Extraction-Free Quantification of Lignocellulosic-C and Their Temporal Dynamics in Managed Soil Using a 2D-DTG Mixing Ratio Approach

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BACKGROUND

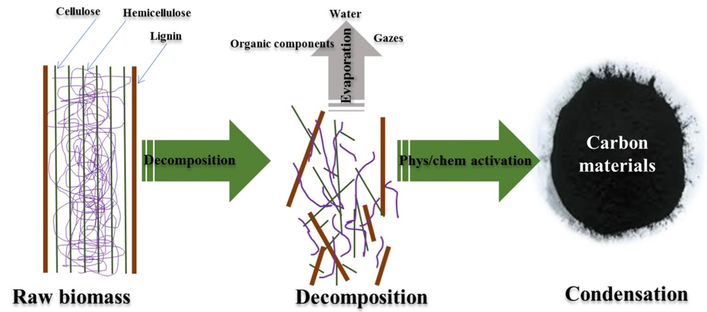

Fig. 1: Conceptual illustration of lignocellulosic biomass decomposition and its transformation into carbon-rich materials via physicochemical activation and condensation (Mergbi et al., 2023)

OBJECTIVE

⇒To quantify lignocellulosic carbon contributions and decomposition dynamics under different soil management using an extraction-free 2D-DTG mixing ratio approach.

METHODOLOGY

- **Study Method**

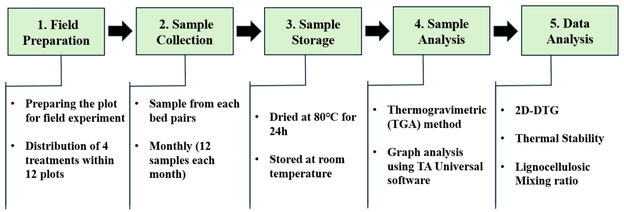

Fig. 2: Study Design

NT (No Treatment); **CC** (Cover Crops); **COMP** (Compost); **CC+C** (Cover Crops and Compost)

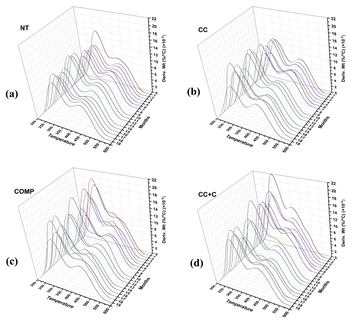

Fig. 3: Derivative Thermograms (DTG) (200 - 600°C) —(a) NT; (b) CC; (c) COMP; (d) CC+C

Table 1: Interpretation for synchronous (Φ) and asynchronous (Ψ) using Noda's rule

Ψ (t_1, t_2)	Φ (t_1, t_2)	Interpretation
+	+	t_1 changes before t_2
-	+	t_1 changes after t_2

RESULTS AND DISCUSSION

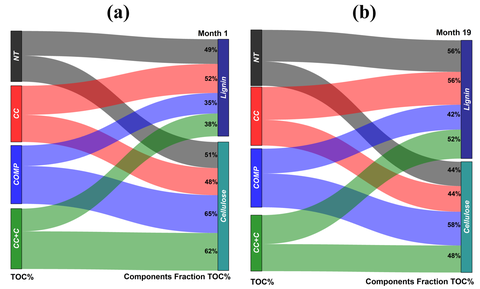

Fig. 5: Lignocellulosic Mixing Ratio— Months 1 (a) vs Month 19 (b)

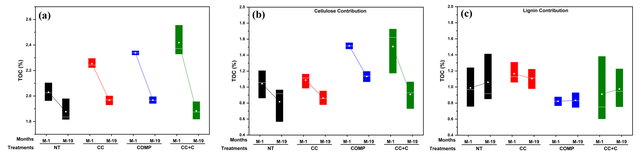

Fig. 6: Months 1 vs Month 19 comparison — (a) Change in TOC%, (b) Cellulose based OC%, and (c) Lignin based OC%

- **Lignin contribution increased** over time **(~38–40% → ~45–49%)**, indicating enhanced incorporation (Fig. 5).
- **CC+C** produces the **most stable and integrated SOC** system → **synergistic effects** (Fig. 5-7).
- **Sequence reorganization** indicates a transition to **more dynamic** carbon systems (Fig. 7)

2D-DTG ANALYSIS

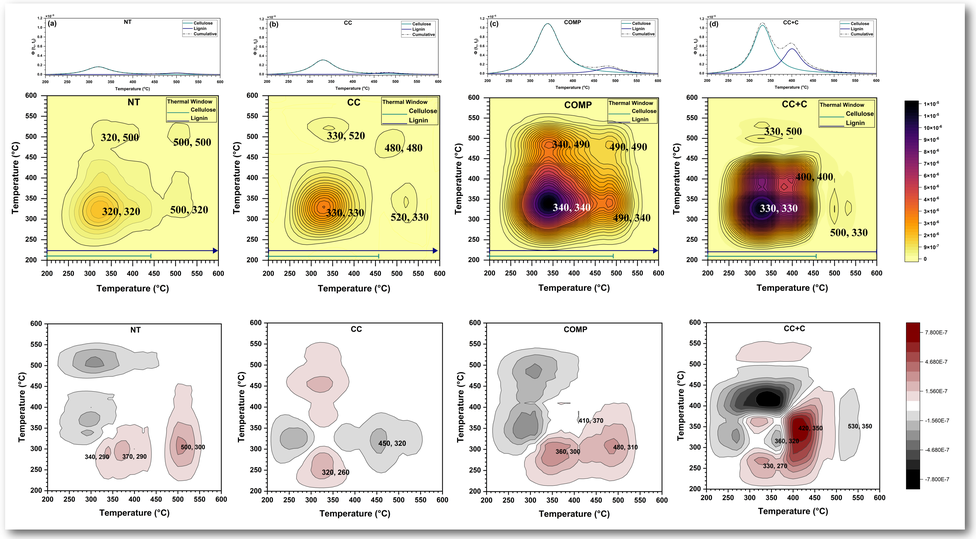

Fig. 4: 2D-DTG correlation — Synchronous (upper panel), asynchronous (lower panel) — revealing lignocellulosic decomposition sequence — (a) NT; (b) CC; (c) COMP; (d) CC+C

- Cellulose intensity order: **COMP ≥ CC+C >> CC > NT**; For Lignin: **CC+C >>> COMP >> CC ≈ NT**
- CC+C shows **smallest thermal window** → uniform C pool + quick availability.

Arrow summarize decomposition precedence from 2D-DTG interpretation

Treatments	Cellulose behavior	Lignin behavior	Takeaway
NT	**340→290** and **370 →290** Stable cellulose precedes less stable cellulose	**500→300** Lignin precedes cellulose	Repeated cellulose stabilization; lignin act separately
CC	**320→260** Earlier cellulose turnover dominates	**320→450** Lignin follows cellulose	Fast cellulose turnover with simpler lignin transition
COMP	**360→300** Stable cellulose before less stable cellulose	**480→310** and **370 →410** Mixed lignin sequencing	Mixed interaction between pools
CC+C	**330→270** and **320 →360** Dual cellulose behavior	**420→350** and **350 →530** Early lignin + stable late lignin	Most dynamic treatment, cellulose reconstructing with latest stable lignin

CC+C shows the most complex and stable decomposition behavior

Fig. 7: Treatment-dependent shifts in cellulose–lignin decomposition pathways

CONCLUSION

- **Cellulosic Backbone of Soil C**

Cellulose-C dominated (57–72%), reinforcing soil structure and long-term carbon stability.

- **Enhanced Reactive Carbon Pools**

Increased signal intensities under organic amendments indicate expansion of reactive carbon pools.

- **Decomposition Sequence Reorganization**

Sequence analysis revealed a shift from separated cellulose–lignin behavior (NT) to coupled and bidirectional interactions (CC+C).

- **Extraction-Free Quantification Advantage**

The 2D-DTG mixing ratio approach provides a rapid, extraction-free method to quantify lignocellulosic contributions and dynamics.

ACKNOWLEDGEMENT

. Funding for this work was provided by Southern Sustainable Agriculture Research and Education grant LS22-372.

. Field work associated with this work was performed at Opal's Farm, Unity Incorporated, Fort Worth, TX.

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