ASSESSMENT OF A NATURE-BASED STRUCTURE TO MANAGE COASTAL DUNE EROSION IN YUCATAN, MEXICO

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BACKGROUND & MOTIVATION

In Yucatan, one of the main causes of coastal erosion is the use of "remedy" measures (groins or "espolones") by communities whom refuses to eliminate them (Medellin, 2015, Ruiz,2016). The erosion management approach has been dominated by engineering schemes resulting in beach values degradation and despite the development of recovery programs, no actions for protection/restoration of coastal ecosystems particularly, dunes have never been undertaken. In addition, dune flattening and vegetation elimination are common practices associated to coastal land use. Today, 56.1% of coast lacks of any type of dune/vegetation and 32% of sandy beaches are <10 m, increasing vulnerability to erosion and other natural hazards (Cuevas, 2016).

In this sense, the use of solutions designed to harness and mimic natural processes are emerging as an innovative approach for ecosystem restoration and erosion management. This work assessed a nature-based structure (NBSt) capacity for dune building due to wind-blown sand accumulation and vegetation expansion for potential applications on erosion management.

NATURE-BASED STRUCTURE AND STUDY SITE

The nature-based structure (NBSt) was design and built following and accomplish the next principles:

- Biomimetic design that mimics dune vegetation function promoting/enhancing wind-blown sand trapping and was based on the architectonic concept of linear structures which is a reduction of any volume to lines.
- Environmentally friendly through the use of recycled materials from octopus fishery (bamboo poles or "jimbas"), henequen rope and seawrack as part of foundation. Biodegradable, easy elimination, low cost element and easy to replicate (compared to conventional schemes).
- NBSt followed recommendations for orientation and porosity used on conventional methods for dune building. The structure (≈5 x1.20 m) was installed ≈1.5 m seaward from dune toe and behind high tide level to ensure its permanence.
- Tool for coastal dune erosion management: being an element into coastal landscape to wide aesthetic value of coastal ecosystem, creating awarness and community participation in dune/vegetation care.

STUDY AREA

NBSt was built in Chelem, a highly urbanized beach with dense structural engineering on shoreline due to erosion rates. Study site is located in Yucatan peninsula, a low lying coast subject to a microtidal regime and characterized by low wave energy conditions (Hs=1 m, Tp<4 s) except during winter and tropical storms. Area is subject to easterly trade winds, local breezes and winds from north associated with cold-fronts ("Nortes" season November-February). Beach presents a gentle slope (5%), widths <15 m. Patches of dunes and vegetation are found in the zone.

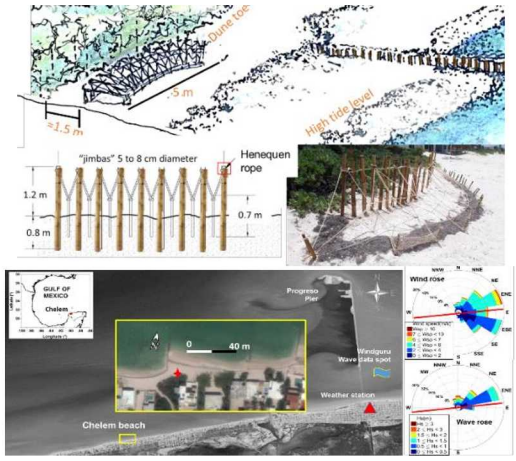

Figure 1. a) Nature-based structure sketch, b)Study site in Chelem beach, c) Wind and wave conditions during study period(Jul 22th.2017 - Feb 21st,2018).

MONITORING METHODOLOGY

Wind and wave data conditions were obtained from the nearest wheather station (Davis vantage Pro2, anemometer 10-m from ground) and from windguru forecast website respectively, to investigate directions from where sand should be transport for dune building and to associate beach changes and damages to structural design. Winds from SE directions were not considered (Fig.1) Beach profiles, adjacent and across NBSt, were carried out to estimate sand volume accumulated (m3/m) due to wind. Grain size distributions (D50, Sorting σ) were calculated from samples on beach berm, natural dune (before NBSt emplacement) and NBSt trapped sand along study period. Wind-blown sediment transport was estimated according to Coastal engineering manual using Hsu (1986) relationship and results were compared to volume measured from beach profiling. Threshold wind for transport was compared to threshold speed at which sediment fluxes were registered by a piezoelectric sensor to quantify aeolian sand transport (Raygosa et. al, 2017). Vegetation expansion was documented.

RESULTS

NBSt capacity for dune building was controlled by the occurrence of favorable and adverse conditions. Maximum accumulation behind NBSt was observed (July 22th - Aug 20th & Dec 17th, 2017- Feb 21st, 2018) under the favorable conditions (Fig.2a) of:

-High frequency winds blowing from NE-ENE, typical directions of sea-breezes in the zone.

-Mean wind speed from those directions was 5.5 m/s or more reaching maximums of 8 m/s.

-Low occurrence of northerly winds and low energy waves.
No accumulation was observed (Sept 15th- Dec 17th,2017) under adverse conditions (Fig 2b) of:
- Increment of northerly winds (NNW-NNE) related to rains and cold-fronts during winter season (Nov-Feb).
- Wind speed from those directions averaged 5.4 m/s, exceeding northeasterly mean speeds.
- Despite frequencies and persistency, northeasterly directions reduced mean speed to 4.6 m/s, diminishing wind capacity for transport.
- Waves (Hs>2m) associated with storms eroded beach and washed off wind-blown sand deposited at the initial part of study period.

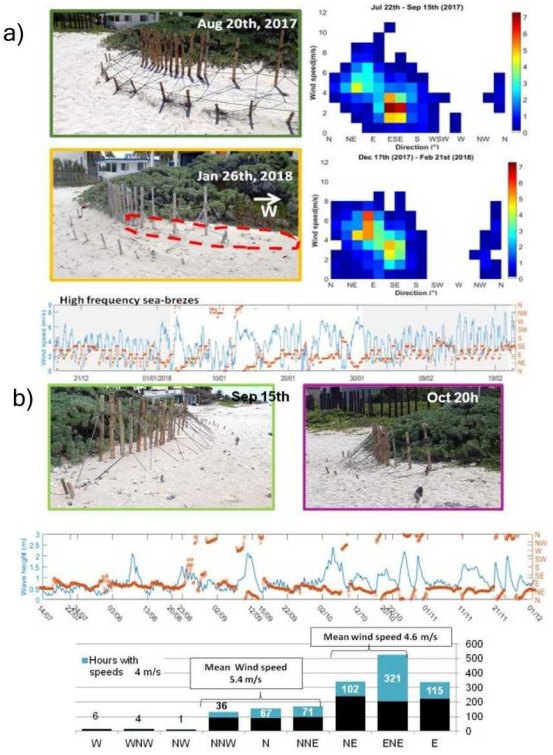

Figure 2 a) Favorable, b) adverse conditions to NBSt for dune building

Grain size distributions indicated that NBSt induced deposition of medium sands (average D50: 0.24 mm) moderately well sorted to well sorted. A natural wind-blown sorting was identified. Trapped sand showed to be coarser than those in natural dunes (D50=0.21 mm, very well sorted) but finer than beach berm (D50=0.39 mm, moderately sorted).
According to volume change obtained from average profiles (beach profiling in Dec 17th, 2017 and Feb 21st, 2018), NBSt induced the accumulation of 0.11 m3/m. Volume and textural characteristics allowed the expansion of *Sesuvium portulacastrum* creepers acting as sand binding specie on the seaward dune face.
Treshold value for transport was calculated on 6.1 m/s for 0.24 mm (D50) particles (Theoretical model). Wind measurements exceeding threshold value indicate that greatest potential for wind transport occurred from Dec-Feb but diminishing from Jul-Sept,2017 (Fig.3) as field observations confirmed. The largest volume of transported material was produced from the ENE (0.65 m3/m) and NE (0.25 m3/m) directions. Resulting potential transport was directed towards W-WSW (Fig. 8) following shoreline orientation as depositional pattern showed (Jan 26th, Fig 1a).

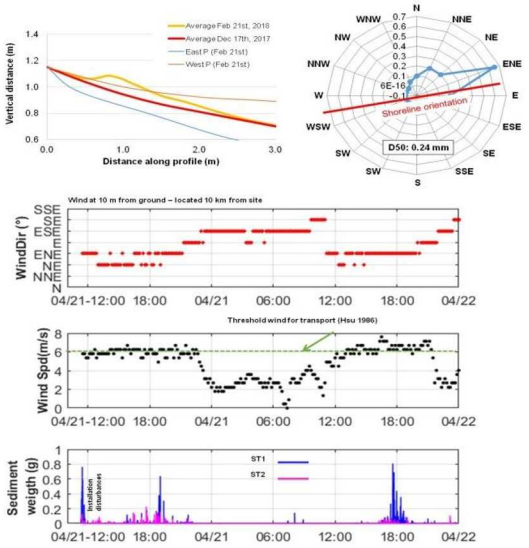

Figure 3 a) Accumulated volume induced by NBSt, b-c) Wind-blown sediment transport and sediment fluxes from field test usign piezoelectric sensors

Two traps (piezoelectric sensors) were installed in front (ST1) and behind (ST2) a conventional fence using same materials as NBSt. Measurements indicated that maximum fluxes are related to seabreezes (NE-ENE) with peaks around18:00 and wind speeds around 6 m/s.

CONCLUSIONS

Implementation of nature-based solution are suitable for dunes protection/restoration in zones where beaches values are degraded. NBSt capacity for dune building due to wind-blown sand was controlled by oblique wind directions typical of sea-brezees regime (ENE-NE) and speeds ≥5.5-8m/s allowing vegetation expansion.
NBSt structural design showed robustness and a high potential to be used as part of dune erosion management approach.

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