Tufts UNIVERSITY

Soil Suitability at the Arnold Arboretum

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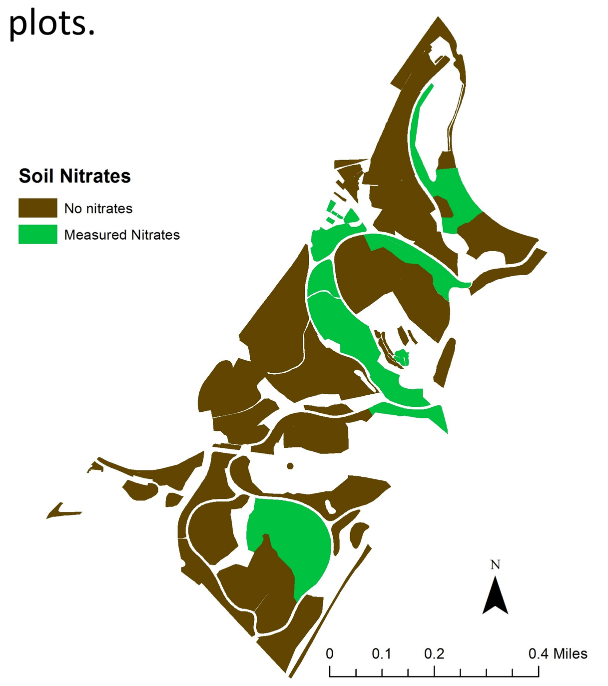
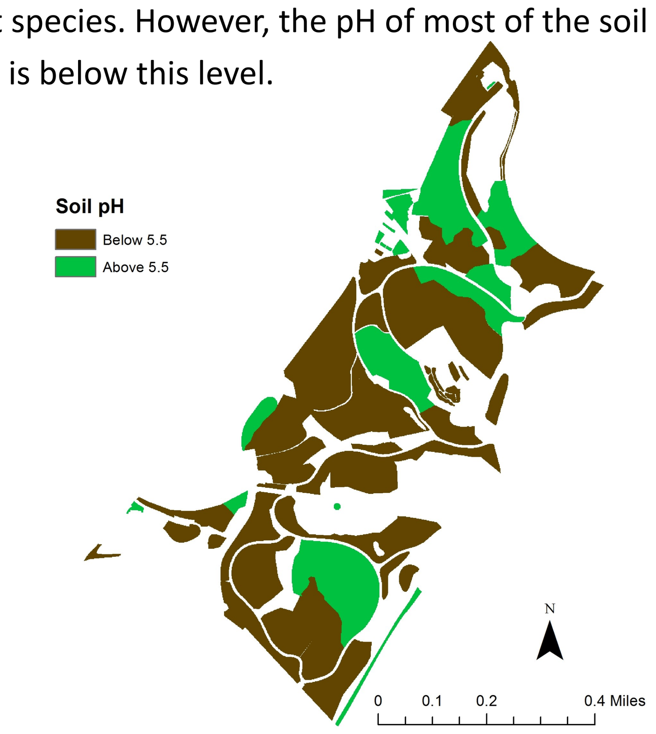
Low Nitrate Concerns

Nitrogen is the most important nutrient for foliage and leaf growth in plants. Soil nitrates are an important source, although not the only source, of nitrogen for plants. However, no measureable nitrates were found in many of the soil plots.



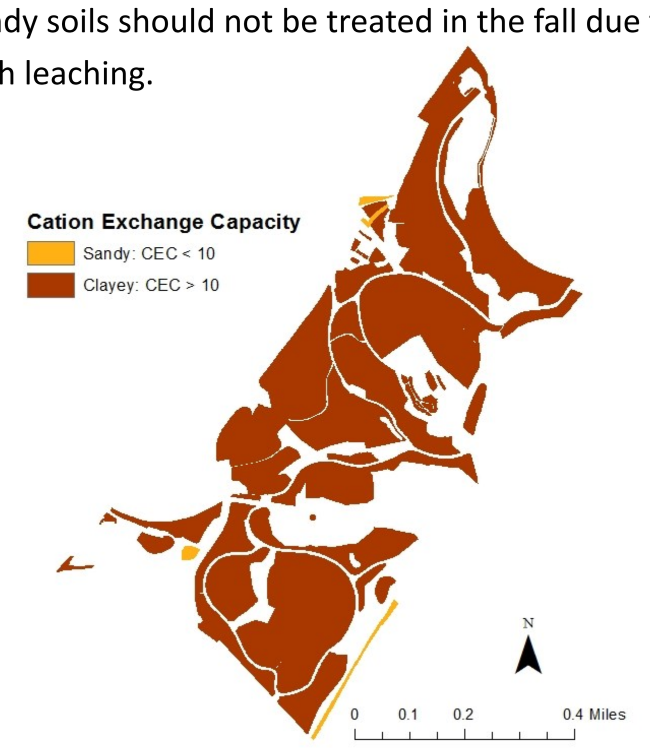
Soil pH Concerns

A soil pH of 5.5 is listed by the Farmer's Almanac as the lower bound of the optimal pH range for many plant species. However, the pH of most of the soil plots is below this level.



Cation Exchange Capacity

The CEC relates to the soil's ability to hold ions and to resist nutrient leaching. The CEC determines best treatment methods for soil problems. Low CEC sandy soils retain less water and nutrients while high CEC clayey soils need more lime to improve pH. For pH adjustment, sandy soils need less lime more often than clayey soils and for fertilizing, sandy soils should not be treated in the fall due to high leaching.



Overview

The Arnold Arboretum in Jamaica Plain, MA, cultivates a diverse range of plant species. Researchers there recently collected data on over 100 soil properties. The goal of my project was to create a measurement of relative soil health using the following soil characteristics: nitrate concentration, pH, cation exchange capacity, organic matter fraction, phosphorus concentration, and potassium concentration. Additionally, comparing the maps shows which property is responsible for a plot's high or low score and can help determine what remediation effort would increase its suitability.

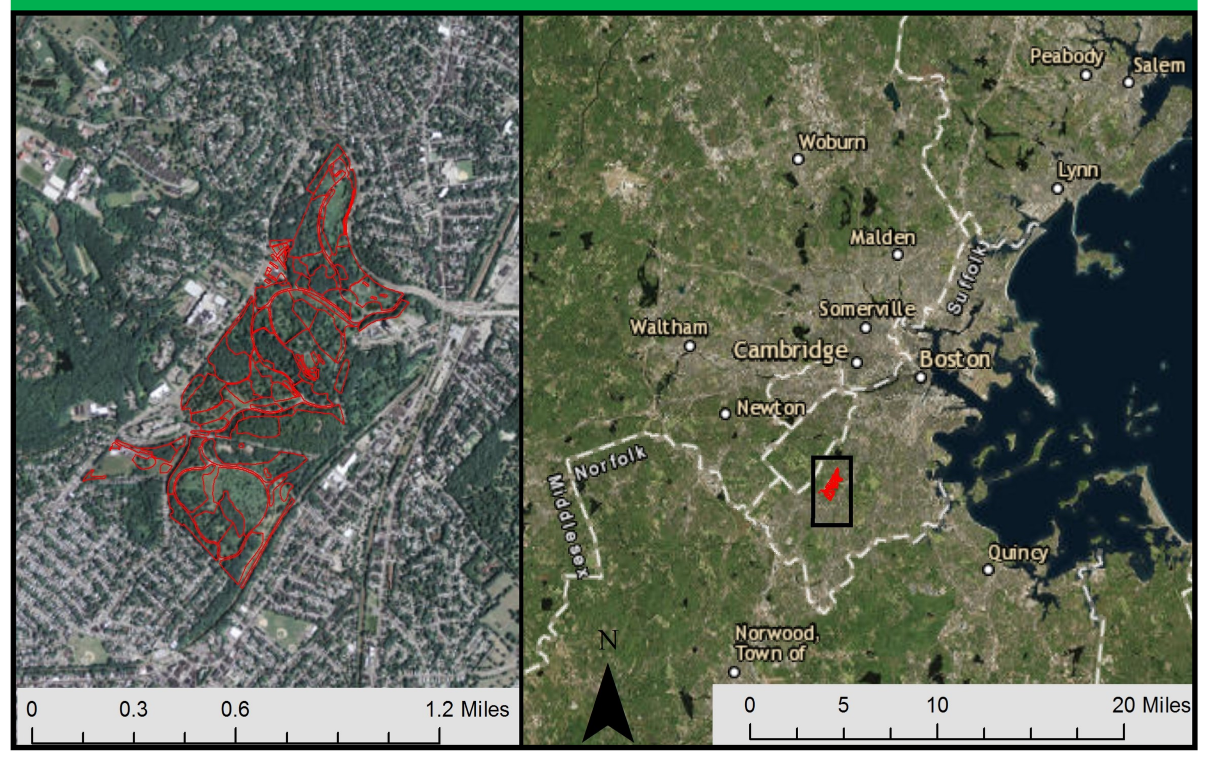
Methodology

I turned polygon data into raster layers and then used raster calculators, shown in the model builder below, to modify and combine the soil characteristics into several different health scores. Each raw data raster was modified by raster calculator into a measurement of how far each property was from the ideal amount. These "deficit" raster layers rate the soil plots from 0 to -1 with a calculation of: $\text{Deficit} = -\left|(X - X_{ideal}) / X_{ideal}\right|$
The health score maps to the right were created with different methods of weighting and combining the six properties into a single health score.

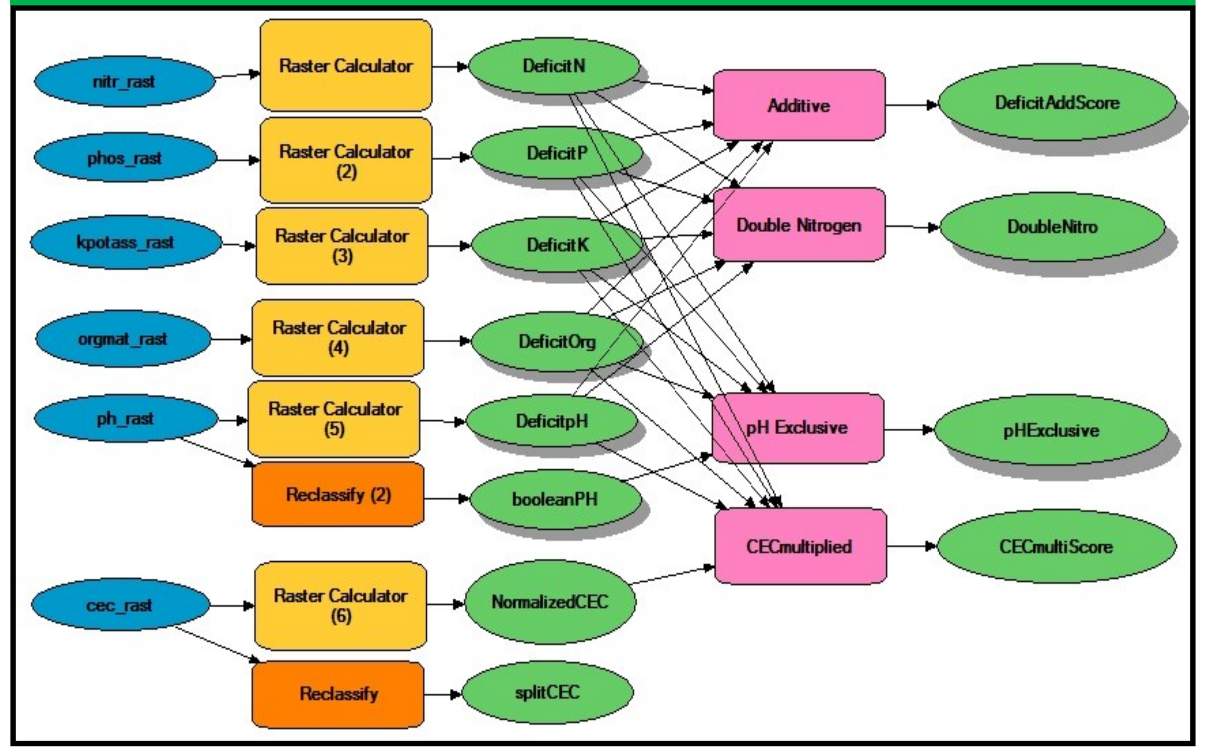
Discussion

Both the raw data maps and the combined health scores show that low nitrate concentrations and low pH values are the most influential negative factors on the final health scores. The differences between the different health score calculations show that the soil suitability for plant growth varies greatly by the requirements of the plant species. The algorithm for the score can be modified to be more accurate by prioritizing the most important needs of a particular species, the way that Score 2 is modified for a nitrogen-intensive species or Score 3 is modified for a pH-sensitive species.

Location of the Arnold Arboretum

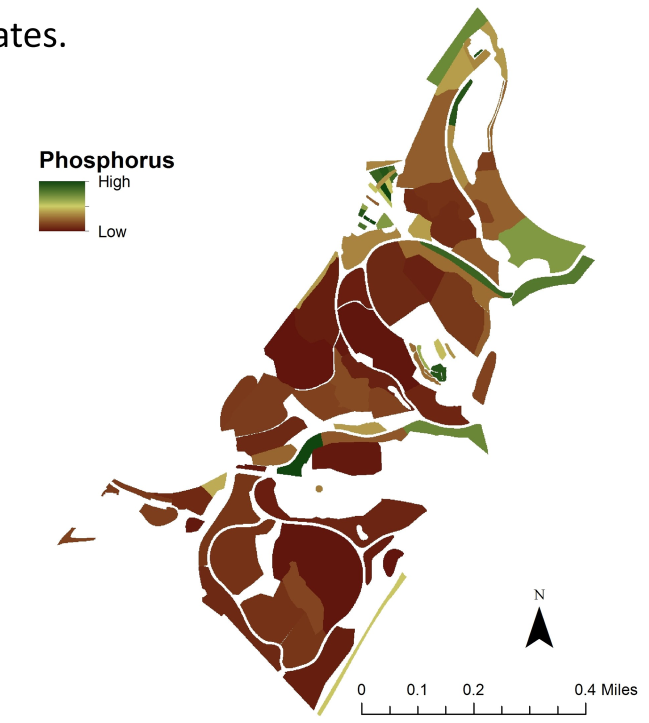


Model Builder Calculations



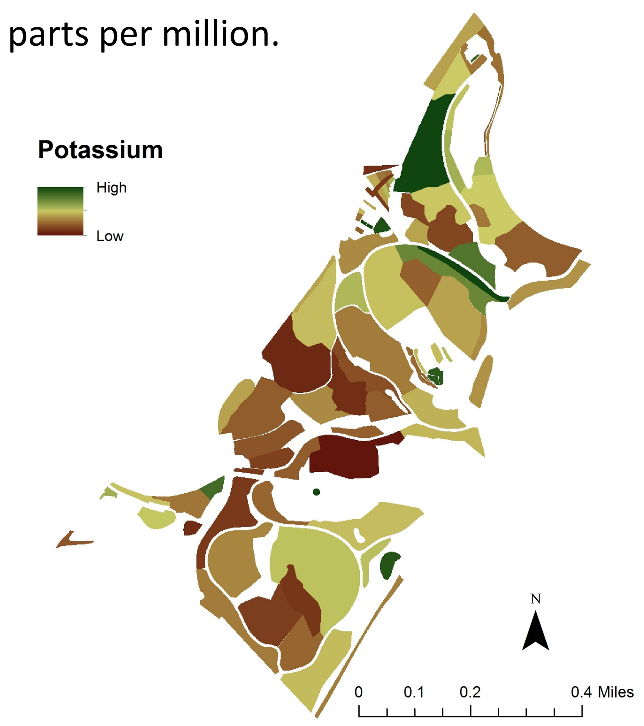
Phosphate

Phosphorus is another important macronutrient for plants, especially root and flower growth. It is largely obtained from soil phosphates.



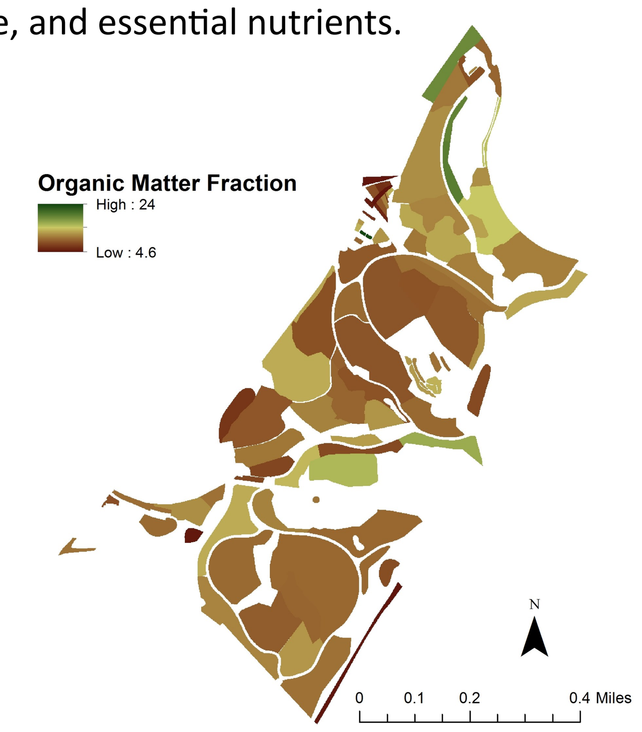
Potassium

Potassium is another macronutrient that is important for fruit and flower growth. Potassium amounts in soil are ideally in the range of several hundred parts per million.

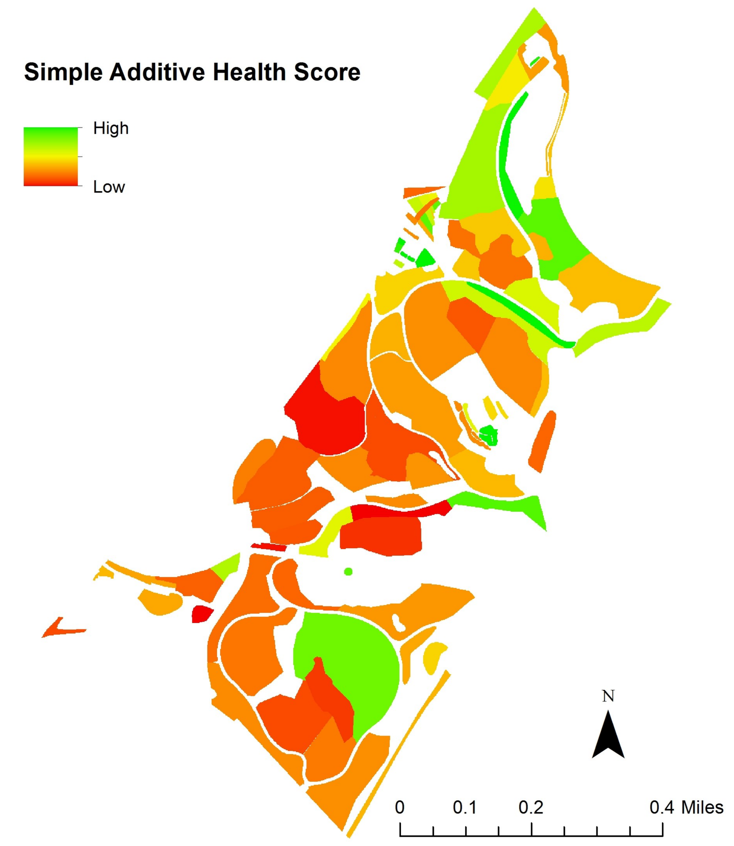


Organic Matter Fraction

The organic matter fraction is the percentage of the soil that is made up of decaying organic material. Organic matter in soils helps provide stability, moisture, and essential nutrients.



Results



Score 1: Simple Additive Score

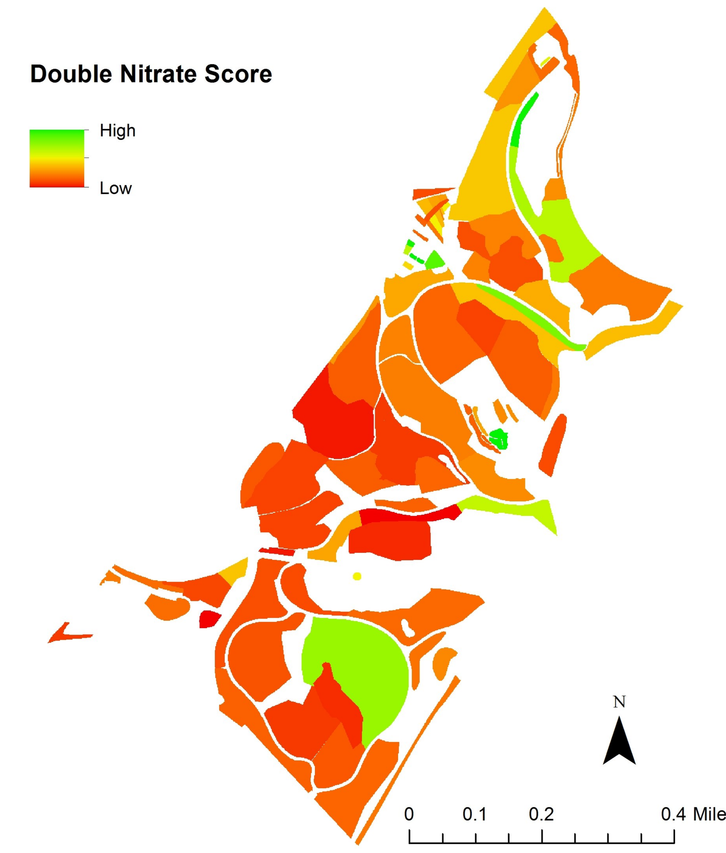
(DN + DP + DK) + DpH + DOrg = Score

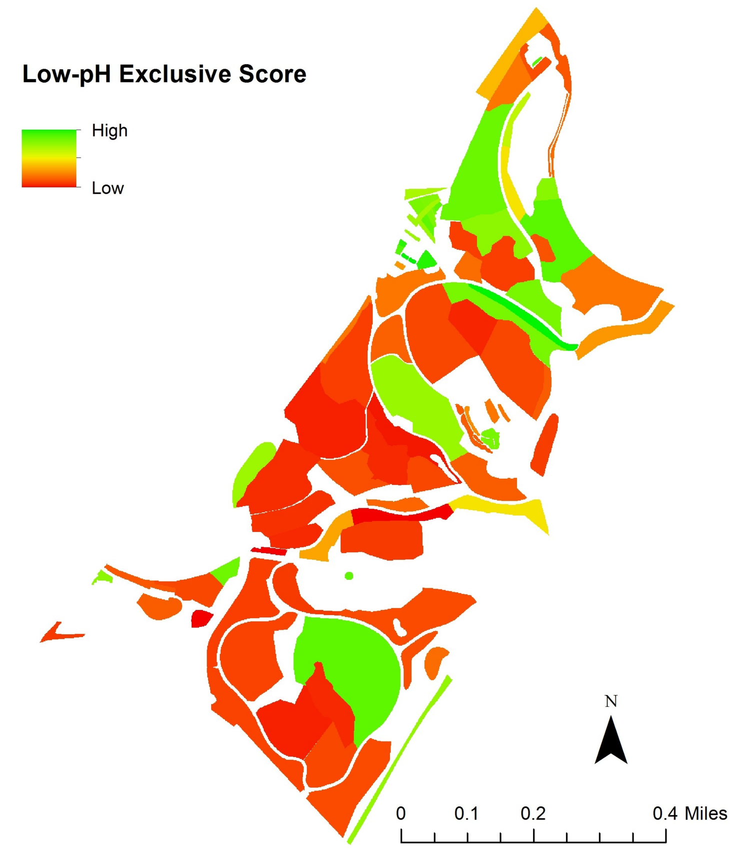
This score is the simplest model. It adds the normalized deficit of each property (ranging from 0 to -1) to create a total score (from 0 to –5). This model operates on the assumption that plants are equally sensitive to all five factors.

Score 2: Double Nitrate Score

*2*DN+DP+DK + DpH + DOrg = Score*

This score gives double weight to nitrogen and is a more accurate suitability score for nitrogen sensitive plants.





Score 3: Low-pH Exclusive

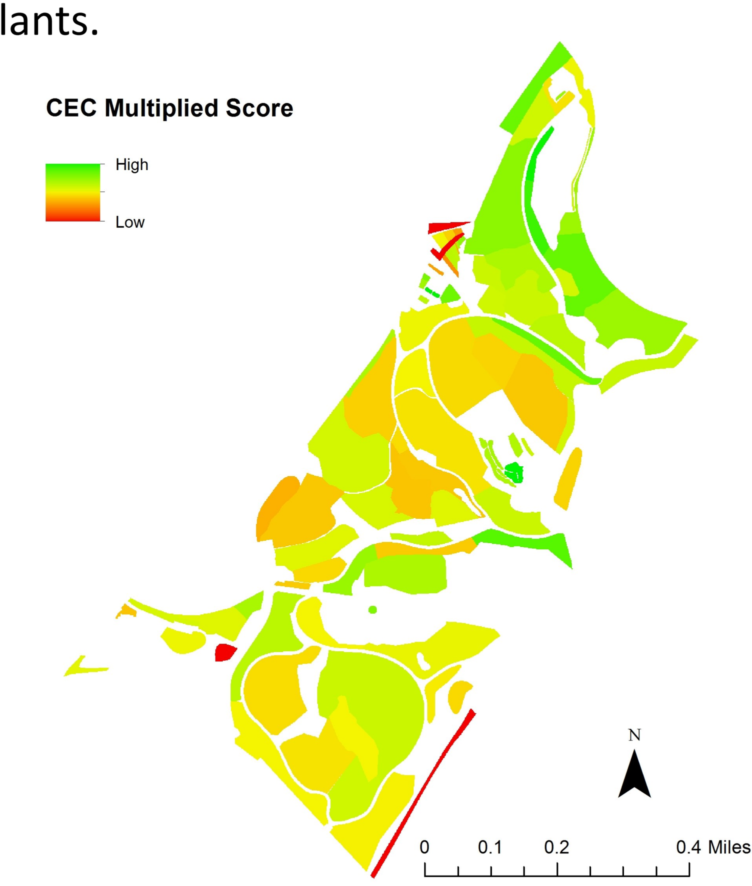
(DN+DP+DK + DOrg)(2- DpH) = Score*

This score excludes soils with a pH < 5.5 from having high scores and is a more accurate suitability score for pH-sensitive plants.

Score 4: CEC Multiplied Score

*(DN+DP+DK)*1/DCEC + DpH+ DOrg =Score*

This score takes into account the way that the CEC controls nutrient availability. Low nutrient areas can still have high scores if the CEC is high, because it assumes no nutrient leaching.



Data Sources

World Imagery Basemap. Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS user community.
Arnold Arboretum. Arnold Arboretum Office of the Curator of Living Collections. 125 Arborway, Boston, MA 02130-3500

Projection: NAD_1983_StatePlane_Massachusetts_Mainland_FIPS_2001_Feet