application, more was spent on the camera setup and surface moisture datalogger during the project. There was not enough money available to conduct an extra drone survey. Fortunately, drone surveys could be conducted at least once every month. The surface moisture datalogger has not been used yet since we are still waiting on the provided short course by the company. The following table provides specific information on the expenses that have been made during this research:

Name	**Price (in €)**
2x GoPro HERO 9 Black	816,00
4x SanDisk MicroSDXC Extreme 256 GB 160MB/s + SD Adapter	335,96
2x GoPro HERO 9 Black Max Lens Mod	193,98
2x GoPro Large Tube Mount Roll Bars + Pipes + More	103,98
Goal Zero Sherpa 100 Powerbank (25600 mAh)	185,98
Xtorm Solar Panel 21 Watt	139,00
AVR auger 9cm	81,69
GP2 - DELTA-T LOGGER GP2	1975,81
LBAT4 - Rechargeable battery LBAT4 12V 10Ah sealed lead acid battery with spade terminals	188,76
LBC4 - Battery charger for LBAT4 Mains battery charger for 10Ah lead acid battery	208,85
ML3 - Soil Moisture Sensor Mains battery charger for 10Ah lead acid battery	631,26
SMSC/sw-05 5m cable Mains battery charger for 10Ah lead acid battery	36,18
Delivery costs	27,23
Total	***4924,68***

4. Pictures

A set of five pictures (low resolution in this document). The five High Resolution pictures should be delivered to VLIZ by email to karen.rappe@vliz.be.