Potential Distribution of Japanese Knotweed (Polygonum cuspidatum) in Massachusetts

Introduction

Geographic Information Systems offer powerful tools for natural resources management and planning. The new version of ESRI’s ArcGIS will provide cutting-edge functionality for managers to assess and predict its implications for habitat distribution and biodiversity. LCM (Land Change Modeler) for ArcGIS designed by ClarkLabs will include a sophisticated tool for modeling potential distribution of species using the Mahalanobis typicality method. In this study, we applied LCM in ArcGIS to predict distribution of an invasive plant in Massachusetts. The results from LCM were compared with another modeling method frequently used in conservation studies – ecological niche factor analysis.

Predictive Distribution Modeling

Predictive Distribution Modeling (PDM) is an innovative GIS method that allows us to create range maps of potential distribution of animals, plants or habitats. The probability of distribution is calculated based on the known locations of species presence or absence and underlying environmental characteristics, i.e., precipitation, temperature, elevation, slope, etc. (Guisan and Thuiller 2005). Various predictive models have been developed based on different conceptual considerations, statistical approaches and data availability. We used two methods based on data with species presence only.

Mahalanobis typicality is derived from Mahalanobis distance which represents the likelihood that a set of environmental variables at a specific location is typical to a known location of the species. The model tells us how typical the area being analyzed compared to those used as a reference (Sauramps and Eastman 2007).

Environmental niche factor analysis (ENFA) compares, in the n-dimensional space of ecological variables, the distribution of the localities where the focal species was observed to a reference set describing the whole study area. It computes factors (like Principal Component Analysis) that explain the major part of the ecological distribution of the species (Fier et al. 2003).

Methods

Environmental Variables Chosen: Eight different environmental variables were chosen for use in predicting the occurrence of Japanese Knotweed from locations that documented its spread as an invasive species. Elevation was chosen to restrict its spatial prediction since this species is not able to thrive at very high elevations and is mostly found to occur in areas of moderate slopes in the riparian sections of a landscape. Its tolerance for lower elevations is about -30 C and it prefers damp and humid climates (Breeding, 1990). The temperature extremes layers and the precipitation layers were thus included in the model. The plant grows profusely along watercourses, thus justifying the use of the distance to hydrological features as a predictive variable. In addition, studies have shown that the species is more sensitive to shade from understory vegetation and hence can quickly cover an open land. This, therefore, led to inclusion of distance to open land as a factor for predicting the species potential distribution accuracy.

Japanese Knotweed

Polygonum cuspidatum is a herbaceous perennial with long slender stems reaching the height of 1.3 m. It is native to Japan, Korea and China and was introduced to the United States around 1850 as a horticultural plant. Since then, it has naturalized in the entire New England and can be found in most US counties today. Although producing winged fruits, it spreads mostly via long rhizomes whose fragments can sprout new plants. It thrives in riparian and wetland areas but is often found along roads and at disturbed sites. It is considered an invasive species in the US as well as in Europe, since it forms dense, persistent thickets which outcompete native vegetation and are hard to eradicate. Therefore, it represents a threat to local species and habitat diversity (PANe 2004). Knowing its potential distribution is essential for its effective management.

Study Area

Data: Data on Polygonum cuspidatum presence (103 points) were downloaded from the Invasive Plant Atlas of New England [http://niih-nin.cirrus.columbia.edu/ipa/index.html]. Environmental variables of elevation and slope were derived from DEM obtained from the Clark University HERO database. The index of southerness was calculated with modifications from aspect according to Biers et al. (1966). Climate data used in the analysis were downloaded from the Worldclim database [http://www.worldclim.org]. The precipitation map represents the annual average precipitation for the period 1950-2000. The temperature data include average maximum July and minimum January temperatures for the same period. The source of hydrology and land cover data is MassGIS [http://www.mass.gov/mgis]. The proximity to streams, ponds and wetlands, as well as proximity to all categories of open land were considered in the analysis. All the data were formatted to the resolution of 90 x 90 meters.

Results

Figure 4. represents the suitability maps for Polygonum cuspidatum generated using the two described techniques. Black and dark blue areas are the least suitable locations for the species, while red and orange areas represent the most suitable locations. Both models predicted the eastern-central part of the state as highly suitable.

Discussion and Conclusions

Mahalanobis typicality and ENFA are few of the most widely used models for predicting species distribution. In this study, Mahalanobis exhibited overall better performance than ENFA, although ENFA did slightly better in predicting the highest suitability. The results are highly dependent on the species presence data as well as on the considered environmental variables.

Our study presents the new capability of ArcGIS for conservation management purposes. Moreover, Mahalanobis typically used for predicting species distribution, which is included in the LCM tool of ArcGIS, seems to be highly comparable with other species prediction models, such as ENFA in the Biomapper software.

References