Investigation of Sediment Cells in a Michigan Dune System

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Abstract

Determining the sources and sinks for sediments in a coastal system is an important part of calculating sediment budgets, but this analysis has not been extended from the shoreline into Michigan dune systems. Our study explores the patterns of sediment movement on a parabolic dune system in P.J. Hoffmaster State Park to identify cells of sediment movement. We made predictions of erosion, deposition, and stable areas based on the presence of vegetation, spatial patterns and topography, and evidence of sediment disturbance; we mapped our predicted areas using GPS. We measured sand movement over a two-week sample period using erosion pins, and the data was compared to the predicted areas. Two clear cells of sediment movement were suggested by the data: 1) from the beach and scarp to the windward foredune and 2) from the windward side of the parabolic dune crest to the slipface. In general, predictions were consistent with the collected data. Some anomalies did occur, such as deposition occurring on the windward side of the foredune. Our results indicated erosion areas were easy to predict from the bare sand, but deposition and stable areas were more difficult to predict because of vegetation.

Introduction

Sediment movement in a dune system is highly dependent on the type and amount of vegetation [1], and sand can move in cells similar to those found in the littoral environment. Understanding these cells and their interactions can benefit coastal management. This study investigated sediment cells, including sources and sinks, in a parabolic dune system.

Study Objectives:

- Predict and measure areas of erosion, stability, and deposition.
- Determine factors that influence erosion and deposition by observing vegetation presence in those areas.
- Identify sediment cells.

Study Area

Our study area was located on the Lake Michigan shore in Hoffmaster State Park (Fig. 1). The study focused on a parabolic dune system (Fig. 2) at the southern end of the park.

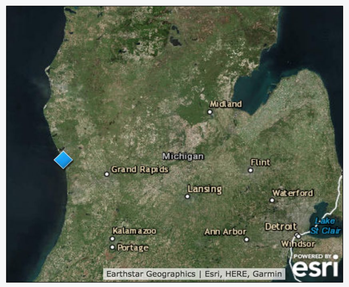


Figure 1: Location of Hoffmaster State Park (blue diamond).

Figure 2: Oblique aerial view of study area (US Corps of Army Engineers 2012).

Methods

We predicted areas of sediment movement on the dune according to four criteria (Table 1). We mapped those areas using GPS. We measured vegetation type and density using a quadrat survey. We measured sediment change using erosion pins over a period of two weeks. From measurements of adjacent erosion and deposition areas, we identified sediment cells.

Predicted Movement	Vegetation Type	Vegetation Density	Sediment Disturbance	Topography
Erosion	None or pioneering species [2]	Low	High	Windward slope, depression areas
Deposition	Pioneering species or forest	Moderate to high	Moderate to high	Leeward slope
Stable	Forest, collection of organic debris	High	Low	Variable

Table 1: Criteria for prediction areas.

Results

Predictions:
We predicted areas of erosion on the windward slopes and in blowouts on the parabolic dune, and deposition on the leeward slopes and more vegetated areas (Fig 3). We also predicted a large stable area in the center of the dune due to the presence of mature vegetation.

Measurements:
Our measurements showed that erosional areas were on the beach, leeward foredune, dune ridge, and main trough. Depositional areas were on the windward foredune and in the foredune trough (Fig. 3). Vegetation was present throughout the dune, with a minimal number of plants being present on blowout areas. Vegetation was most abundant on the windward foredune, and the main trough was inhabited with a large, mature forested area (Table 2).

Comparison:
Our predictions did not always match our measurements, with agreement between them found only on the foredune trough and the dune ridge (Table 2).

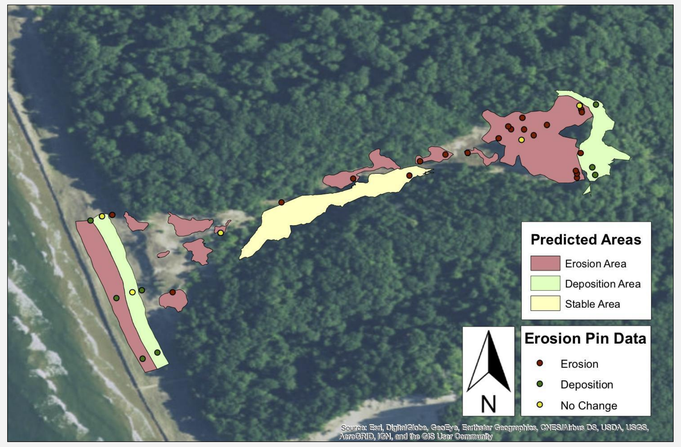
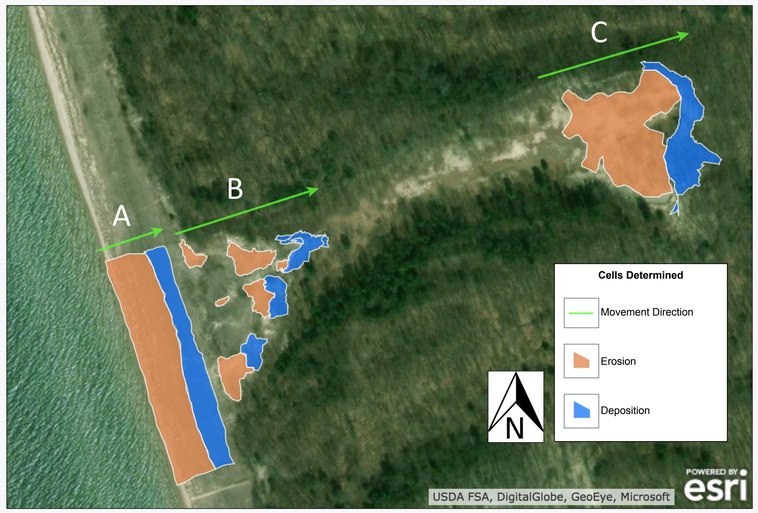


Figure 3: Shaded areas indicate predictions, points represent data collected.

Dune Area	Average Number of Plants per m^2	Predicted Sediment Movement	Measured Sediment Movement
Windward Foredune	60	Erosion	Deposition
Leeward Foredune	30.6	Deposition	Erosion
Foredune Trough	24	Deposition	Deposition
Dune Ridge	30.6	Erosion	Erosion
Main Trough	15.3	Stability	Erosion

Table 2: Predictions and measurements for each dune area.



Sediment Cells:
The data we collected showed evidence of two sediment cells (A and C) (Fig. 4). We were able to predict a third cell in the middle of the dune (B). In Cell A, sediment moved from the beach to the foredune. In Cell B, sand moved from a series of blowouts to the local slipfaces in a vegetated area. In Cell C, sand moved from a series of blowouts near the top of the dune to the terminal slipface. Sediment movement was generally to the northeast, consistent with wind data from the study period.

Figure 4: Sediment cells and direction of sediment movement.

Discussion

As we expected, areas with sparse vegetation were good indicators of erosional areas (Fig. 5), and our results suggest that there was a significant deposition area on the slipface. Unexpected deposition occurred on the windward side of the foredune, which was likely due to the beach being a source of sediment.

These cells show how sand moves within the dune in compartments, with defined areas of sediment sources and sinks. Further measurement over a longer period of time would be necessary to determine if the cells are a closed system or if they lose or gain sediment.

The first cell showed movement landward from the beach to the foredune, which would make the dune a sediment sink. The movement in this cell, however, may be reversed by changing beach conditions.

Figure 5: Blowouts were a reliable sediment source area.

Conclusions

Our study predicted surface-change areas based on several indicators, but measurements did not support most of our predictions. Vegetation was a poor indicator of sediment change, but performed better when considered with other factors. Three major sediment cells were observed on this dune, showing that estimation of erosion and deposition areas, once the method is refined, can predict sediment cells.

Acknowledgements

We would like to thank our professor, Deanna van Dijk, for providing us the support and resources we needed to succeed. We would also like to thank Calvin College, Department of Geology, Geography, and Environmental Studies, and Hoffmaster State Park for allowing us to complete our research there. Funding was also provided by the Michigan Space Grant Consortium.

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