A Comparison Between an Artificial Dune and Lake Michigan Coastal Dunes

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Abstract

In August 2020, Calvin University brought 630 tons of sand to its campus, 40 miles from Lake Michigan, to simulate a dune environment as a COVID-19 adaptation for student research. Our research focused on how this artificial dune named Perseverance Dune compares with Lake Michigan dunes and whether sand is leaving the dune area over time. At Perseverance Dune, we measured minerology, grain size distribution, wind characteristics, erosion, deposition, sand depth, spread, and slope angles as well as collecting observational data and aerial imagery. We compared these with prior research, LiDAR data, and sand samples from the Michigan lakeshore. Our results show that Perseverance Dune is a layer of sand roughly 41 cm deep spread over an existing slope which determines its slope angles. The sand is smaller than Michigan dune sand but has a similar composition with mostly quartz grains and traces of magnetite. Sand is leaving the dune, but surface changes from wind processes are consistent with coastal dunes. However, water erosion on the lower dune is unusual. Measurements suggest the dune will shrink in sand volume over time. Similarities with Lake Michigan coastal dunes make Perseverance Dune a suitable simulation for certain various kinds of dune research.

Introduction

Dunes are sometimes constructed by humans for coastal management [1] but rarely for research purposes. However, in August of 2020, Calvin University created an artificial dune on its campus for student research (Figure 1). Our project focuses on how the artificial dune, named Perseverance Dune, compares with Lake Michigan coastal dunes.

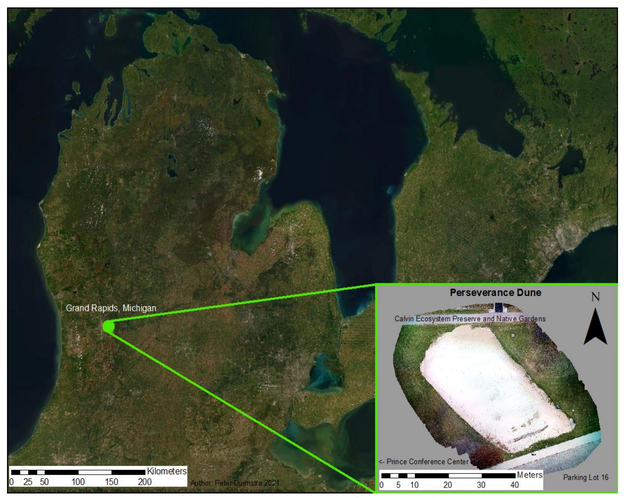

Figure 1: Study site location in Grand Rapids is roughly 40 miles from Lake Michigan dunes

Study Objectives

1. To investigate the general characteristics and variables that affect Perseverance Dune.
2. To complete a detailed investigation of the sediments of Perseverance Dune.
3. To compare these results to Michigan coastal dunes.

Methods

We employed a variety of methods to investigate dune characteristics and sediments for Perseverance Dune (Table 1; Figure 2) and Lake Michigan dunes. Then we compared the results to identify similarities and differences.

Objective	Variable	Method for Perseverance Dune	Method of comparison to Michigan dunes
#1: Investigate characteristics and variables	Dune slope angles	Abney level	LiDAR
	Dune dimensions	Aerial imagery and field measurements	LiDAR and literature
	Sand movement	Erosion pins, field observation	Literature review
	Wind patterns	Wind vanes, anemometers.	Literature review
	Dune vegetation	Field observation	Literature review
	Animal activity	Field observation	Literature review
	Human activity	Field observation	Literature review
#2: Investigate sediments	Sand grain size	Dry sieving	Analysis of sand samples from lakeshore and literature review
	Sand mineralogical composition	Examination under microscope	
	Dune depth/height	Coring	Literature review

Table 1: Variables and methods for assessing dune characteristics

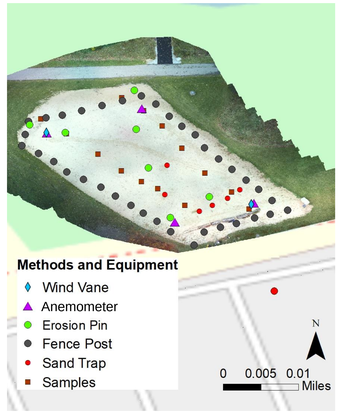

Figure 2: Perseverance Dune method locations

Results

Perseverance Dune is ~23 m wide by 40 m long with a rectangular shape. The dune is composed of a layer of sediments (average depth of 41 cm) on top of an existing slope with the previous lawn beneath the dune (Figure 3). Dune slope angles range from 0° to 7°. In addition, a variety of early successional dune species were planted on Perseverance Dune.

There is evidence that Perseverance Dune sand is moving due to wind, human transport, water erosion, and deer activity (Table 2). Perseverance Dune sand is composed of >98% quartz but with trace amounts of magnetite (Figure 4). The majority of grains are between 250 – 180 micrometers.

Most Lake Michigan dune characteristics had wider ranges for variables (Table 2), including slope angles and directions (Figure 5).

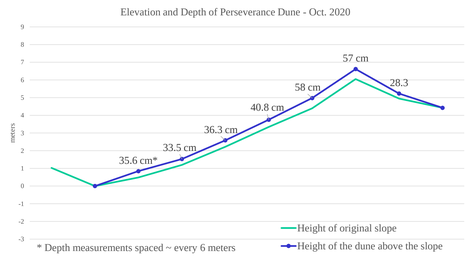

Figure 3: Height of Perseverance Dune and underlying slope

Perseverance Dune		Lake Michigan Dunes	
Variables	Results	Comparison Data	Source
Dune shape	~Rectangular	Elongated ridges or parabolas	LiDAR (Figure 2) and [2]
Dune dimensions	23m x 40m – and spreading	400m-600m long for parabolic dunes	LiDAR (Figure 2) and [2]
Dune depth/height	~ 41 cm	~5-15m for dune ridges ~50-55m for parabolic dunes	[2]
Dune slope	0°- 7°	0°- 26.5° for windward faces 26.5°- 41.5° for leeward faces	LiDAR (Figure 2)
Sand movement	By wind, water, and humans - An unusual amount of fluvial erosion was observed.	Wind is the major process. Water also plays a role.	[3]
Wind patterns	Average speed = 1.2 m/s Max speed = 3.7 m/s Average direction = 212°	Average speed = 8.0-6.0 m/s Average direction = West	NREL wind data and [2]
Dune vegetation	Bare sand and sparse forbs and grasses are on the edges.	Young dunes: mainly grasses- occasional other herbaceous plants Older dunes: more herbaceous plants and grasses, shrubs and vines, trees such as cottonwood, basswood, and jack pine Later succession: mesic forest	[3]
Evidence of human and animal activity	Human footprints Tracks from deer, small mammals, and birds.	Human foot traffic and recreation Tracks from deer, small mammals, and birds were observed.	[4] and field observation
Sand grain size	Majority = 250 - 180 µm All = 250 - 63 µm	Majority = 500 - 250 µm All = 2,000 - 62.5 µm	[5]
Sand mineralogical composition	>98% quartz, traces of magnetite	Magnetite present, peaking at 40-50% in fine sand. Percentage of quartz peaks at between about 80-90% in light colored sand.	[5] and [6]

Table 2: Summary of results and comparison to Lake Michigan dunes

Figure 4: Perseverance Dune sand

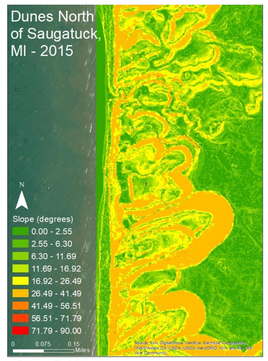

Figure 5: Michigan dune slope angles

Discussion

Perseverance Dune's dimensions are not usual for Michigan coastal dunes, but its shape and depth may continue to change as processes act on the dune. The slope upon which Perseverance Dune is spread gives it slope angles similar to those of the top of a foredune or the lower windward slope of a parabolic dune. Although the vegetation is similar to early successional dune vegetation, it is possible that inland plant species may invade the Perseverance Dune area.

Evidence was found of wind activity and processes moving sand on Perseverance Dune. However, the amount of fluvial erosion was abnormal (Figure 6). This is possibly due to the layer of grass below the dune that impedes infiltrating water.

Perseverance Dune sand and Lake Michigan dune sand have similar mineralogical compositions possibly because they derive from similar glacial deposits. The smaller grain size on Perseverance Dune will make it more susceptible to aeolian processes. Since there is no natural supply of sand to replenish it, we can expect Perseverance Dune to diminish in sand volume over time.

Figure 6: Fluvial erosion on Perseverance Dune

Conclusions

Perseverance Dune has similar sediment characteristics and processes acting upon it as Michigan coastal dunes, despite not being in a coastal environment. However, the water erosion, shape, and depth of Perseverance Dune are unusual. With no nearby sand sources, the dune is expected to diminish in sand volume over time. But Perseverance Dune does simulate coastal dunes enough to support research on sedimentology, sand movement, vegetation, and aeolian processes.

Acknowledgements

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