

THE ROLE OF VEGETATION STRUCTURE ON REDUCING DUNE EROSION AND WAVE OVERTOPPING

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INTRODUCTION

Dunes provided habitat for wildlife and coastal protection against high water levels during storms (Duran and Moore, 2013). The relationship between dune morphology (i.e., dune crest and toe elevation) and extreme water levels (runup and setup) allows to determine the storm impact regime on barrier islands (Sallenger, 2000). On the other hand, dune vegetation is also important for controlling the morphology and the growth rate of dunes (Ruggiero et al., 2018). Laboratory experiments have been conducted over the past decade to elucidate the role of vegetation in coastal protection. The main challenge while conducting physical model experiments is the scaling between the flow, plants, and the sediments. Laboratory experiments suggest that vegetation density reduced wave erosion (e.g., Silva et al., 2016). However, a recent study suggests that dune vegetation can accelerate foredune erosion during extreme events (Feagin et al., 2023). Here, a laboratory experiment is conducted to investigate the role of different vegetation structure, using four different species, on the reduction of dune erosion and wave overtopping.

METHODS

We employed wood boxes filled with sand to grow different dune species. The species employed were *Hymenocallis littoralis*, *Canavalia rosea*, *Cakile edentula* and *Suaeda linearis*. The plants seeds were germinated and transplanted into the boxes in their first pair of true leaves, were growth inside the boxes for 6 months to allow the formation of roots. Eight different boxes were prepared using single species or a combination and including a control box without vegetation (Table 1).

Laboratory experiments were conducted on a 40-m long, 0.80 m wide, and 1.2 m high wave flume. The flume is equipped with a piston-type wave maker with a 1.2 m stroke to generate solitary waves. A fixed bed, consisting on a 1:6 slope followed by a flat-bed, was built in order to induce wave breaking and bore propagation on the testing boxes simulating a vegetated dune. The wave flume was divided by plexiglass to conduct two simultaneous and independent tests with different dune vegetation structure arrays (Figure 1c). A reservoir to measure the overtopping and sediment volume was installed on the lee-side of the dune (Figure 1a).

Table 1 - Dune tests with different vegetation structures. Each test was run with three different water levels and solitary waves.

Test	Box
1	<i>Hymenocallis littoralis</i>
2	<i>Canavalia rosea</i> - <i>Cakile edentula</i>
3	<i>Canavalia rosea</i> - <i>Suaeda linearis</i> - <i>Cakile edentula</i>
4	No vegetation
5	<i>Cakile edentula</i>
6	<i>Suaeda linearis</i>
7	<i>Canavalia rosea</i> - <i>Suaeda linearis</i>
8	<i>Canavalia rosea</i>

Four different water levels ($h = 0.341$ m, 0.391 m, 0.441 m, and 0.491 m) were considered employing a solitary wave with $H = 0.2$ m. Two runs were conducted at each water level in order to evaluate the dune morphology response to 8 solitary waves. The bed level was measured using a laser scanner along a transect without vegetation before and after each run. The overtopping volume was quantified and the sediment was stored for its further analysis (dry and weight). The (wet and dry) vegetation biomass were quantified for each test box considering the aerial (leaves and stem) and subterranean structures (roots).

An independent run was conducted without plants to characterize the swash hydrodynamics at each water level. Resistance wave gauges, an electromagnetic current meter, and Acoustic Doppler Profilers were employed to measure wave transformation and flow velocities at the dune toe and crest.

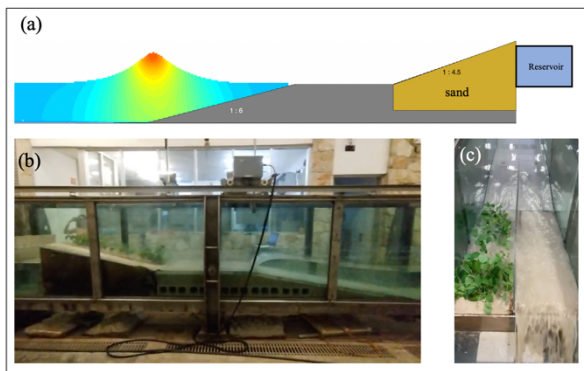


Figure 1 - Experimental setup. (a) Sketch of the location of the fixed bed, movable bed, and reservoir to measure overtopping and sediment volume. (b) Side-view of the experiments. (c) Plan view of the combination *Canavalia-Suaeda-Cakile* and without vegetation.

RESULTS

Wave breaking occurred in the flat bed for the lower water depth condition (Figure 1b), whereas for the higher water depth a direct wave attack occurred at the dune toe. The solitary wave breaking induced a swash event with flow velocity magnitudes similar to the field. Wave overtopping for the control test occurred at all levels, whereas vegetation prevents overtopping for the low water level conditions (see Figure 1c).

The bed evolution for the Tests 1 and 4 are shown in Figure 3. The control test presented a bed elevation decrease along the whole profile for all water levels (Figure 2a). The planar slope change into a convex shape, while the toe remained with small changes. On the other hand, the test with *Hymenocallis littoralis* presented changes near the dune toe, increasing the dune slope. The morphology near the dune crest does not present changes for the first runs (low water levels) due to wave attenuation by the vegetation (Figure 2b). The overtopping volume was significantly lower for the *Hymenocallis littoralis* with respect to the control case. The analysis of vegetation biomass, wave overtopping sediment and water volumes, and morphological changes will be presented in the extended abstract.

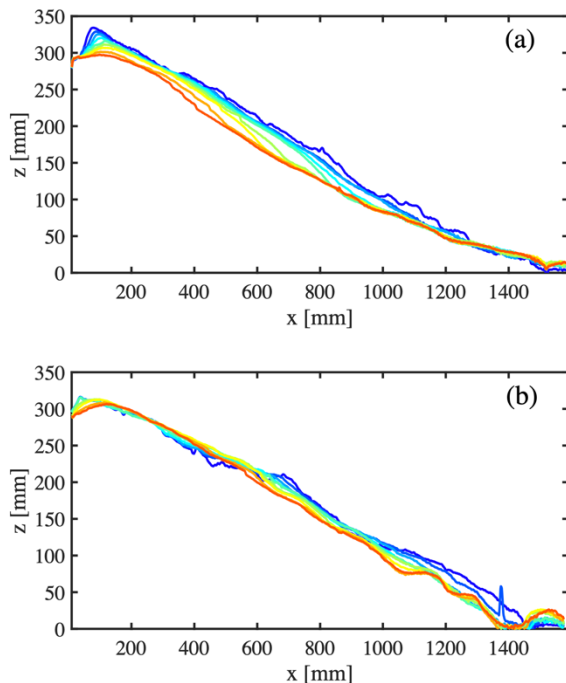


Figure 2 - Dune evolution in (a) the control case (Test 4) and with (b) *Hymenocallis littoralis* (Test 1). The initial and final dune profiles are depicted by the dark blue and dark red lines, respectively.

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