Modeling Soil Addition Profiles of Carbon, Nitrogen, Lead and Manganese Across a Climate Gradient

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1. Abstract

Lead, manganese, carbon and nitrogen can all form what is known as a soil *addition profile,* where an element, after correction for changes in the concentration of other elements, increases in concentration from the underlying parent material to the surface. Lead and manganese both are toxic to humans in varied quantities. Most Pb and Mn deposition has been attributed to anthropogenic sources such as fossil fuel burning and metal refineries. Carbon and nitrogen, however, are mostly added by the natural processes of fixation by plants and microorganisms.

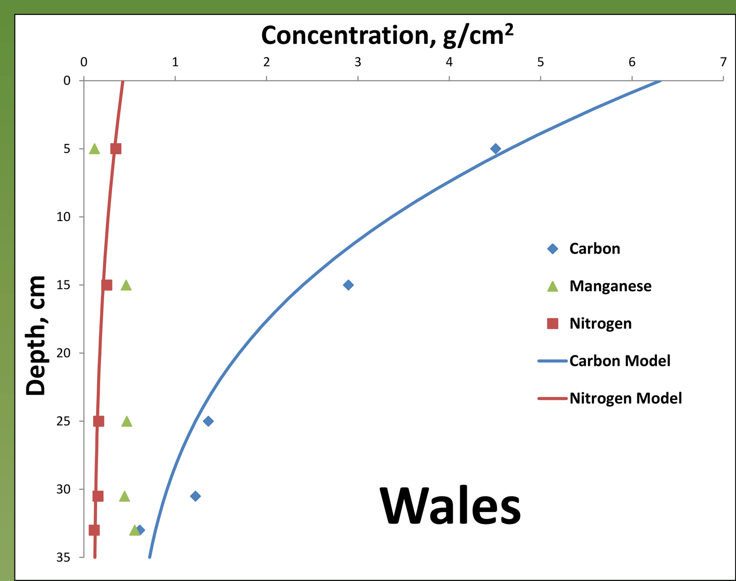
It is prudent to quantify the processes which affect these elements because of their potential toxic effects on humans (Pb and Mn) and management of environmental resources in a warming climate (C and N). **The purpose of this study was to analyze element depth profiles for Pb, Mn, C, and N in soils along a soil climosequence developed on shale and to model how soil mixing and atmospheric deposition control the observed concentration profiles.**

2. Methods

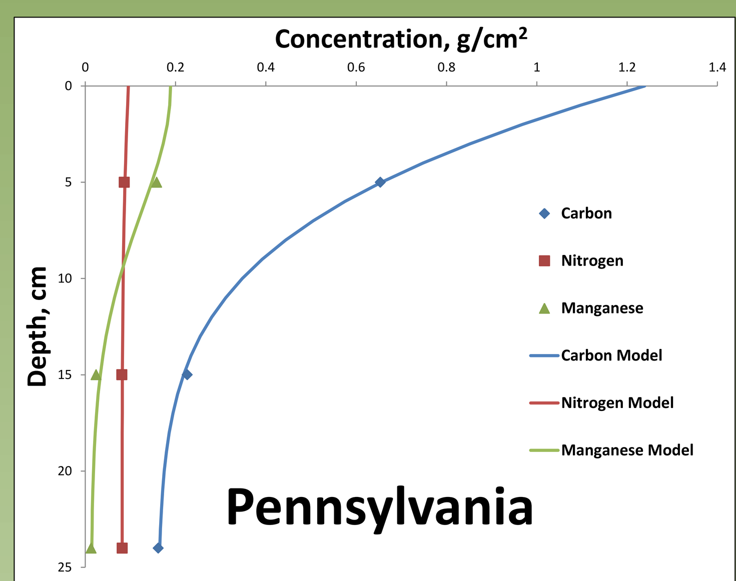
Field Data. Soil samples were collected in ≃10 cm intervals from soil pits at five sites along a climate transect down the east coast of the US and two additional sites in Puerto Rico and Wales. All sites were chosen on soils developed on the Rose Hill shale or a geological equivalent. The samples were dried and ground to 100 mesh. Major cations were determined using ICP-AES and total carbon and nitrogen was determined with a CHNS Analyzer.

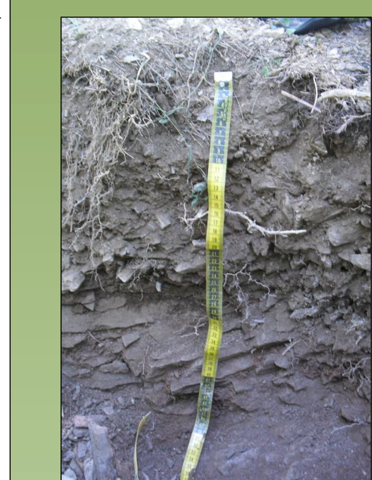
Model. Concentrations versus depth were modeled using a model equation for addition profiles that only incorporated diffusion-like mixing and atmospheric deposition (Drivas et al 2011). The analytical solution was fit using Matlab under different assumptions: a temporally-continuous deposition model was used in fitting C and N concentration profiles while a temporally-finite surface deposition model was used to fit the Mn profile. (Pb data are still being analyzed). Best fit curves were achieved by altering the rate of element deposition, the diffusion coefficient describing soil mixing, the time duration of deposition (Mn), and the elapsed model time. Model equations fit data to ±20%.

3. Results & Discussion

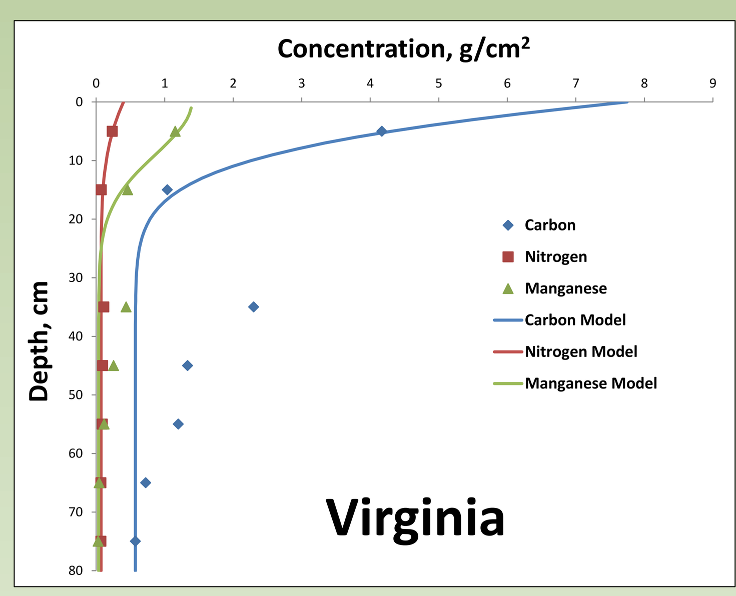


Diffusional Mixing Coefficient: 2.000 cm^2/yr
Carbon Flux: 0.455 g/cm^2yr, %Fit: 17.185
Nitrogen Flux: 0.0435 g/cm^2yr, % Fit: 11.496

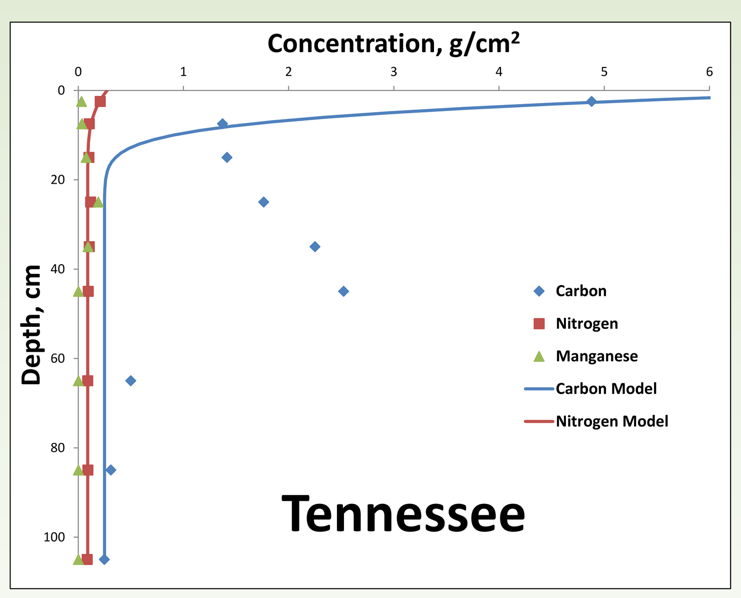


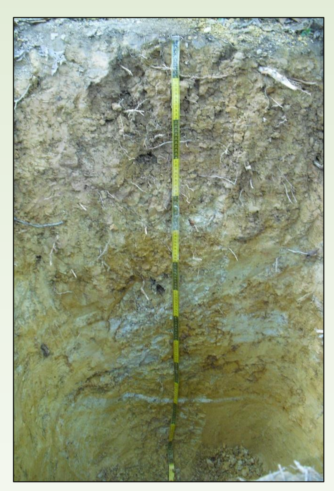


Diffusional Mixing Coefficient : 0.415 cm^2/yr
Carbon Input Flux: 0.0615 g/cm^2yr, % Fit: 2.076
Nitrogen Input Flux: 0.0008 g/cm^2yr, % Fit: 1.229
Manganese Input Flux: 0.0222 g/cm^2yr, % Fit: 18.142

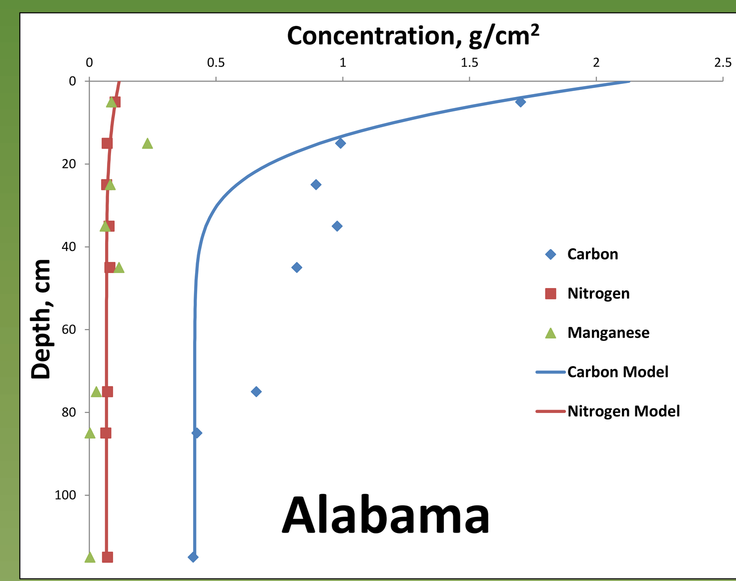


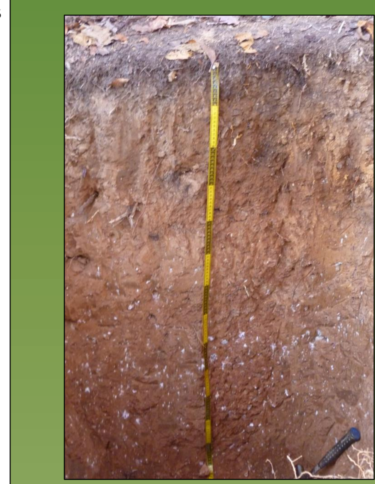
Diffusional Mixing Coefficient : 0.57 cm^2/yr
Carbon Input Flux: 0.48 g/cm^2yr, % Fit: 32.340
Nitrogen Input Flux: 0.0709 g/cm^2yr, % Fit: 17.404
Manganese Input Flux: 0.310 g/cm^2yr, % Fit: 43.947



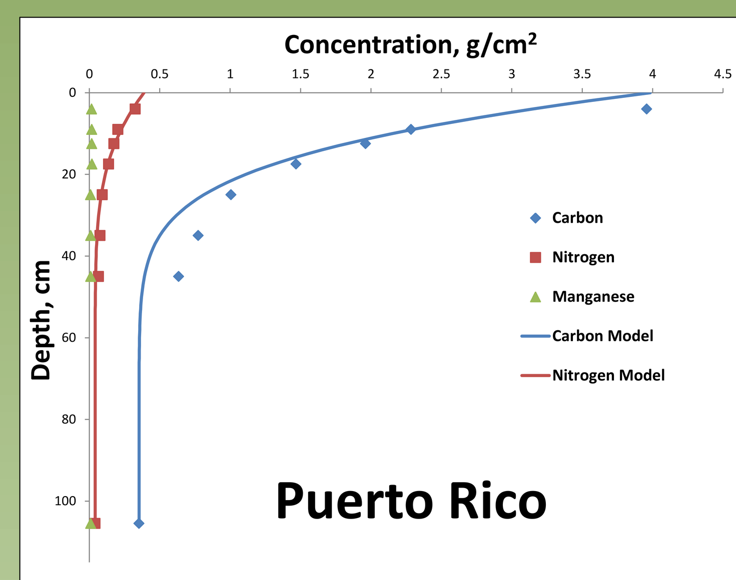


Diffusional Mixing Coefficient : 0.240 cm^2/yr
Carbon Input Flux: 0.340 g/cm^2yr, % Fit: 50.150
Nitrogen Input Flux: 0.008 g/cm^2yr, % Fit: 10.570



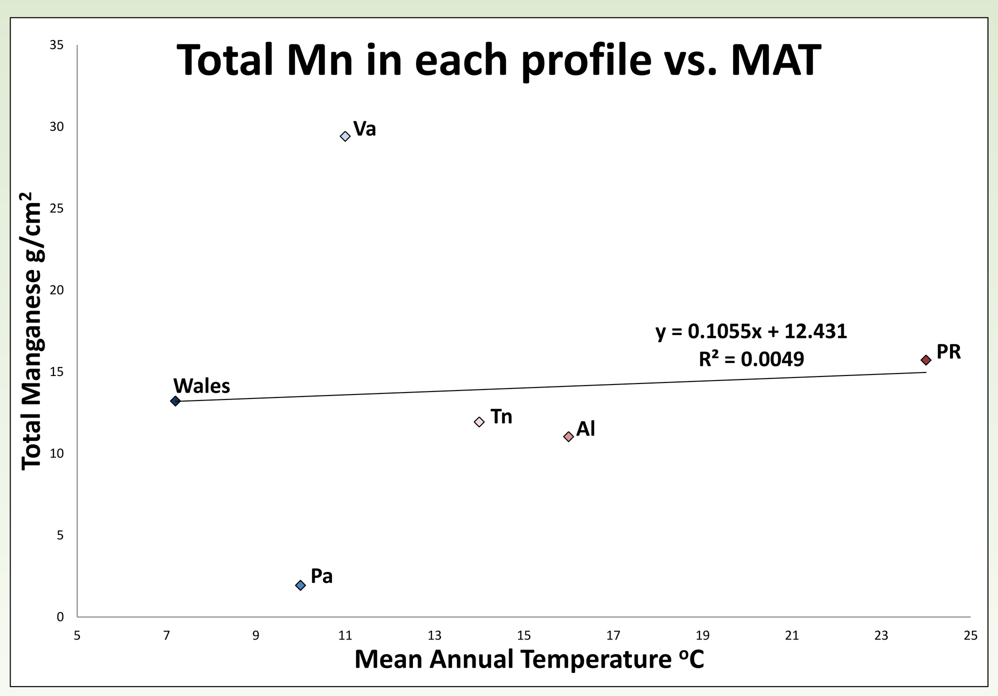


Diffusional Mixing Coefficient : 1.650 cm^2/yr
Carbon Flux: 0.195 g/cm^2yr, % Fit: 23.858
Nitrogen Flux: 0.0057 g/cm^2yr, % Fit: 8.523

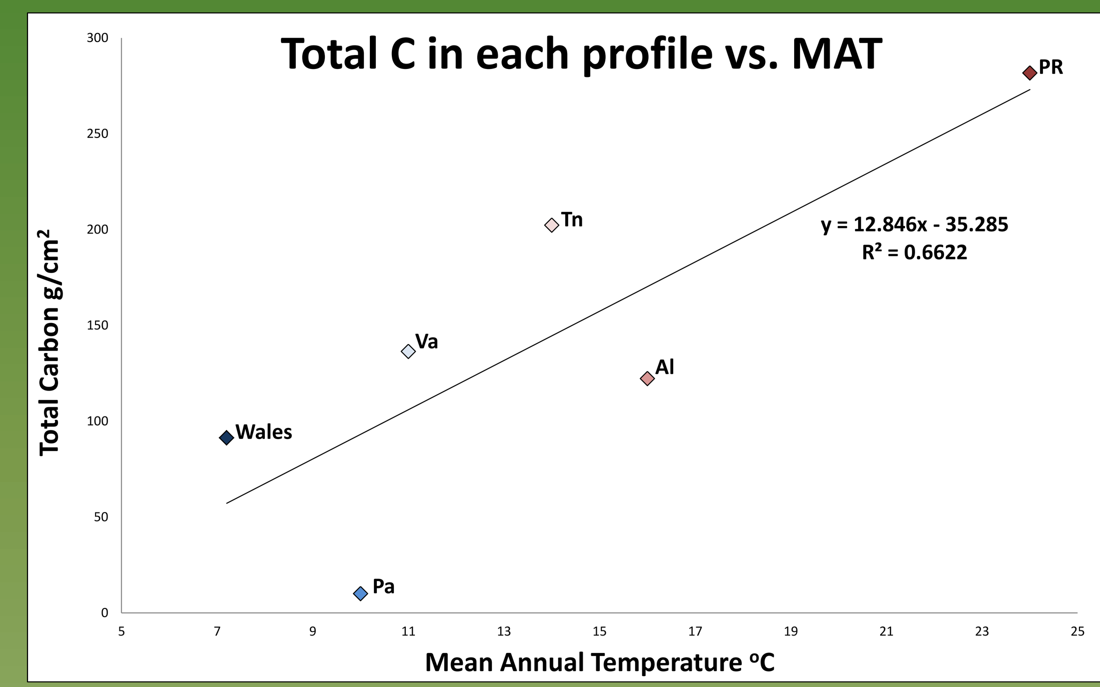


Diffusional Mixing Coefficient : 2.000 cm^2/yr
Carbon Input Flux: 0.455 g/cm^2yr, % Fit: 17.185
Nitrogen Input Flux: 0.0435 g/cm^2yr, % Fit: 11.495

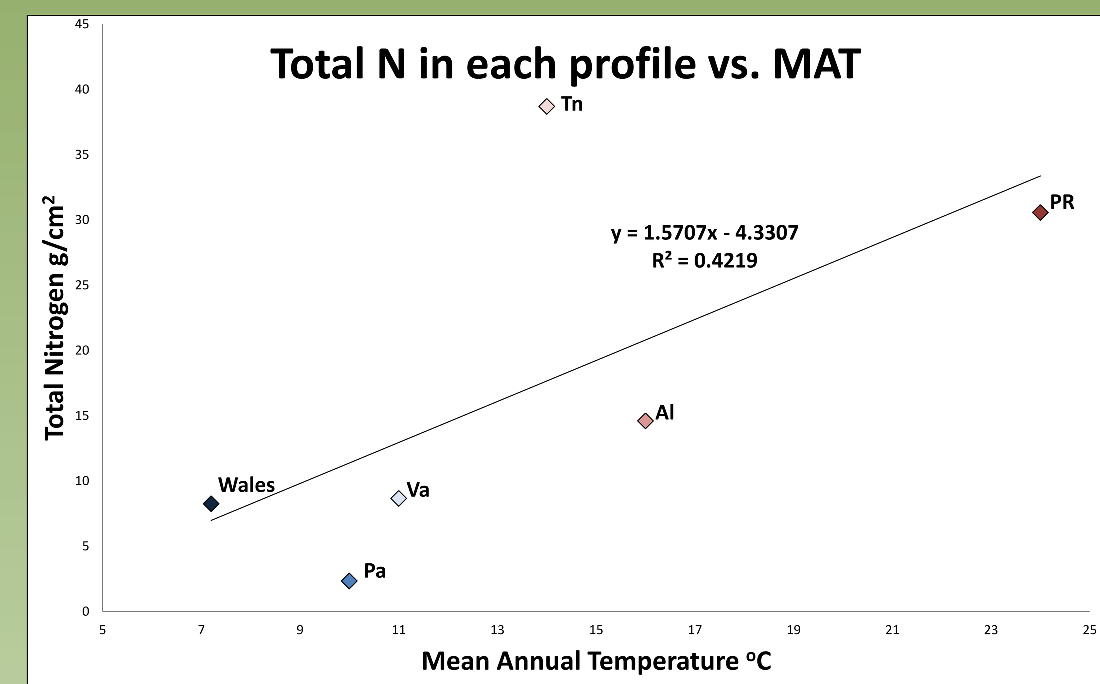
Transect Sample Sites established as part of Shale Hills Critical Zone Observatory



Manganese is a contaminant that is input to atmosphere from point sources and thus does not show a correlation with temperature.



The depth-integrated inventory of total carbon in each profile is positively correlated with mean annual temperature along transect, i.e., soil organic matter in the soil increases with temperature.



Like total carbon, we see a positive correlation between total nitrogen inventory and MAT. Nitrogen, included in SOM, increases with increasing temperature.

4. Conclusion

C and N were always observed as addition profiles. Mn addition profiles were only present in Pennsylvania and Virginia. For all addition profiles, the analytical model fit the data to within ~20%. Lack of fit at some depths is attributed to processes that are not included in the model. For example, the spike in C concentration at ~30 cm in Virginia, Tennessee and, to a lesser extent, Alabama, cannot be explained by atmospheric deposition + simple diffusional mixing but will require a model that includes a permeability barrier or root-related processes.

Inventories of C and N increased along the climosequence. Thus, preservation of C and N in a shale-derived soil increases with temperature. Mn inventories varied along the transect based on industrial inputs (no trend with temperature). Efforts are ongoing to augment the model by incorporating i) leaching, ii) deep inputs of C at root depth. CENTURY will also be used for the modeling work.

5. Acknowledgements

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