Controls on Plant Species Distributions in a Young River Delta

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Research Problem

Plants in coastal marshes are well-known to be sensitive to variation in the frequency, depth, and duration of flooding. Coastal salt marshes frequently exhibit sharp elevation-based zones, with superior competitors dominating higher elevations while less competitive species dominate lower elevations. Few studies, however, have examined the factors that control plant distribution at such elevations, where both fluvial and coastal processes influence environmental conditions. Additionally, while plants are known to influence erosion, deposition, and organic matter accretion in river deltas, models of their distribution generally fail to account for their role in controlling sedimentation. This study was aimed at understanding the factors that determine plant species distributions in deltas. For this study, our goal was to explore which factors, other than elevation, influence plant species distributions in river deltas. We used classification and regression tree (CART) analysis to model the distribution of six freshwater wetland species at Wax Lake Delta, a small, young deltaic estuary of the Mississippi River.

Study Objectives

• Use CART to test the importance of elevation, proximity to water, sheltering, succession, proximity to other patches of the same species, and micro-topographic variation, in controlling distributions of six plant species in the Wax Lake Delta

• Compare the multi-variate CART model to a single-variate CART model built using only elevation as an explanatory variable to determine the relative importance of elevation compared to other controlling variables

The Wax Lake Delta

The Wax Lake Delta Delta is a small, prograding hyperdeltal delta located at the North of the Wax Lake Outlet in the lower Mississippi River Valley. This delta is characterized by a large, flat-lying shoal that serves as the primary source of organic matter and nutrients in the sediments. The wax lake delta is the most important driver of species distributions in this deltaic wetland system. Erosion alone explained approximately 50 percent of the variance in species distribution in this deltaic wetland system. To answer the question of what is the most important driver of species distributions, we used CART analysis to determine the relative importance of elevation compared to other controlling variables.

Explanatory Variables

- Distance to tip of island
- Island age
- Area of tree island
- Island orientation
- Distance to trip of island
- Slope
- Nearest-neighbor distance

Results: Full CART Model

<table>
<thead>
<tr>
<th>Species</th>
<th>Full Model Accuracy (%)</th>
<th>Elevation Model Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nymphaeaceae polystachya</td>
<td>79</td>
<td>77</td>
</tr>
<tr>
<td>Nelumbo nucifera</td>
<td>85</td>
<td>77</td>
</tr>
<tr>
<td>Potamogeton nodosus</td>
<td>68</td>
<td>68</td>
</tr>
<tr>
<td>Potamogeton lucens</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>Colocasia esculenta</td>
<td>80</td>
<td>68</td>
</tr>
<tr>
<td>Other SAVs</td>
<td>63</td>
<td>49</td>
</tr>
</tbody>
</table>

Results: Accuracy and Variable Importance

- Elevation: 79%
- Island age: 48%
- Area of tree island: 48%
- Island orientation: 39%
- Distance to trip of island: 22%
- Slope: 20%
- Nearest-neighbor distance: 19%

Methods

Classification and regression tree analysis (CART) is a non-parametric decision tree learning technique that recursively divides the multidimensional space formed by the predictor variables into otns that are as homogeneous as possible in terms of the response variable. Unlike parametric statistical methods, it requires no assumption that the data fit a normal Gaussian model, as an assumption that is frequently violated by species responses to environmental gradients. A binary decision tree is constructed where successive splits are made based on values of one of the explanatory variables. The variable split is chosen which maximizes the homogeneity of the child nodes, with homogeneity defined by the Gini (divisibility) index. The Gini index measures the probability that two elements selected at random from the same node will belong to different classes. The bottom nodes, or leaves, represent the final classifications.

We generated a random sample of 100 points for each plant species and sampled each of nine candidate explanatory variables at each point. CART analysis was performed on the resulting data using the Salford Systems CART software program. The optimal classification tree was selected to minimize both classification error and tree size.

Discussion

Erosion alone explained approximately 50 percent of the variance in species distribution in this deltaic wetland system. To answer the question of what is the most important driver of species distributions, we used CART analysis to determine the relative importance of elevation compared to other controlling variables.

Summary

Most of the variation in plant species distributions in the Wax Lake delta was attributable to elevation, indicating that it is the most important driver of species distributions in this freshwater, deltaic setting. However, it is not the only important factor that is captured in our model.

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WorldView-2 Image
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