GIS-based Spatial Analysis of Rare Plant Populations on Gravel Hill Prairies: Habitat Suitability Modeling

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Background

Habitat loss is consistently identified as the single most influential cause of species loss (Bender et al 1998, Fahrig 1997, Dirzon and Raven 2003, Rahmig et al 2008). This loss of habitat is particularly evident throughout the Midwest of the United States (Sampson and Knopf 1994, Rahmig et al. 2008). By many estimates, agriculture and development have transformed as much as 80-99% of the Great Plains prairies, and fragmented the once continuous landscape into small remaining habitat fragments (Sampson and Knopf 1994, Rahmig et al. 2008). These fragments are, in some cases, the last holdfast for many plant species.

Introduction

Characterized by the rocky, gravel rich substrate found near the surface, gravel hill prairies are typically nutrient poor and dry in nature (Owens and Ebinger 2008). Gravel hill prairies were formed through glaciation and are named for the characteristic gravel material deposited (Owens et al. 2006).

Since the year 2000, the Chicago Botanic Garden's (CBG) Plants of Concern (POC) monitoring program has been collecting data on rare species in the greater Chicago area, including the two gravel hill prairie species, *Cirsium hillii* (Hill's thistle) and *Asclepias lanuginosa* (Wooly milkweed). The POC has monitored over 230 plant species listed as rare, threatened, or endangered. With the help of citizen scientists and land managers, the POC program collects data to understand population trends and inform land managers and landowners about trends, threats and possible management strategies in effort to conserve these rare species.

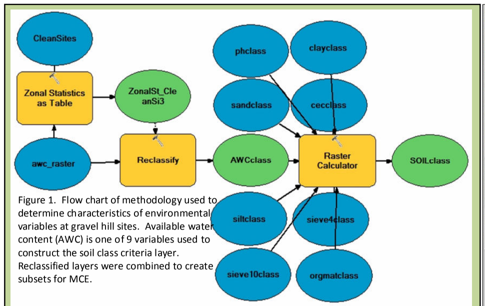


Figure 1. Flow chart of methodology used to determine characteristics of environmental variables at gravel hill sites. Available water content (AWC) is one of 9 variables used to construct the soil class criteria layer. Reclassified layers were combined to create subsets for MCE.

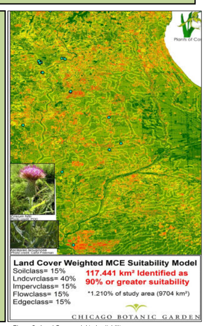


Figure 2. Land Cover weighted suitability map

Research Question

Using environmental characteristics and data from the Plants of Concern monitoring program, can we characterize and identify potential suitable habitat for rare gravel hill species?

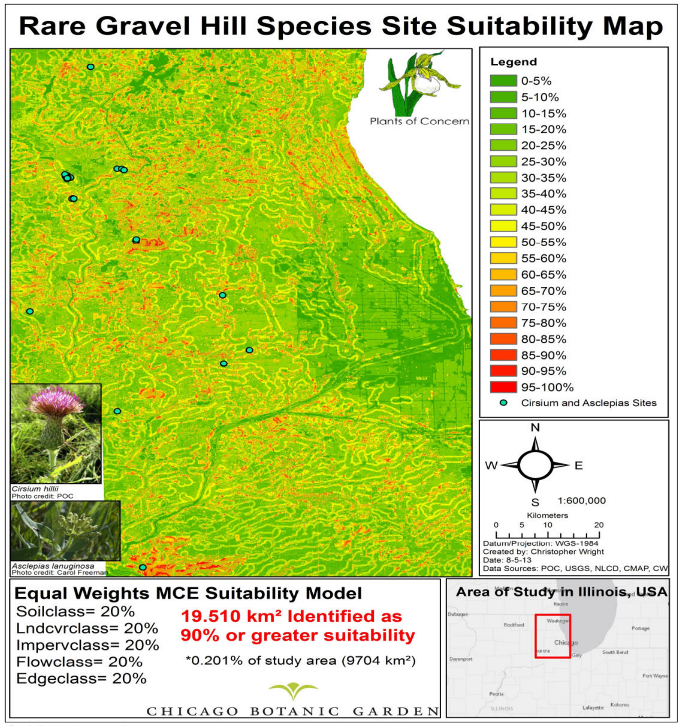
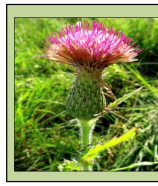


Figure 3. All criteria weighted equal suitability map

Rare Gravel Hill Species



Left:
Cirsium hillii, photo credit: POC

Right:
Asclepias lanuginosa, photo credit: Carol Freeman

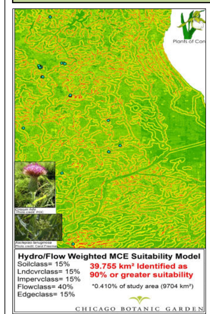


Figure 6. Impervious surface weighted suitability map

Results

Six suitability models (Figures 2-7) based on assigning varying importance to five subsets of environmental spatial data were created. Using a threshold of ≥90% to identify the most suitable habitat, percentage of study area coverage and area in km² was determined for each model (Table 1). Only one MCE model produced a suitability coverage area greater than 1% of the coverage area. Percent suitability ranges from as high as 100% to as low as 20%. Fluctuation, based on weights assigned during the MCE modeling, was seen in all but two of the sites. Site #12 and #13 were found to have 100% suitability in all models (Table 3). Comparison of subpopulations at the least (Site #1; *C. hillii* only) and the highest (Site #13; *A. lanuginosa* only) suitability monitoring sites were made via an intermediate site (Site #10; largest # of subpops of both spp.) using stem density as a metric of population health (Table 2).

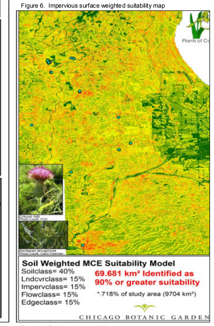


Figure 5. Soil weighted suitability map

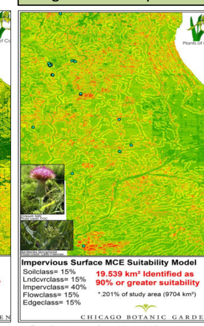


Figure 7. Impervious surface weighted suitability map

Table 1. Area and spatial coverage of most suitable habitat as identified by each MCE model. Area of analysis ≈ 9704 km²

Model Name	% Coverage	Area (km²)
EDGEweight	0.058	5.602
EQUALweight	0.201	19.510
IMPERVweight	0.201	19.539
FLOWweight	0.410	39.755
SOILweight	0.718	69.681
LANDCOVERweight	1.210	117.441

Table 2. Average stem density comparisons of *C. hillii* and *A. lanuginosa* between different sites. Average densities calculated from recorded stem counts and coverage reported. Average suitability score at subpop: (Site #1 (subpop2)=30%, Site #10 (subpop17)=70%, Site #13 (subpop1)=100%, Site #10 (Subpop1)=70%).

Cirsium hillii

Site Number	Average Density (stems/m²)
#1	0.053
#10	0.291

Asclepias lanuginosa

Site Number	Average Density (stems/m²)
#13	0.7857
#10	1.792281

Methods

•Create cleaned data for gravel hill training sites by averaging centroids of 47 subpopulations (records from several years of monitoring) from thirteen monitoring sites
•Using zonal statistics, identify values at training site locations for environmental criteria
•Using these identified values (the mean as the most suitable and the maximum standard deviation as the range of suitability) all criteria layers were reclassified (Figure 1)
•Reclassified criteria layers were used in Multi Criteria Evaluation (MCE) modeling to produce six habitat suitability maps
•Using a threshold of ≥90%, the area of the most suitable habitat was calculated for each model
•Reclassifying the results of MCE models so the maximum suitability of each of the 13 monitoring sites was established as a percent suitability for comparison.
•Using density (stems/m² of coverage), three monitoring sites were used to compare % suitability and population dynamics.

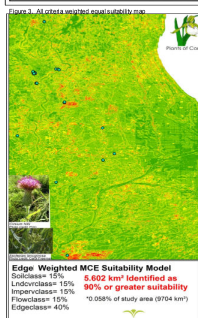


Figure 4. Edge weighted suitability map

Conclusion/Discussion

Area of high suitability (≥90%) varies depending on model weighting structure
•The chosen structure could be modified as understanding of gravel hill habitat increases
Higher % suitability doesn't represent health/size/density of subpopulations
•Stem density may not be the right metric to understand gravel hill population health
Management practices and the size of natural areas have an impact of subpopulation size and health.
•Ability to use this data from POC data in a spatial context will allow further population analysis
Habitat suitability modeling shows that varying amounts of suitable habitat exist in addition to know habitat
•Newly identified habitat may contain undiscovered populations or be used for introductions of new populations
•Suitability maps can be used as a tool for land managers to determine management strategies

Table 3. Percent suitability of monitoring sites as determined by MCE models where known populations of focal gravel hill species occur. Percent suitability shown represents the maximum suitability modeled at each location

Site #	Soil	Imperv. Surf.	Land Cover	Hyro/Flow	Equal	Edge
1	40	30	30	40	30	20
2	60	60	70	60	60	60
3	90	80	90	80	80	80
4	90	70	80	70	70	70
5	90	80	80	90	80	40
6	90	80	90	80	80	90
7	90	80	90	70	80	80
8	90	80	90	80	80	90
9	90	90	100	80	90	90
10	90	90	100	80	90	90
11	100	90	100	100	90	90
12	100	100	100	100	100	100
13	100	100	100	100	100	100

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DATA SOURCES:

•National Land Cover Database, Chicago Wilderness, Plants of Concern Database, USGS SSURGO Database, Chicago Metropolitan Agency for Planning

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