Predicting Slope Stability After Tree Removal in a Coastal Dune Environment

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Introduction

Ceratocystis fagacearum, commonly known as oak wilt, is a destructive forest pathogen which targets and kills oak trees [1]. In order to stop the spread of infection, selected oak trees are killed and their trunks removed. ArcGIS may help determine the most effective treatment method and the stability of the environment after tree removal.

The objectives of the study are:

- To use ArcMap to document the locations and quantity of removed trees;
- To use geospatial analysis to predict the location of future slope instabilities.

Background

Standard mitigation practices for areas infected with oak wilt require severing underground root systems and destroying all above ground material [1]. Resource managers are exploring whether an experimental treatment used elsewhere may be an effective mitigation method in North Ottawa Dunes (Table 1).

Traditional Trenching	Experimental Treatment
Trench 2 meters wide and 2 meters deep	Circle with a radius of 50 meters with infected oak tree in the center
Kills all trees located within the trench	Kills only oak trees located within the circle
Tree removal can be spread out over larger distance	Localizes tree removal to a more concentrated area

Table 1: Key differences between the two mitigation methods.

Study Area

The study was conducted in North Ottawa Dunes, a county park located in Ottawa County (Figure 1). The park consists of 513 acres of forested dune terrain between Lake Michigan and residential properties [2]. Recently park managers discovered an infestation on park property.

Figure 1: Map of Ottawa County, located along the western coast of Michigan.

In the park we randomly selected sampling areas from within each of the dune environments and studied the two areas where treatment is needed (Table 2). Each treatment area boundary was constructed in a 50 meter radius surrounding the infected tree up to the park boundary.

Circle 1	Circle 2
Steeply sloped dune	Relatively flat dune
Crosscut by maintained trails	Far from maintained trails
No blowouts	Existing blowouts

Table 2: Differences between the two treatment circles.

Methods

Data obtained through GPS field mapping and GIS spatial analysis were used to estimate the amount of trees killed during mitigation and potential slope instabilities after mitigation (Table 3).

Data	Area	Methods	Analysis
Tree location and type	C, S	Mapped with Trimble GPS device in the field	GIS mapping for spatial patterns
Tree concentration: oaks and other trees	C, S	Calculated by dividing number of mapped trees by the area	Averaged for different dune environments
Dune environments	S	Employed spatial analysis using variables such as distance from coast and slope	Used in tree mortality calculations
Number of trees	C, T	Mapped in field with GPS (C) or calculated using dune environments and averaged tree concentrations (T)	Used in comparison of treatment impacts
Number of trees saved	C, T	Compared total trees in trench area to oak trees in the experimental circles	Identify the treatment with the lowest tree mortality and by how much
Slope environments	C	Designated environments using DEM and criteria such as slope and elevation	Apply existing stability knowledge to predict future stability
Slope stability	C	Paired knowledge of tree locations, existence of blowouts, and slope of dune to locate areas of possible slope failures and instabilities	Identify areas of high vulnerability during mitigation efforts

Table 3: The methods of collection and analysis of the various data sets used in the study. Area denotes the specific locality of the data: C for the circles of experimental treatment efforts, S for sampling areas in park, and T for trenched area.

Results

Trees and Dune Environments

Five major dune environments were identified in North Ottawa Dunes (Figure 2). Inland flatlands had the greatest density of both oaks and total trees (Table 4).

Dune Environment	Tree Density
Coastal Flatland	0.250
Coastal Slope	0.214
Inland Flatland	0.361
Inland Slopes	0.213
Bare Sand Areas	0

Table 4: Averaged density (trees/m^2) of all trees for each dune environment.

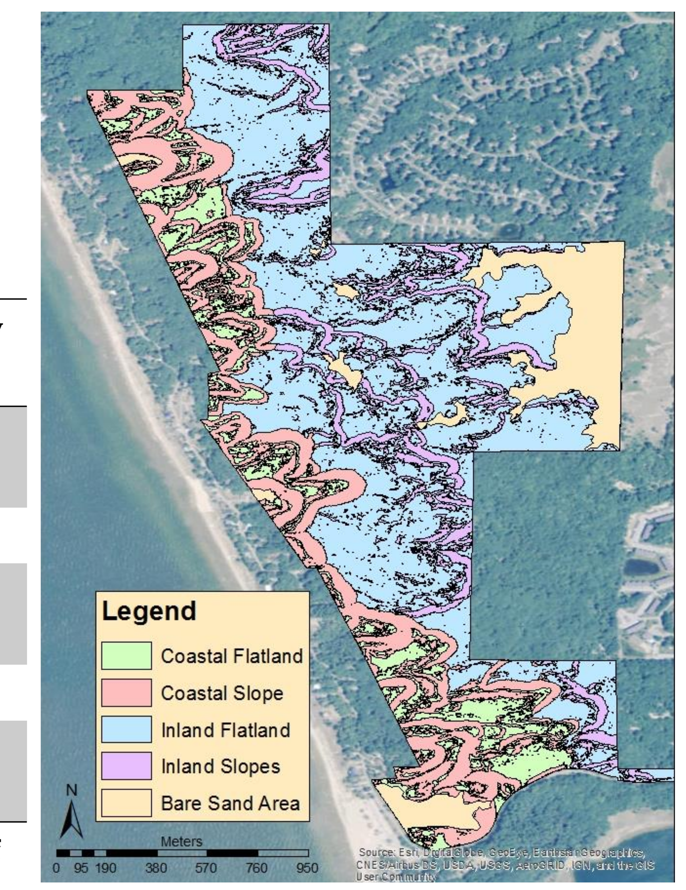

Figure 2: The five dune environments in North Ottawa Dunes.

Results

Trees Saved

Experimental areas covered a much larger space (12,465.3 m^2) when compared to the trenching area (3,463.2 m^2) (Figure 3). Experimental treatment areas also contained more oak trees (326) and more total trees (1071) compared to the trench area (215 oaks and 600 total trees) (Figure 4).

Since the experimental method kills only oak trees while trenching kills all trees, a total of 274 trees may be saved using the experimental method.

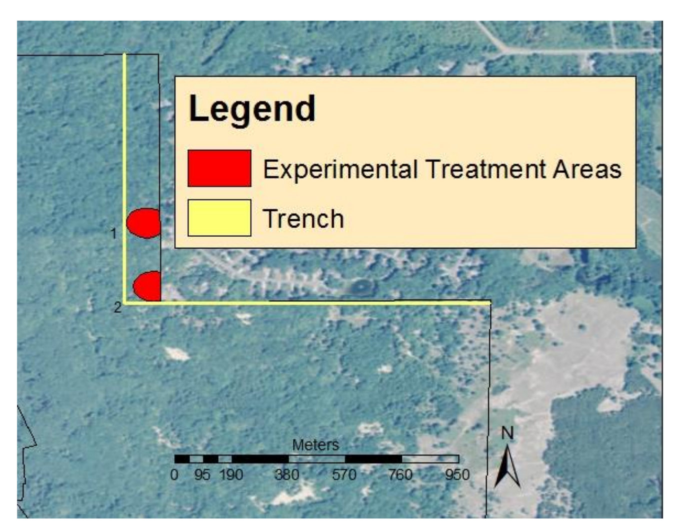

Figure 3:Locations and areas of the experimental treatment circles and the trench.

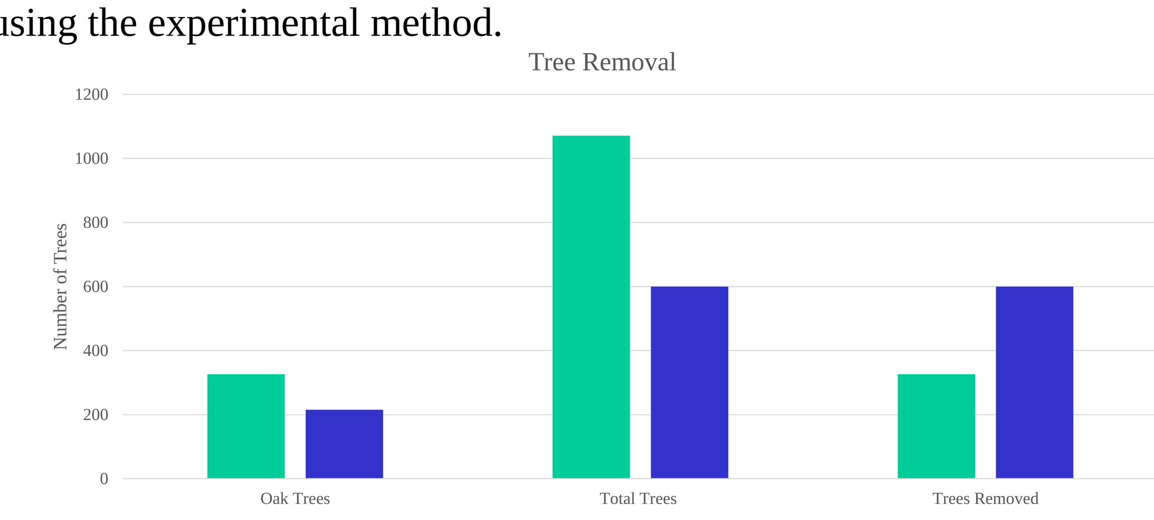

Figure 4: The amount of trees located in and the amount of trees being removed from the mitigation areas.

Slope Stability

In Circle 1 the ratio of oak trees to other species is much smaller than in Circle 2 (Figure 5). Removing oaks will result in 16% of trees removed from Circle 1 compared to 58% from Circle 2. Circle 2 has a larger percentage of blowouts and toes of slope (Figure 6).

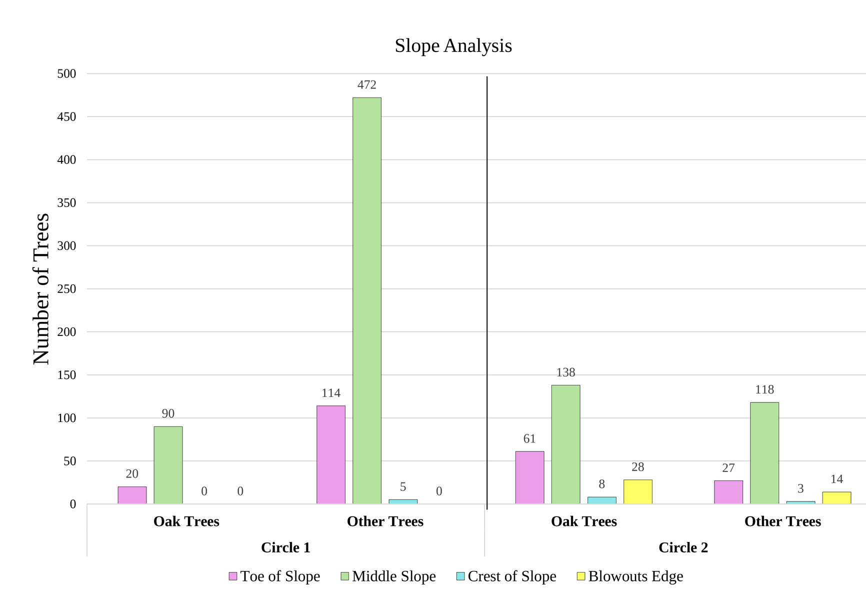

Figure 5: Tree amounts in each slope environment for Circle 1 and Circle 2.

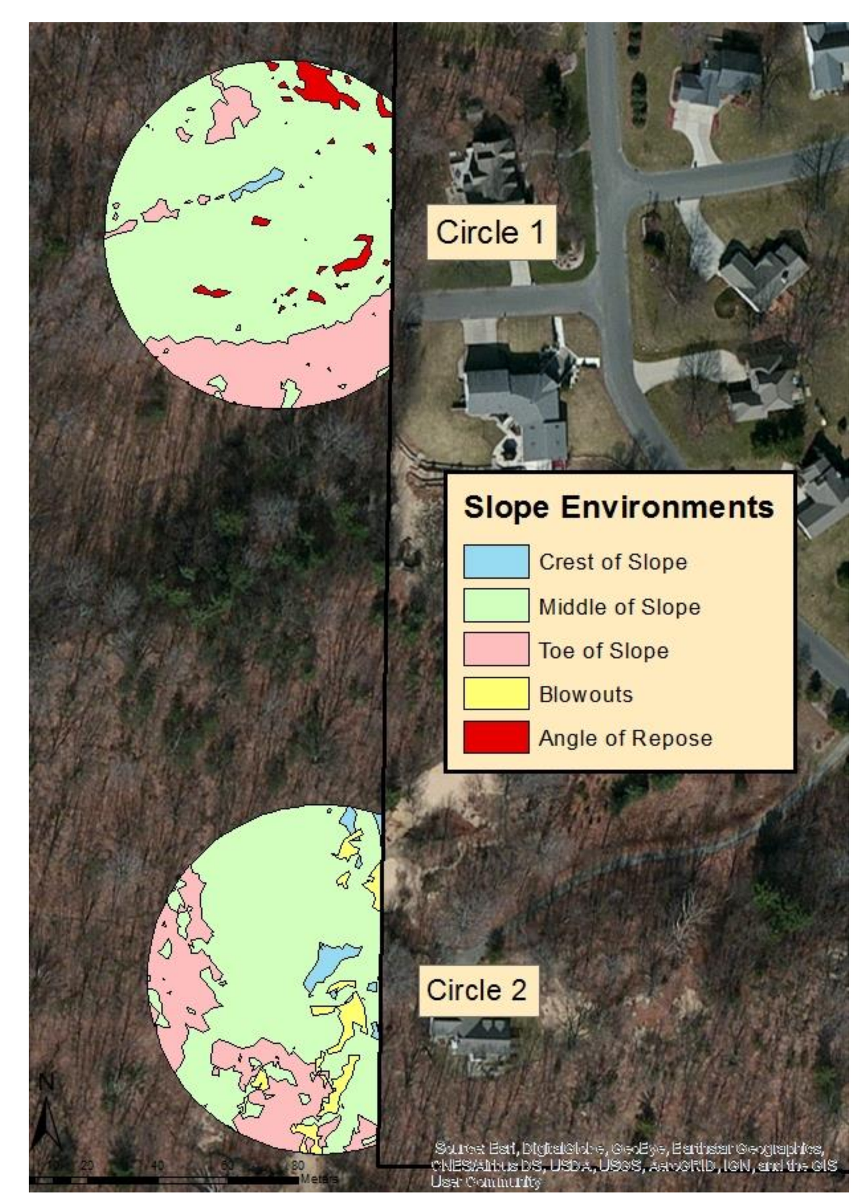

Figure 6: Slope positions present in the two experimental treatment areas.

Discussion

Our results indicate that the experimental treatment saves trees overall, even when the mitigation areas are larger. The reduction of tree mortality is due to the traditional method requiring all trees to be killed within the trench, whereas the new mitigation method only kills oak trees.

Our results also suggest that Circle 2 is more likely to experience dune instability than Circle 1. This is due to the higher ratio of oak trees to other trees in Circle 2 and the amount of blowouts (Figure 7) that occur within the mitigation area already. This is especially true for the trees being removed from the toe of the slope, which is the most vulnerable area [3]. Circle 1, despite being located on a very steep hill, has a lower ratio of oak trees to other trees which will continue to help stabilize the dune after oak tree removal.

Due to our analysis we recommend that park managers focus more recovery attention on Circle 2. This attention could include such activities as targeted plantings of native grasses or trees.

Figure 7: Dune blowout discovered in Circle 2.

Conclusions

Using ArcGIS, we were able to analyze the spatial distribution of oak trees in North Ottawa Dunes and determine the likely repercussions of a tree removal event on slope stability. We were also able to estimate the number of trees that will be saved by switching to an experimental treatment method as opposed to a traditional trench mitigation method.

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References

[1] Frei, Heidi. 2015. "Detection and control of oak wilt, *Ceratocystis fagacearum*, in Michigan State Parks." *Department of Natural Resources*, Michigan. 1-37.

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[3] Ali, N., Farshchi, I., Mu'azu, M.A., Rees, S. W. 2012. "Soil-Root Interaction and Effects on Slope Stability Analysis." *Electronic Journal of Geotechnical Engineering*. 17: 1-10.