Sub-millimeter-resolution digital elevation models created by structure-from-motion photogrammetry provide new insights in dune sediment dynamics during storm and calm periods

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1. INTRODUCTION

Coastal dunes are important features located along the land-sea interface, providing an initial barrier against storm surges and other large-waves event that endanger coastal communities. In addition to absorbing incoming wave energy, coastal dunes collect large quantities of sand transported from the beach. The ability of coastal dunes to collect sand, i.e., trapping sand grains entrained by wind, is highly dependent on their vegetation cover. American beach grass (Ammophila breviligulata) is one of the most dominant dune plant species along the Mid-Atlantic US coast and plays a major role in dune recovery during storm-free(calm) periods and dune stabilization during storms (e.g., preventing washovers).

The ability of beach grass to colonize coastal dunes is largely due to its tolerance to salt spray, heat, and sand burial. Aboveground blades trap wind-blown sand and belowground rhizomes expand in both existing dunes and new dunes. The underground rhizome network functions as a complex root system anchoring the plant and keeping the sand in place. American beach grass is prone to grow, vertically and horizontally (Maun 1998), during periods of accretion and can face deterioration during periods of erosion. In the context of dune growth dynamics, dune accretion coincides with inter-storm periods, whereas dune erosion coincides with strong wind and storm events. This study investigates the impact of coastal storms, exemplified by Tropical Storm Elsa hitting the US east coast on July 9th, 2021, on local plant patch-scale sedimentation and erosion. We first validate a structure for motion (SfM) technique creating sub-millimeter-resolution digital elevation models (DEM) with classic sedimentation-erosion bar (SEB) measurements (Verma and Bourke 2019). And subsequently compare sedimentation-erosion patterns during a calm and a storm period between different plant patch organizations of mimics and natural plants.

2. METHODS

Artificial plants (hereafter mimics) were constructed using zip ties simulating various plant densities of Ammophila breviligulata on an expanding foredune in Cape Henlopen, Delaware, US. Two treatments in three replicates each: sparse (interplant distances of 40 cm) and dense (interplant distance of 10 cm) were deployed on the beach during summer 2021. Sedimentation and erosion in the mimics as well as adjacent natural vegetation was monitored. Field monitoring was conducted before and after Tropical Storm Elsa using sediment erosion bar (SEB) and structure-for-motion (SfM) photogrammetry method using a newly established local coordinate reference system (Agisoft). Digital elevation models (DEMs) produced from photogrammetry were exported as GeoTiffs and post- processed using MATLAB.

3. RESULTS – DISCUSSION

Our results show that spatial averaged sedimentation/erosion data collected with the SfM and the sedimentation erosion bar (SEB) technique are well comparable (Fig.1) showing the potential of sub- mm DEMs for dune monitoring (Fig.2).

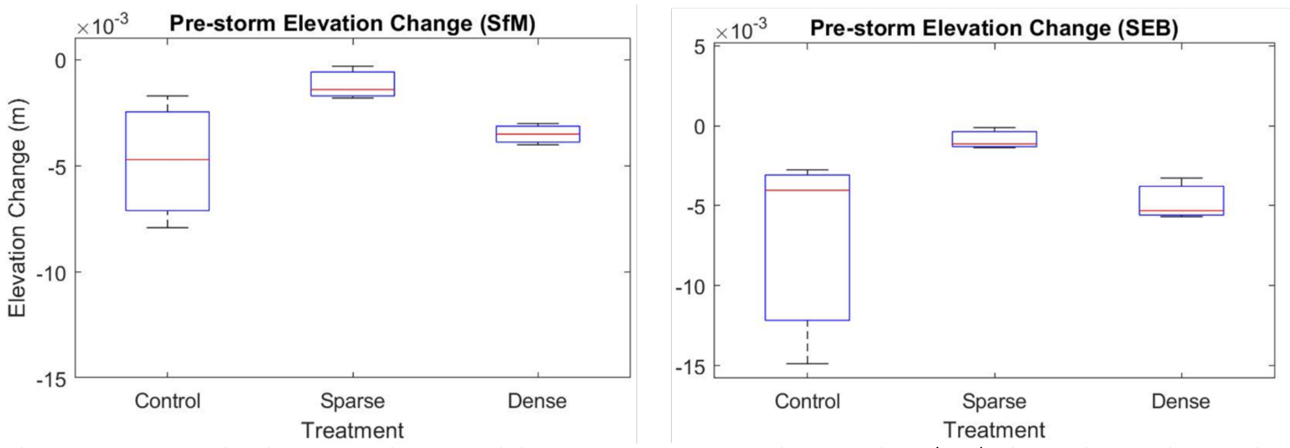

Figure 1: Method validation comparing sub-millimeter structure for motion technique (SfM) with sedimentation erosion bar measurements (SEB). Data was collected at Cape Henlopen state Park, DE, US, measurements were collected from June to August 2021 in a two-wee

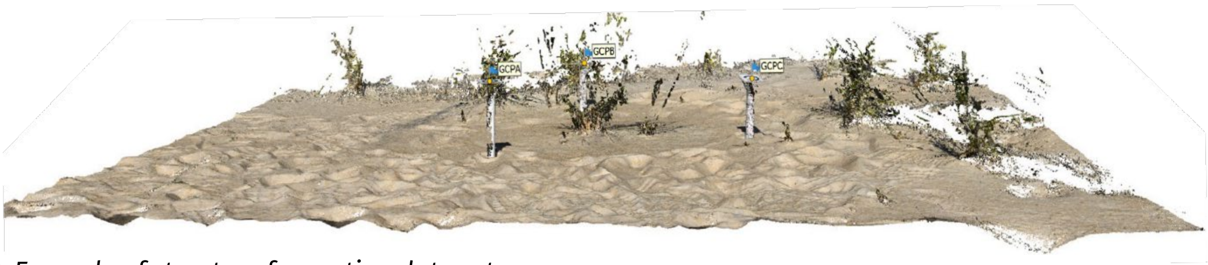

Figure 2: Example of structure for motion data set.

A comparison between the pre-storm and storm observations revealed that sedimentation patterns during calm periods and erosion patterns during storm periods are highly correlated to the spatial organization of the vegetation patches. In turn raising the question of which growth strategies would be optimal to maximize sedimentation during calm periods while minimizing erosion during storms.

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