Biomechanical parametrization of dune vegetation strengthening nature-based solutions in coastal protection

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1. INTRODUCTION

Nature-based solutions in coastal protection are attracting more attention from research and engineering alike due to their promising potential for biodiversity conservation and climate change adaptation. Especially, coastal dunes offer a high value ecosystem for beach plant and animal species; at the same time, they serve as a natural barrier against flooding due to wave impacts and storm surge. Even though pilot-projects - like the construction of an artificial dune in front of a dike in Ostend (BEL) or in Petten (NL) - show first examples of how an ecosystem-based approach can be integrated in coastal zone management, further research remains crucial; specifically, considerable lack of knowledge exists on the biomechanical characteristics of dune vegetation.

This field study develops a novel acquisition method for the biomechanical parametrization of *Ammophila arenaria* as a typical white dune plant species. As pilot site, a single free-standing dune at the northern coast of the North Frisian island of Spiekeroog, is selected for vegetation sampling. First results include vegetation height and density measurements as well as three-point bending tests to identify the biomechanical properties of aboveground plant parts.

2. METHODS

Spiekeroog offers a variety of dune systems exposed to divergent environmental conditions such as established and incipient dunes as well as artificially-constructed ones. A free-standing dune was chosen for this field study, which is part of the northern white dune system. The select dune offers great potential for investigating dependencies between biomechanical plant traits and local environmental conditions like wind exposure and sand flux, as it features four geographic flanks for erosion and accretion processes to take place. The average wind speed at Spiekeroog is 7.9 m/s with a prevailing wind direction between west and north (source: Deutscher Wetterdienst). The dune covers an area of 3'005 m² and extends approximately 90 m along its north-south axis and reaches a maximum width of 45 m east-west. For sampling, the area is subdivided into ten zones (see Figure 1). Vegetation height and density (in stems per 0.20 x 0.20 m²) are manually assessed using a ruler and aboveground vegetation samples are collected. These vegetation samples are divided into three representing elements, that are separately subjected to three-point bending test, in accordance to Liu et al. (2021), to identify the specific bending modulus.

3. RESULTS

Field data collected between December 2021 and January 2022 indicate that for both measurements, the maximum average vegetation height is about 88 cm and is found in the northern part of the dune (see Table 1). Lowest average values of about 57 and 60 cm, respectively, are achieved in the south-eastern dune zones. Regarding vegetation density, maximum average values of 35 and 23, respectively, are obtained in the north-western dune zones with minimum average values ranging between 8.5 (east) and 9.5 (south-west).

Three-point bending tests were conducted on the aboveground plant parts "stem", "greenish leaf" and "brownish leaf" sampled in December 2021 and January 2022. The average values of the specific bending

modulus are 1700, 2574 and 1866 MPa (December 2021), and 1352, 2459 and 2003 MPa (January 2022), respectively. Depending on the orientation, a correlation between the maximum bending modulus and the north-western dune areas is only observed in January.

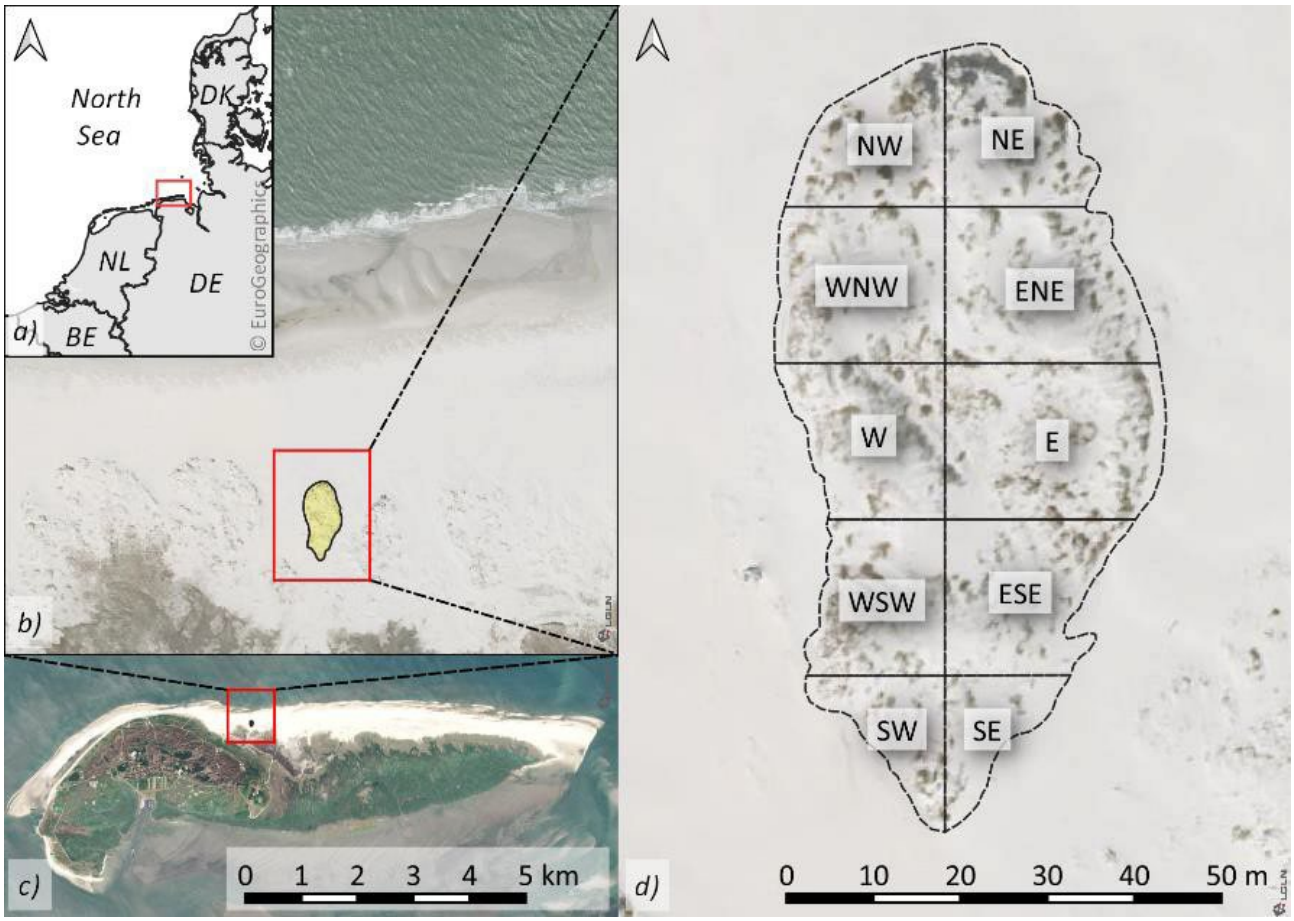

Figure 1: a) Regional map of the North Sea with neighboring coastal countries; b) Birds eye view of the investigated dune c) Overview map image of the tidal barrier island of Spiekeroog with the location of b) marked; d) Detail view of the dune with areal zones delineated. Coordinate Reference System used: EPSG:3034 – ETRS89 – Extended / LLC Europe; ©EuroGeographics for the administrative boundaries. Background image source: TrueDOP – Excerpt from the geodata of the state office for geoformation and survey Lower Saxony, ©2020[1)]

Data	Dune zone									
	NW	NE	ENE	E	ESE	SE	SW	WSW	W	WNW
Zone size (m²)	254.6	268.5	415.8	475.9	327.8	144.5	161.1	276.9	309.4	369.8
December 2021										
V. height (cm)	75.0	88.0	78.5	56.7	73.3	68.3	71.7	72.3	70.0	71.0
V. density	29.0	18.5	34.33	16.0	29.5	11.0	9.5	25.0	35.0	28.5
Sample number	10	10	10	10	10	10	10	10	10	10
January 2022										
V. height (cm)	87.9	68.8	81.1	64.4	83.3	59.4	74.5	75	73.3	72.5
V. density	23.3	13.5	16.0	8.5	15.5	12.5	13.0	17.3	17.0	17.5
Sample number	10	10	10	10	10	10	10	10	10	10

Table 1: Overview of areal size, average vegetation height and density (stems per 0.20 x 0.20 m²)

4. DISCUSSION AND CONCLUSIONS

The data collection will continue monthly (starting from December 2021) as well as complementary parameters serving as a basis for surrogate modelling of dune vegetation for physical and numerical experiments in the light of nature-based solutions for coastal protection.

5. ACKNOWLEDGEMENTS

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6. REFERENCE

Liu, J.; Kutschke, S.; Keimer, K.; Kosmalla, V.; Schürenkamp, D.; Goseberg, N.; Böl, M. 2021. Experimental characterisation and three-dimensional modelling of Elymus for the assessment of ecosystem services. *Ecological Engineering*, 166. doi.org/10.1016/j.ecoleng.2021.106233