How Molecules in Soil Composition Can Determine Climate Resilience

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Introduction

Anthropogenic climate change is projected to increase extreme weather events, desertification, and negative human health consequences globally.

This research seeks to identify possible trends in carbon sequestration potential in the continental United States. This analysis is done on the top layer of soil (TOP: 0-10 cm) and a lower layer (BTM: 20-30cm) for each site.

Objective To find patterns in carbon sequestration and resilience to carbon release as they relate to the five major ecosystem regions in the United States.

Materials and Methods

The data for this study comes from the "One thousand soils" Bowman et al. research using Fourier-transform ion cyclotron resonance mass spectrometry (FTICR-MS).

Data points from across the country.

Figure 1. Map with soil locations

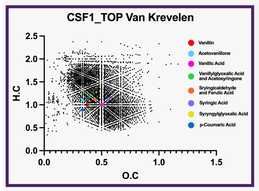


Figure 2a. Van Krevelen with H/C and O/C ratios

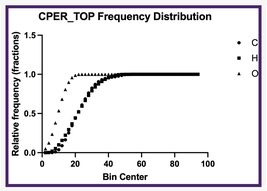


Figure 2b. Frequency distribution of H, C, and O

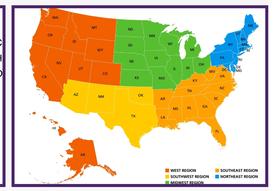


Figure 2c. Map of regions in the United States

↑ C_n (carbon #) = ↑ storage amount

↓ O.C or H.C ratio = ↑ storage duration

Find the maximum organic molecular formula for each soil, top and bottom.

Plot the maximum organic formulas' H.C and O.C on a Van Krevelen.

A map shows the maximum organic formula and the regions of the United States.

Oxidation states are calculated to understand susceptibility of carbon release.

Results

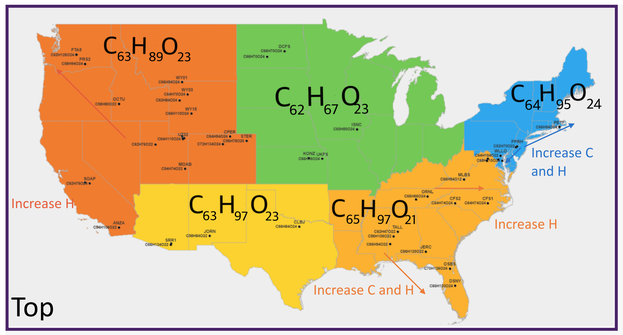


Figure 3a. Map of maximum organic formulas for United States regions with trendlines of Hydrogen and Carbon composition changes in TOP soils

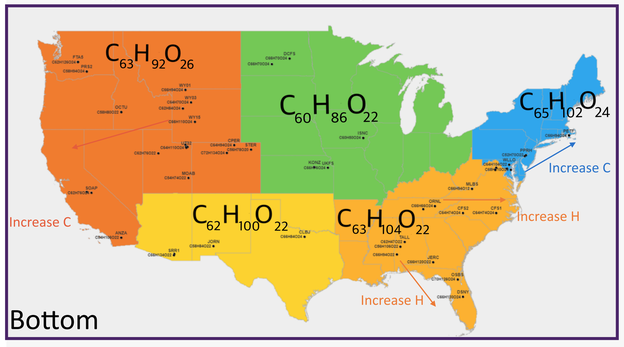


Figure 3b. Map of maximum organic formulas for United States regions with trendlines of Hydrogen and Carbon composition changes in BTM soils

Within regions, there are some trends in hydrogen and carbon increase coming from the Central United States.

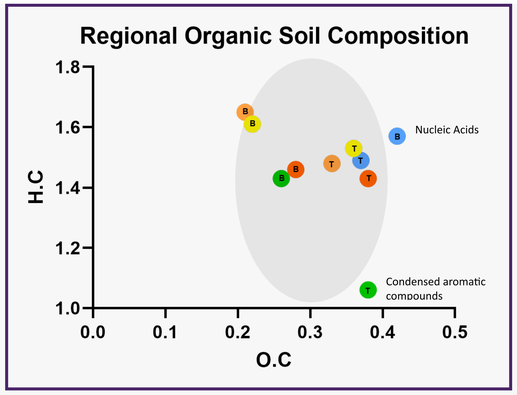
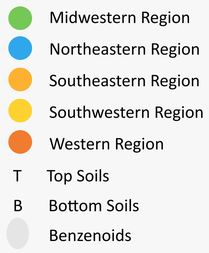


Figure 4. Van Krevelen showing H/C and O/C ratios for United States regions in TOP and BTM soils. Soils in the gray oval are benzenoids.



Top soils seem to have similar O/C ratios, while bottom soils tend to be more similar in terms of H/C ratios.

	Region	Carbon	H/C	O/C	Maximum Formula	C oxidation #
TOP	Midwest	62	1.057	0.376	$C_{62}H_{67}O_{23}$	0.79
	Northeast	63	1.490	0.371	$C_{64}H_{95}O_{24}$	0.69
	Southeast	65	1.484	0.329	$C_{65}H_{97}O_{21}$	0.64
	Southwest	63	1.532	0.357	$C_{63}H_{97}O_{23}$	0.67
	West	62	1.427	0.376	$C_{63}H_{89}O_{23}$	1.06
BTM	Midwest	60	1.433	0.256	$C_{60}H_{86}O_{22}$	0.70
	Northeast	65	1.569	0.235	$C_{65}H_{102}O_{24}$	0.83
	Southeast	63	1.651	0.212	$C_{63}H_{104}O_{22}$	0.95
	Southwest	62	1.613	0.220	$C_{62}H_{100}O_{22}$	0.90
	West	63	1.460	0.283	$C_{63}H_{92}O_{26}$	0.63

Table 1. Averages of different measures of soil composition in relation to region and soil layer

Carbon oxidation state = how resilient the soils are to releasing the carbon back into the atmosphere.

A low or negative number = less susceptible to carbon release

A high number = releases carbon easily (CO_2: +4 oxidation state for carbon)

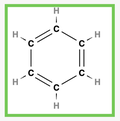


Figure: Benzene Carbon oxidation state -1

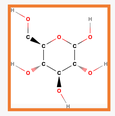


Figure: Glucose Carbon oxidation state 0

Compared to a high carbon oxidation state, like CO_2 (+4) which readily releases into the atmosphere, benzene (-1) needs more electron transfers than glucose (0) to reach that state.

Discussion and Conclusion

Between regions, the differences in soil composition are not very significant. The Midwest region top soils were consistently lower in hydrogen, which may be indicative of more carbon-richness.

Overall, the bottom soils had higher oxidation states by 0.124 on average. The soil layer differences were not extremely different, but the top soils tend to be more oxygen-rich than those on the bottom.

More data collection can occur in the Midwest and Northeast regions in the future to allow for more definitive and reliable results. Comparing soil composition with the median formula numbers instead of the maximum may show different patterns in soil composition across the United States.

As of now, this study can apply to further research on soil composition trends within U.S. regions.

References