Stable carbon isotopic composition of biomass burning emissions – implications for estimating the contribution of C3 and C4 plants

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Savannah Fires in Africa

**C₃ Plants:** Trees, shrubs

**C₄ Plants:** Savannah grass

**Carbonaceous Aerosols**
- Elemental Carbon (EC)
- Organic Carbon (OC)

**How much of the emissions stem from C₃ vs C₄ plants?**

**CO₂**

**CO**
$^{13}$C for distinguishing C3 and C4 plants

2 stable carbon isotopes:

$^{12}$C

$^{13}$C (~ 1%)

$^{13} R = ^{13} C/^{12} C$

$\delta^{13} C = \frac{^{13} R_{Sample} - ^{13} R_{VPDB}}{^{13} R_{VPDB}} \times 1000\%$

C3 plants contain less $^{13}$C than C4 plants
Research Question

“How do $C_3$ and $C_4$ plants in the savannah fires contribute to the ORGANIC CARBON?

Lab Experiments
- How does delta value of OC fit with the $^{13}$C signature of $C_3$ (willow) and $C_4$ plants (corn)?
- What is the impact of the proportions of $C_3$ and $C_4$ plants in mixed fuels?

Field Experiments
- What is the source contribution?
Methodology

Aerosol sample Collection

Filter preparation
Biomass burning & sample collection
Sample preservation

Aerosol sample Measurement
Sunset OC/EC analyzer
δ¹³C-Thermogram system

Data Calculation & Analysis
Overview of African biomass fuels

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Biomass Burnt</th>
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<tbody>
<tr>
<td>FE1</td>
<td>C$_3$ plants (27.8‰), savanna grasses (12.9‰), dung</td>
</tr>
<tr>
<td>FE2</td>
<td>C$_3$ plants (27.8‰), savanna grasses (12.9‰), dung</td>
</tr>
<tr>
<td>LE1</td>
<td>Willow (28.98‰)</td>
</tr>
<tr>
<td>LE2</td>
<td>Corn (12.64‰), willow (28.98‰)</td>
</tr>
<tr>
<td>LE3</td>
<td>Corn (12.64‰), willow (28.98‰), corn + willow</td>
</tr>
<tr>
<td>LE4</td>
<td>Wood (26.75‰)</td>
</tr>
<tr>
<td>LE5</td>
<td>Corn (11.98‰) + Wood (26.75‰)</td>
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</tbody>
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![Graph showing 13C signatures for field campaigns](image)
The diagram represents the δ\(^{13}\)C\(_{OC}\) for willow and corn (Lab).

- Delta value of OC for willow is higher than \(^{13}\)C signature of fuel.
- Delta value of OC for corn is slightly lower than \(^{13}\)C signature of fuel.
Impact of MCE and moisture on $\delta^{13}C_{OC}$

- Modified combustion efficiency, MCE = $\Delta CO_2 / (\Delta CO_2 + \Delta CO)$
- MCE seems to have no relation
- With moisture delta value increases
Results: Delta $^{13}$C vs %Corn (Lab)

- Not linear: For a 50-50% mixture delta $^{13}$C of OC is closer to $^{13}$C signature of corn than that of willow.
Results: OC/EC Ratio vs %Corn (Lab)

- OC/EC ratio of Corn is higher than that of willow
- OC/EC ratio increases with increasing proportion of corn in the mixture.
Results: Delta $^{13}$C (Field Campaign)

- $\delta^{13}$C: -25‰ to -22‰
- Delta value: close to $^{13}$C signature of C$_3$ plants
Conclusion & Discussion

• LAB: $\delta^{13}$C values of OC: close to $^{13}$C signature of fuel
• Mixture of corn & willow: corn (C4) => higher contribution
• Field: $\delta^{13}$C values of OC: close to $^{13}$C signature of $C_3$ plants

• $C_3$ plants => higher contribution in Savannah fire
  • Mass of trees vs grasses
  • $C_3$ plants burn longer – $C_4$ grasses burn faster
  • Aerosol collection
  • Impact of moisture
  • Impact of combustion efficiency

• Further investigation: future research
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