Soil Chemistry Two Centuries after Mining

An Analysis of Residual Cation Distribution in Subsoil from a Historic Tennessee Iron Operation
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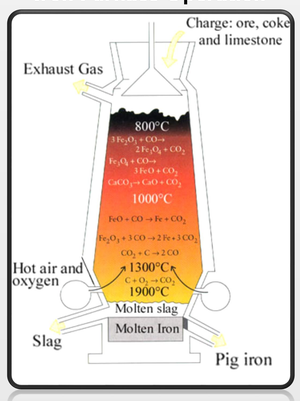
Introduction

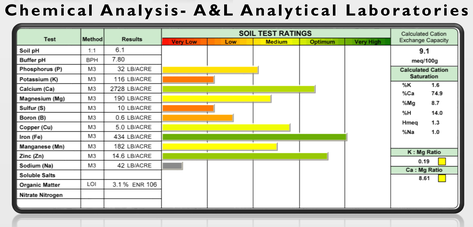
Prior to regulations set forth by Congress and the EPA in the mid-twentieth century, businesses and mining operations which produced potentially hazardous byproducts were unrestrained in their disposal of waste. Historically, this waste would simply be abandoned at a site of production, such as a blast furnace. Laurel Furnace in present day Montgomery Bell State Park was one such site and operated as the primary source of pig iron for Middle Tennessee in 1815. In operation through 1855 and producing 660 tons of pig iron annually, waste such as massive slag heaps were deposited on location. Slag from a blast furnace contains primarily silicon dioxide, metal oxides, sulfides and various transition metals; deposited in concentration, this waste may have a significant impact on soil chemistry several centuries later. Chemical analysis of subsoil cores in the vicinity of Laurel Furnace reveal areas of unusually high concentrations of iron, zinc, magnesium and manganese cations. Geostatistical interpolation of this data reveals insights into the practices of this mining operation, as well as current impacts on the local environment.

Iron Furnace Operation



Slag from the site of Historic Laurel Furnace, Montgomery Bell State Park

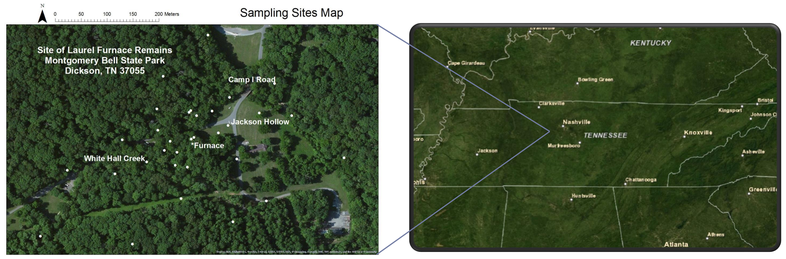
Chemical Analysis- A&L Analytical Laboratories



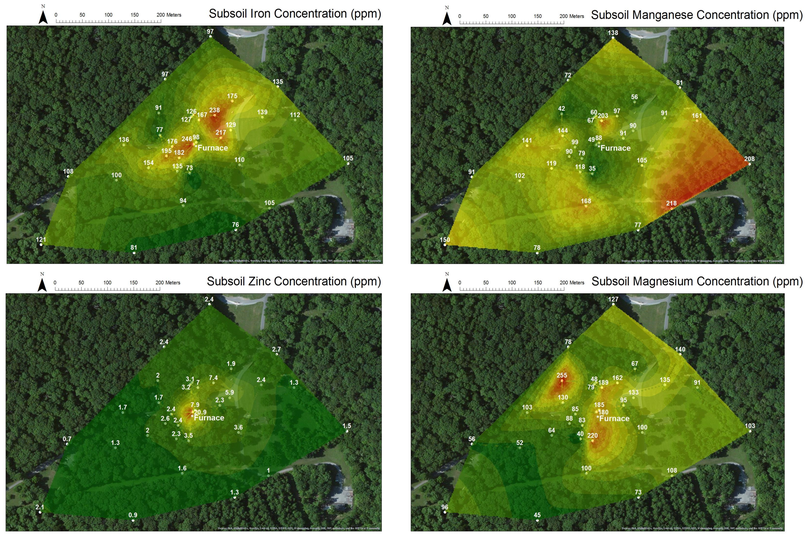
Test	Method	Results
Soil pH	1:1	6.1
Buffer pH	BPH	7.80
Phosphorus (P)	M3	32 LB/ACRE
Potassium (K)	M3	116 LB/ACRE
Calcium (Ca)	M3	2728 LB/ACRE
Magnesium (Mg)	M3	190 LB/ACRE
Sulfur (S)	M3	10 LB/ACRE
Boron (B)	M3	0.6 LB/ACRE
Copper (Cu)	M3	5.0 LB/ACRE
Iron (Fe)	M3	434 LB/ACRE
Manganese (Mn)	M3	182 LB/ACRE
Zinc (Zn)	M3	14.6 LB/ACRE
Sodium (Na)	M3	42 LB/ACRE
Soluble Salts		
Organic Matter	LOI	3.1 % ENR 106
Nitrate Nitrogen		

Interpolations

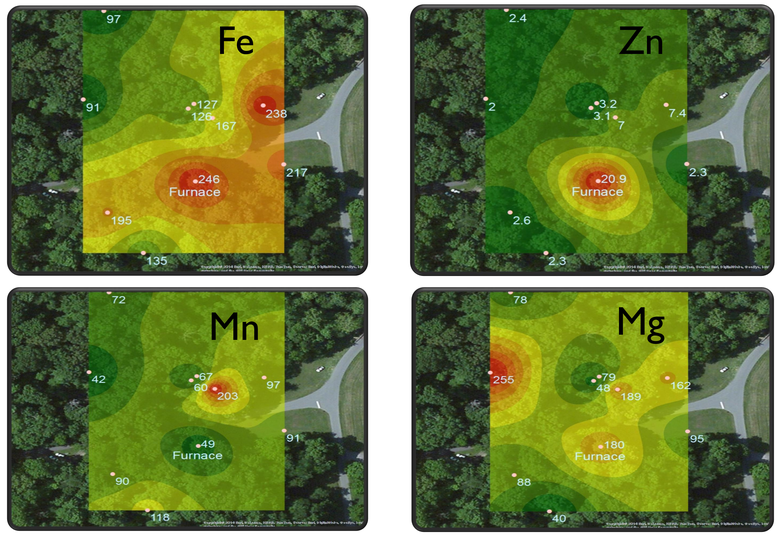
- Inverse Distance Weighting (IDW) is a type of deterministic method for multivariate interpolation with a known scattered set of points. The assigned values to unknown points are calculated with a weighted average of the values available at the known points.
- Inverse Distance Weighting interpolation explicitly implements the assumption that things that are close to one another are more alike than those that are farther apart. In the case of this project, that refers to the measurements of the cation concentrations within the vicinity of the furnace.
- To predict a value for any unmeasured location, IDW uses the measured values surrounding the prediction location. The measured values closest to the prediction location have more influence on the predicted value than those farther away. IDW assumes that each measure point has a local influence that diminishes with distance. It gives greater weights to points closest to the prediction location, and the weights diminish as a function of distance, hence the name inverse distance weighting.
- Natural Neighbor interpolates a raster surface from data points using a natural neighbor technique. This algorithm finds the closest subset of input samples to a query point and applies weights to them based on proportionate areas to interpolate a value within the range of sample values. This method does not infer trends and cannot predict peaks or valleys on a contour map.
- The natural neighbors of any point are those associated with neighboring Thiessen polygons. A Thiessen diagram is constructed of all the given points, then a second layer of Thiessen polygons is applied for each new interpolation point and the proportion of overlap between the second and initial polygons is used as weights for final result.
- In contrast to IDW which uses only the distance from the interpolation point to produce a value, natural neighbor uses percentage of a Thiessen polygon and may be more representative of the true contour surface in some cases.



Contour Maps of Cation Concentration (ppm)



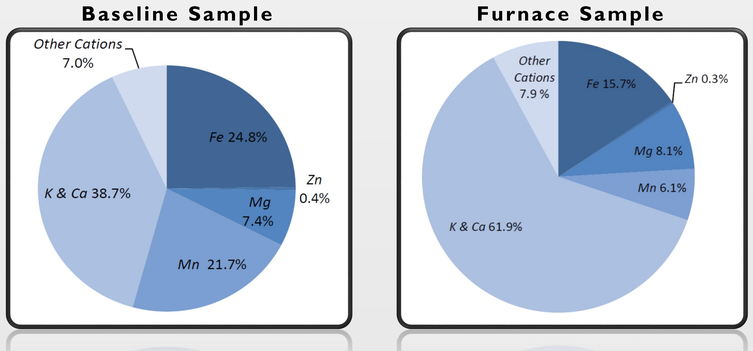
Above, natural neighbor interpolation maps of subsoil cation concentrations in the vicinity of historic Laurel Furnace. Areas of higher concentrations display in red and lower concentrations in green. These metals are common in slag, a waste byproduct of pig iron furnaces. Below, inverse distance weighted interpolation maps of subsoil cation concentrations.



Procedures

- A subsurface soil sample taken at the location of the Laurel Furnace remains in Montgomery Bell State Park was sent to A&L Analytical Laboratories for chemical analysis to determine if unusual levels of cation concentrations are present at the historic site.
- High levels of iron, zinc and magnesium concentrations in this sample warranted additional analysis of the area. Additional samples in the immediate vicinity were taken with a soil core sampling kit over two years, as well as one sample at a higher elevation two miles away to serve as a baseline for cation concentrations within the park.
- ArcGIS ArcMap©, Garmin©, Theodolite©, and Microsoft Excel© software allows for processing and graphical representation of relationships between concentrations of cations that remain as contamination from this historic furnace.

Relationship of Cation Concentration



Conclusions & Future Work

- Iron zinc, and magnesium cation concentrations at the site of the furnace were found to be above normal, suggesting high levels of localized contamination. Chemical analysis of additional samples within 300 meters show normal levels of concentration with respect to a baseline sample of unaltered subsoil. Several exclusions to this generalization are present as localized hot spots. Significant concentrations of iron and magnesium are found in subsoil 50 meters northeast of the furnace, this is possibly where charge (iron ore, coke, limestone) was stored during active operations in the nineteenth century. The eastern high concentration of manganese is considered anomalous, likely the result of lawn fertilizers. No impact on vegetation is observed despite areas of highly mineralized soil; in fact some of the high levels of concentrations are considered optimum for agricultural purposes.
- More sampling in the vicinity will allow for more accurate representations of potential contamination. Thorough analysis of regolith stratigraphy may reveal the subsoil layers which have dominantly stored and transported contaminants. Hydrogeological analysis may determine the affects of interflow or infiltration on distribution of remaining contamination.

Acknowledgments

A special thanks to Mike Wilson, Director of the APSU GIS Center for providing funding through a non-traditional student research grant, and Dr. Chris Gentry, Director of the Office of Undergraduate Research for providing funding through the student travel grant. Acknowledgements to Austin Peay State University faculty and staff: Dr. Kallina Dunkle and Rick Wheeler, lab manager; alumni: Brandon Crabtree for partnership in the 2014 project development, and Maurice Testa for the preliminary proposal of the project; staff and rangers of Montgomery Bell State Park for permitting a geological study of their historic landmarks.