Suburbanization-induced Elemental and Molecular Alterations in Soil Organic Matter

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Introduction

This study aims to use chemodynamics to engage the interplay between societal actions and environmental response. The project will build upon data from thermogravimetric and isotopic analysis capturing macroscopic soil chemodynamics in response to suburbanization in the Dallas-Fort Worth Metroplex (DFW). The DFW is one of the fastest growing metro areas in the US. Our early data suggests that a minimum of 30-yrs is the required period of lawn care before key chemodynamic indicators of soil health/resilience, such as R_{50} and isotope 13C (quantity and quality, is needed for lawns to return to their pre-suburbanization environmental status.

The **objective** is to examine implications at the microphysical and molecular-level via: Assessing how differences in the molecular composition of soil organic matter from a suburban lawn changes over time.

Methods & Sampling

Data plotting and Site Selection

Using TAD, Tarrant County Appraisal District data, Houses were placed into sample groups based off what year the home was constructed. Years 1987 to 1998 are group 1, 1999 to 2010 are group 2, and 2011 to 2025 are group 3. Examining these homes and groups in GIS random sites within each group were selected and inquired for soil.

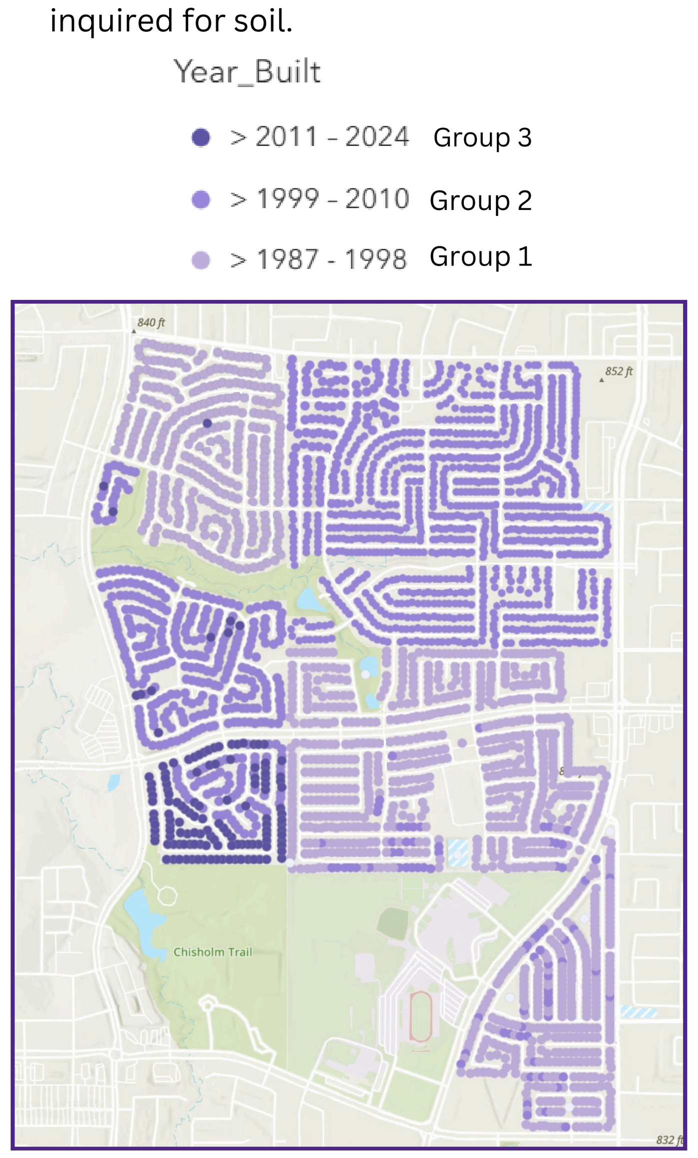

Figure 1. Visualization of distribution of homes and year built across samples neighborhood

Sampling Processing

Three soil cores 6 inches in depth were taken around the oldest tree in the front yard. These cores were placed into a labeled paper bag and weighed back at the lab.

Hydrometer

Detects volumetric water content at each core site.

Sample Preparation

Samples were placed in an oven at 105C for 24 hours. Soil was then ground up using mortar and pestle, then sieved through grain, and sent through the fine grinder for 2 minutes.

Thermogravimetric Analysis (TGA)

utilized around 50 micrograms of sample heated under air at a flow of 10mL/min. Temperature ramped from 25 C to 900 C at constant rate of 10 C/min

Isotope Analysis

between 1.9 to 2.1 micrograms of sample measured using microbalance and stored in elementar tin boats. Samples shipped to Baylor University for isotope-ratio mass spectrometry by Dr. Ren Zhang

R_{50} - Thermal Maturity

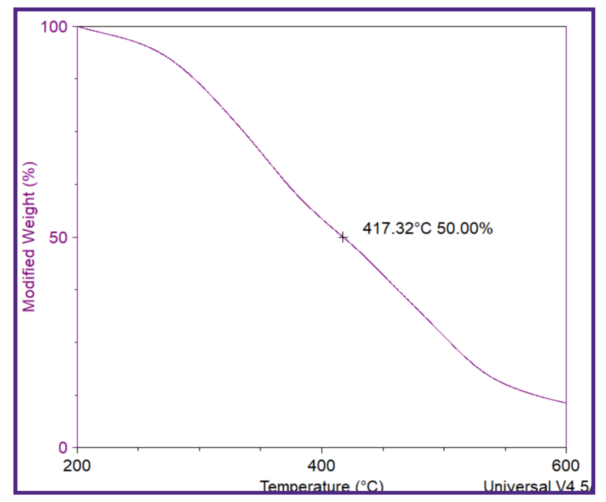

Figure 2. Visualization of T_{50} of 1 - Park

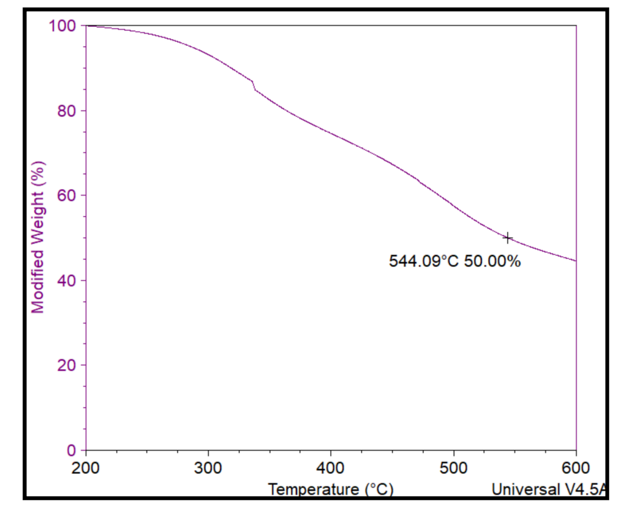

Figure 3. Visualization of T_{50} of 4 - 8717

Equation 1. $$R_{50} = T_{50,x}/T_{50,graphite}$$

$$T_{50,graphite} = 886°C$$

T_{50} is a number that shows when 50% of the weight is lost. Water weight and ash content are excluded from this calculation to specifically identify organic carbon in these soils. Using Equation 1, R_{50} can be calculated to give insight into ...

Park shows an R_{50} of 0.47, classifying this soils as class C indicating this area maybe naturally less thermally mature, Figure 6. Group 1 (3, 5, and 6) have a wide range, with R_{50} being 0.45 to 0.74. Group 2 (2, 7, and 8) demonstrate more narrow range of 0.59 to 0.83. Lastly Group 3 (4) shows an R_{50} of 0.62.

This data helps determine stability of the carbon held in the soil.

Cumulative Curves - Organic Carbon Populations

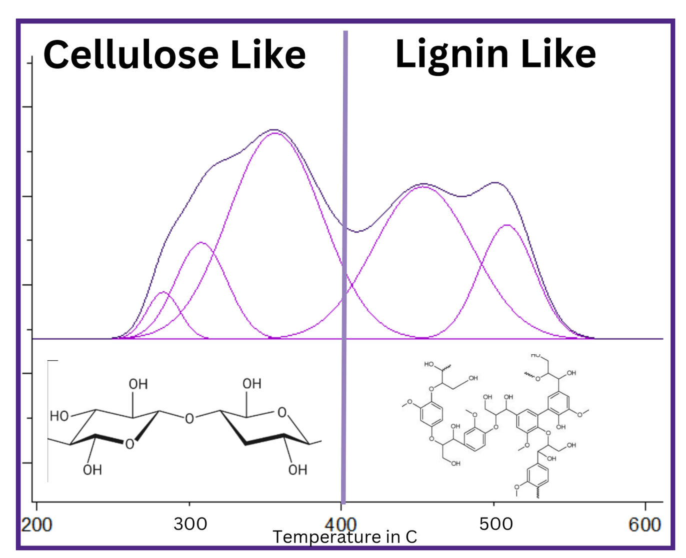

Figure 4. Visualization of carbon populations distribution in soils. 1 - Park

Equation 2.

$X_1 = (A_1 + A_2 + A_n + ...)$

When peak falls in less than 400 C

$X_2 = (A_1 + A_2 + A_n + ...)$

When peak falls in greater than 400 C

$[X_1/ (X_1 + X_2)]*.44$ = Labile Organic Carbon %

$[X_2/ (X_1 + X_2)]*.6$ = Non-LabileOrganic Carbon %

Park shows well distributed peaks creating a smooth cumulative curve, Figure 2. Group 1 (3, 5, and 6) have broader peaks that are moderately spread out. Group 2 (2, 7, and 8) demonstrate more narrow sharper peaks on both sides of the center line. Lastly Group 3 (4) shows a sharp narrow peak to the left of the line at 400C.

Isotopic Analysis

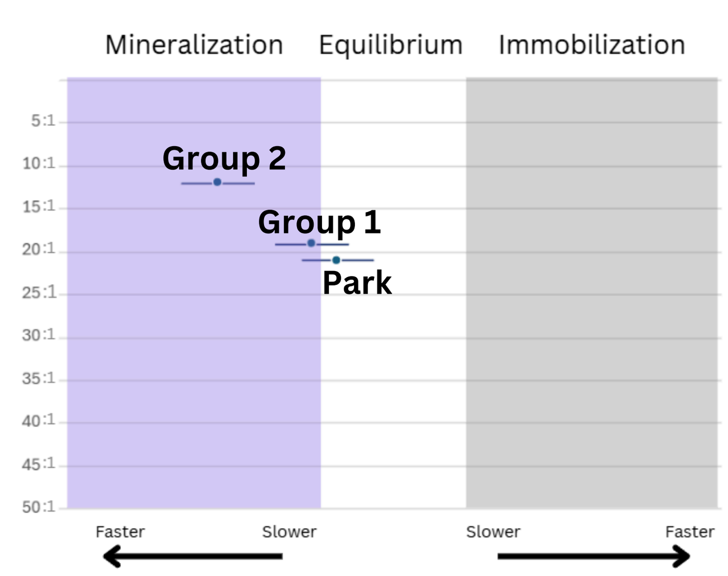

Figure 5. C:N ratio plot to demonstrate microbe activity.

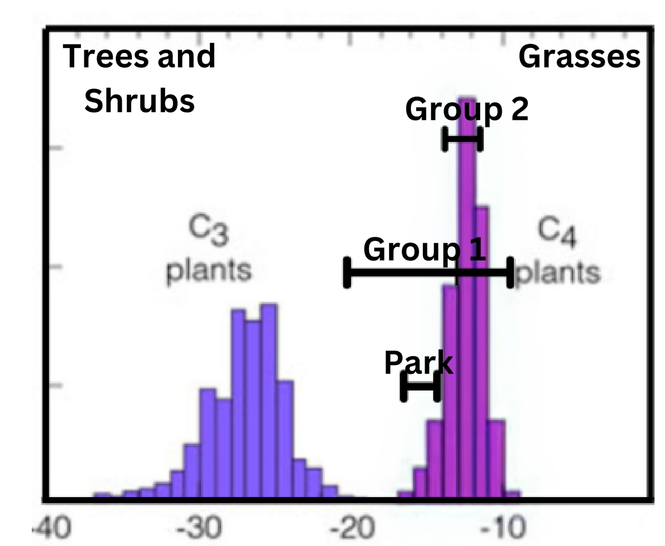

Figure 6. Visualization of carbon 13 compared to C_3 and C_4 distribution of isotope C13

Sample Group	Control	Group 1				Group 2				Group 3
Years Built	Pre Exisiting	1987 - 1998				1999 - 2010				2011 - 2024
Sample Site	1 - Park	3 8112	5 8120	6 5105	Average	2 8324	7 4524	8 ocean	Average	4 8717
Bulk Density	1.05	0.856	1.17	0.996		0.954	0.858	1.09		1.24
Porosity	0.604	0.677	0.558	0.624		0.64	0.676	0.587		0.532
R50	**0.47**	0.68	0.56	0.62	**0.62**	0.81	0.59	0.83	**0.74**	0.62
δ13C	-18.2	-10.1	-11.3	-21.6	-14.3	-14.8			-14.82	-13.36
C:N	**12**	24	21	13	**19.1**	21			**21.00**	
δ15N	7.9	7.5	8.4	10.7		8.1				
Labile Organic Carbon %	33	37	29	36	34.3	28	32	24	27.78	24
Non-Labile Organic Carbon %	20	17	22	18	18.9	24	21	27	23.81	27
Class	C				C				B	C

Figure 6. Table of all soils sampled during this study. Including bulk density, porosity, $R_{50,}$ 13C, C:N ratio, 15N, Labile Organic Carbon %, Non-Labile Organic Carbon %, and Class.

Discussion and Conclusion

The study reveals patterns in how suburbanization alters soil organic matter at the molecular level over time.

The R_{50} value (thermal stability indicator) of 0.471 for park soils classifies them as class C, indicating naturally less thermally mature organic carbon compared to some suburban soils. This serves as a baseline for comparing suburbanized areas. Different age groups of suburban development demonstrate varying carbon stability patterns. Groups 1, 5, and 6 show wider R_{50} ranges (0.450 to 0.742), while Groups 2, 7, and 8 have narrower ranges (0.593 to 0.827), and Group 3(4) shows an R_{50} of 0.615. This suggests a **time-dependent transformation of soil organic carbon.** Looking to the cumulative curves displaying carbon populations the data supports an **approximate 30 year age** for carbon populations **to return to pre-suburbanization.**

Isotopic data suggests that even with similar grasses and trees in every yard, different microbial processes of organic carbon occur. The microbe activity shows the Park is likely grass dominated leaning towards trees and shrubs. **Group 1 (1987-1998) is slowly returning to a similar composition as the Park, and Group 2 (1999-2010) only shows grasses for now.**

Carbon sources and cycling processes likely were not fully captured by thermal analysis and provided isotopic data alone. Further data of land management practices, and a larger sampling would greatly enhance this study.

References and Acknowledgments

I would like to thank the home owners that allowed me to sample in their front yard.