Erosion Assessment Using Unmanned Aerial Vehicle Imagery and Geospatial Data at Humboldt Coastal Nature Center, Manila, California

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ABSTRACT

Erosion in dunes systems is a double-edged sword - too little erosion can inhibit natural dune formation, and too much can be indicative of an unhealthy dune system. An erosion index model was created to get an overall picture of current predicted erosion in an area of dunes managed by the Friends of the Dunes in Manila, California. Five factors, Slope Length x Slope Steepness, Aspect, Ground Cover, Official Trails, and Social Trails, and one exclusion, Beach, were used to create this model. The model found that the erosion in the foredunes was high, but this may be due primarily to the many social trails running through the area. The model predicted higher erosion for the eastern edge of study area. Running this model, or a modified version of it, on different sections of dunes within Humboldt county would help provide context and start creating an overall picture of what healthy dune erosion *should* look like.

1. INTRODUCTION

The Humboldt Coastal Nature Center located in Manila, California and run by the non-profit, Friends of the Dunes, sits on an area overlooking more than a thousand acres of Pacific coastline, much of this area being covered in dunes. Coastal dune morphology is determined by the interactions between winds, sediment supply, and the geomorphology of the surrounding environment (Sloss, et al. 2012). Because of this dune system health in many ways is tied to erosion; too much, too little can be indicative of an unhealthy or unnatural dune system.

The objective of this project was to get an overview of the erosion at the dunes at the Humboldt Coastal Nature Center by creating an erosion potential model. Erosion potential is often computed using geographic information systems (GIS) with factors such as land use, slope, soil type, and precipitation (Jain & Debjyoti, 2010). Due to the small size of the study areas common factors such as rainfall, soil type, and wind speed had to be omitted as available data did not have a fine enough spatial resolution. This project did identify five other factors contributing to erosion at a high enough resolution that a model could be created. These factors were Slope Length x Slope Steepness, Aspect, Ground Cover, Official Trails, Social Trails. All the data used here came from the manipulation of Unmanned Aerial Vehicle (UAV) imagery of the project area gather early fall 2018.

2. METHODS

Five factors, Slope Length x Slope Steepness, Aspect, Ground Cover, Official Trails, Social Trails, and one exclusion, Beach, were used to create the erosion index. Due to the small size of the study area land use, rainfall, wind speed, and soil type are all presumed to be effectively homogeneous over the entire area.

Each factor and exclusion was given a weight between 0-10 with a 0 representing zero erosion and a ten representing high erosion.

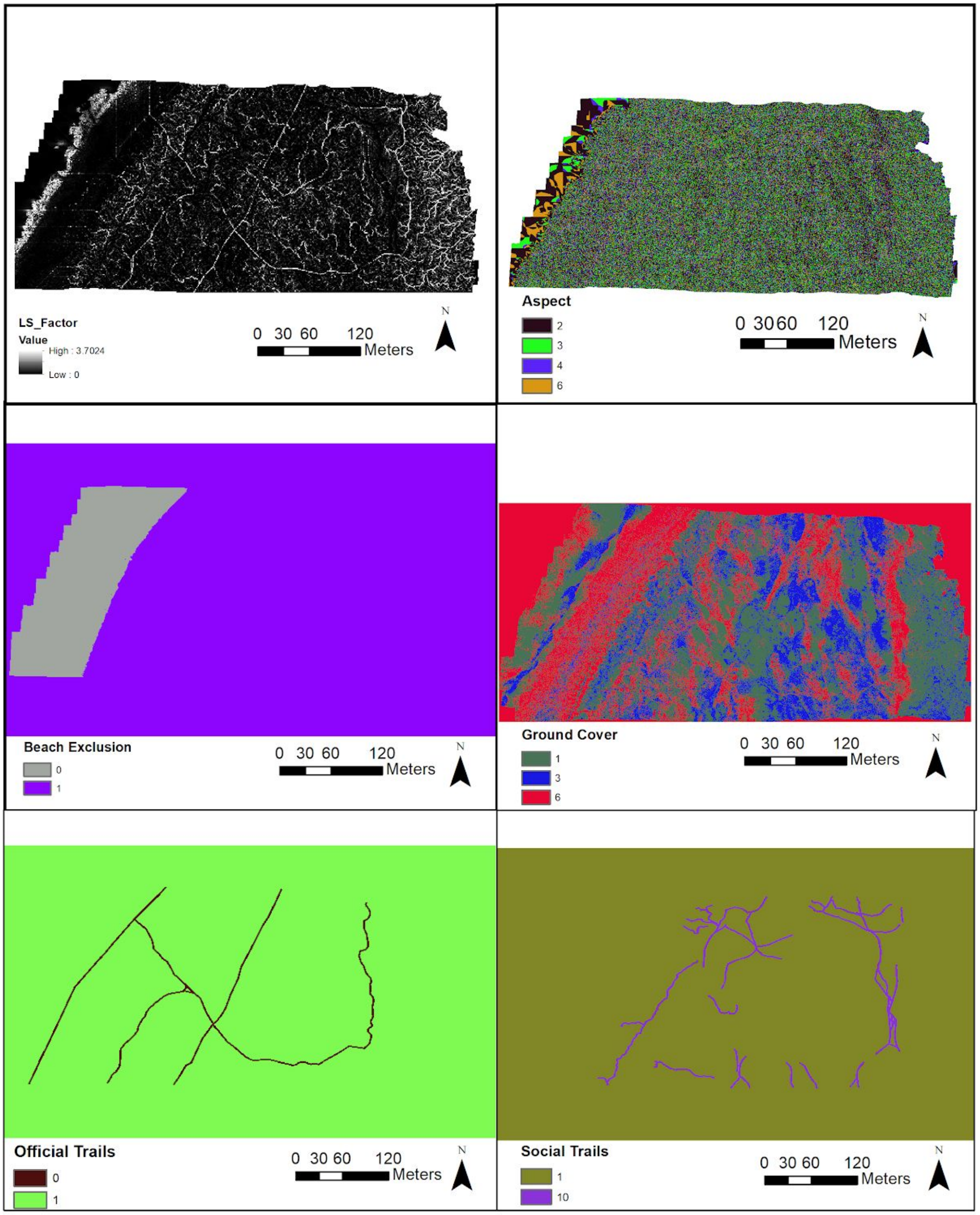

Figure 1. Five factors and one exclusion, in order from left to right, top to bottom; Slope Length x Slope Steepness, Aspect, Beach Exclusion, Ground Cover, Official Trails, and Social Trails.

2.1 Factors

2.1.1 Slope Length x Slope Steepness

Slope Length x Slope Steepness, also known as LS Factor predicts erosion based on the ratio between the length of the slope and how steep the slope is; the longer the slope and the more steep the slope is the higher rate of erosion (Pelton, et al, 2014).

Using the study area DEM and Arc Hydro Tools Flow Direction, Flow Accumulation, and Slope were found and multiplied together using the Raster Calculator tool using the formula:

LS=Power(*"Flow Accumulation"* Resolution/22.1,0.4) * Power(Sin("Slope"*0.01745)/0.09,1.4) * 1.4.

Here resolution means the resolution of the DEM, so for 30m x 30m a 30 would be used here. Due to the high resolution of the DEM .33 or a meter was used for creating this LS Factor. (Figure 1).

2.1.2 Aspect

Aspect is the cardinal direction that each slope faces. As noted by Agassi et. al (1990), weather affects erosion stronger on the windward slope rather than the leeward slope so aspect can be used in this case to get an idea of how weather would affect the project area despite the resolution such data being to small. Using ArcMap's Spatial Analyst tool, the aspect was created from the DEM. Most common monthly wind directions were calculated from Natural Resources Conservation Service (NRCS) National Water & Climate Center's yearly windrose data for Arcata.

Table 1: Wind Direction Per Month

Month	**Strongest Direction**	**2nd Strongest**
January	E	SE
February	SE	E
March	SE	NW
April	NW	E
May	NW	-
June	NW	-
July	NW	-
August	NW	-
September	NW	-
October	NW	E
November	SE	E
December	E	SE

Table 2: Wind Direction Totals

N	0
NE	0
E	5
SE	5
S	0
SW	0
W	0
NW	8

The aspect was then reclassified and assigned weights; more windward facing slopes were given a higher weight, predicting more erosion, and more leeward facing slopes given a lower weight (Figure 1).

Table 3: Aspect Cost Adapted in part from:

Flat	1
N	2
NE	2
E	4
SE	3
S	2
SW	2
W	2
NW	6

2.1.3 Ground Cover

Plant species are highly influential on soil erosion. Species like *Ammophila arenaria,* or European beachgrass, a perennial invasive grass species, drastically change the natural shape of dune systems and how they naturally change over time. *Ammophila arenaria* will form a "higher, steeper foredune, decreasing sand flow to interior dunes (Pickart, 1997). This change in sand flow decreases the speed of natural dune erosion and formation, and will alter the natural succession of native plants, allowing the *A. arenaria* to further replace native species in dune systems (Pickart, 1997).

In order to account for the role of ground in erosion, a ground cover classification was used created by DeYoung, Wood, Corro, Mcdermott, Emerson, and Christiansen. This classification did not identify all plants species in the study area but did divide them into classes based on their general characteristics that could be reclassified based on predicted effect on erosion. Groups such as "YellowPlant", "Beach Bucketweet", "Longerwhitishplant", "BeachGrass", "BeachShrub", "LightgreenShrub Tree", and "DarkerGreenTreeBeachPine?" being given a value of 1, under the assumption more ground cover will equal lesser erosion. *Ammophila Arenaria* fell within this category. Classes “ShortRedMossyStuff”, and “ShortBrownDeadlookingGrass”, were given a value of 3 as the sparseness of this ground cover will do less hold back erosion. Classes “Sand”, and “Shadow”, were being given a value of 6 as the lack of ground cover will allow for the highest rate of erosion (Figure 1).

2.1.4 Trails

The trails within the study area were digitized previously from the UAV imagery by Kennedy, MacAdam, Bueche, Becker, Massey, and Sandhu.

2.1.4.1 Official Trails

A one meter buffer was applied to theses trails. As the official trails maintained by the Friends of the Dunes, these trails have not changed much over the years and are thus given a 0 within the model (Figure 1).

2.1.4.2 Social Trails

A one meter buffer was applied to theses trails. For these trails a value of ten was given as it was theorized that these trails, because they were not being maintained, would have a very high rate of erosion, not just from natural causes, but due to the social nature of the trails themselves (Figure 1).

2.2 Exclusions

2.2.1 Beach

The beachfront was excluded from the final calculations due to frequent tides and storms that make erosion in this area so constant that it does not make sense to include in the model. The beachfront was defined as the sand between the ocean and the start of the first permanently growing plants. As this area is all generally under a certain elevation and the dunes above this height the DEM was reclassified to be only these two classes. This classification was converted into a polygon shapefile and using the aerial imagery any artifacts were removed, such as a few small areas deep within the dunes themselves which were below the designated elevation. The new shapefile was given a value of zero, which would then effectively remove this area from the finial calculations when all the factors were multiplied (Figure 1).

2.3 Calculations

Using ArcMap 10.5.1 Raster Calculator, all five factors and one exclusion were multiplied together to get the total weight, the erosion index, of each pixel (Figure 2).

3. RESULTS

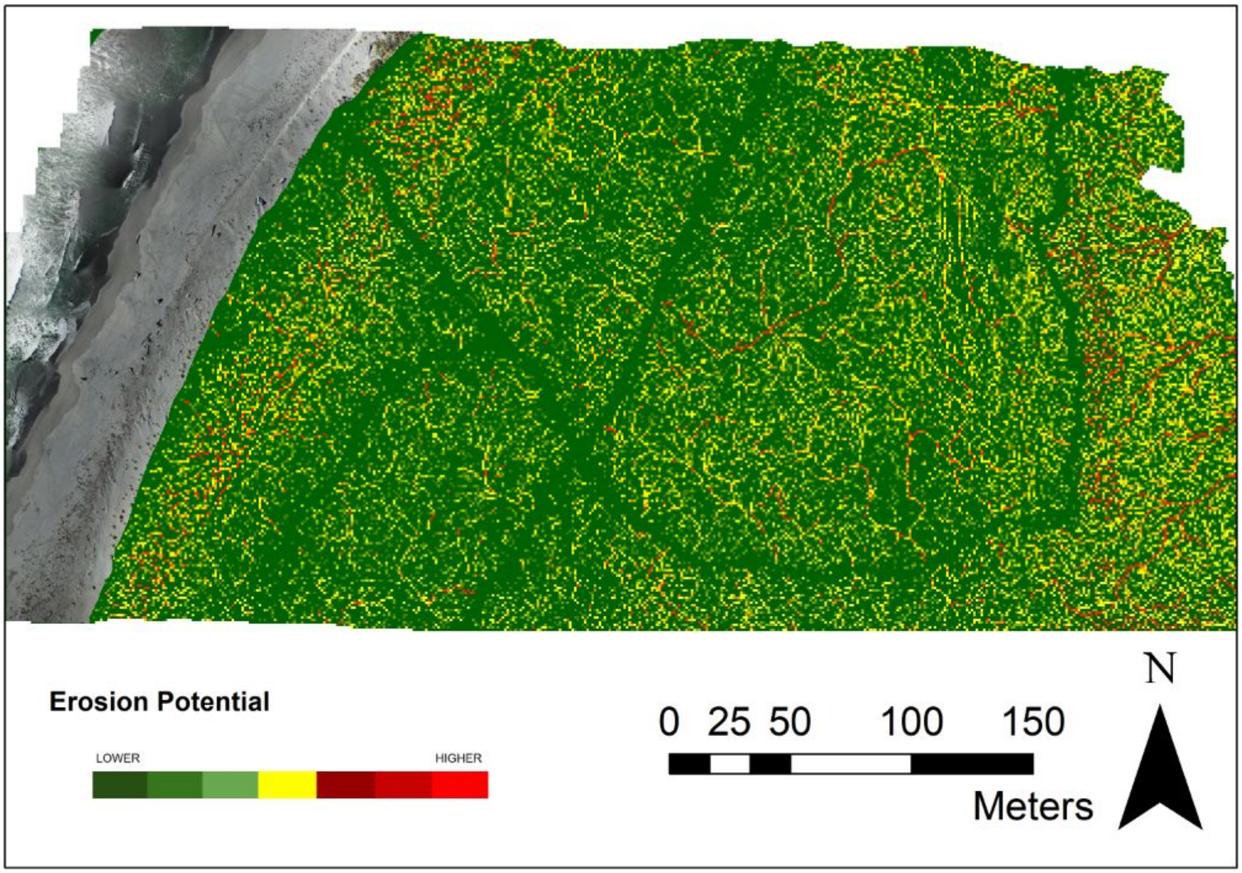

Figure 2: Erosion Risk Potential Map of Dunes surrounding Humboldt Coastal Nature Center, Manila, California .

Visually the results can be broken up into four groups, the beach, which was excluded from the calculations, the foredunes (the swath of yellow and red on the left), the middle (dominated by the low erosion lines of the Friends of the Dunes official trails), and the eastern edge (the grouping of red and yellow on the right handside of the image). The eastern edge and the foredunes appear to have the highest potential for erosion, while the middle has some areas of higher erosion potential mostly centered around the social trails, but overall the erosion potential there is relatively low.

4. DISCUSSION

The high erosion potential for the foredunes is especially surprising given the high levels of *A. arenaria* present. It appears that at least in this case the the presence of European beachgrass is partially countered by the steepness of the dunes and the dune slopes in this areas being primarily windward facing. This area also has a high number of social trails especially in the north-western quarter.

The high erosion on the eastern edge may be partially a result of an artifact of the DEM rather than a perfect reflectance of erosion. This part of the study area happens to be the only part which is covered by relatively dense tree cover. Because the DEM was not made from Lidar data which can penetrate that tree cover, exaggerated LS Factor values were most created here as the tools measured the slopes of the trees rather than the ground itself. The rough north to south area of red in this area correlated to a steep windward facing slope roughly parallel to the official Friends of the Dunes trail, however, curiously there are streaks of higher erosion running through this area which do not correlate to any known factor or social trails.

5. CONCLUSION

Erosion in dunes systems can be something of a double-edged sword; dune movement is normal for dunes systems, but at the same time too much erosion, or erosion in the wrong places can be indicative of an unhealthy system. High erosion in the foredunes in to be expected, however much of this erosion is center around the many social trails riddling these dunes, which is not ideal. The removal of European beachgrass and the social trails in this area would go a long way to promoting a healthy dune system.

The lines or higher erosion in the eastern edge is notable enough that it would be interesting to investigate from the ground.

This erosion index could be greatly improved with a few data upgrades. A Lidar based DEM would help to remove artifacts created from tree cover. A more robust ground cover classification would also go along way to helping create a better model as well help indicate overall dune health. This could be accomplished by ground truthing or using hyperspectral data to really hone in on what species are where, which can be crossed checked with other research to break the current, rather broad classification, into smaller, more accurate parts.

Overall the erosion index is a positive start, however it sits somewhat out of context. To really understand this area, or really any dunes system in Northern California many more project areas would need to be indexed and thus a comparison can be made.

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