ATMOSPHERIC CO$_2$
760 Pg

PLANTS
560 Pg

Photosynthesis
120 Pg yr$^{-1}$

Respiration
60 Pg yr$^{-1}$

SOIL ORGANIC CARBON
1500 Pg

Land Uses
2 Pg yr$^{-1}$

Fossil Fuel
6 Pg yr$^{-1}$

Net Ocean Uptake
2 Pg yr$^{-1}$

Soil Respiration
60 Pg yr$^{-1}$

THE ACTIVE CARBON CYCLE

1 Pg = 10$^{15}$ grams
Grasslands/Savannas/Dry Woodlands

% of Global Total:

Terrestrial Area: 40%
Biomass C: 20%
Net primary productivity: 40%
Soil organic C: 30%
Fire/Grazing

COW POKES
By Ace Reid

"How many head are you plannin' on overstockin' with this summer?"
Aerial view of the study area in southern Texas. Lighter areas are upland **remnant grasslands**. Dark areas within the upland grasslands are **clusters** (smaller spots) or **groves** (larger spots) dominated by woody plants. Continuously dark areas surrounding the uplands are low-lying **drainage woodlands**.
Changes in Woody Plant Cover, 1950-1990:

Landscape 1: 1950

1950 1976 1990
OBJECTIVE

To quantify changes in soil C storage and dynamics resulting from grassland-to-woodland succession in the Rio Grande Plains of southern Texas by:

Quantifying the kinetic characteristics of soil organic matter decomposition in grasslands and in wooded landscape elements using long-term soil incubations under controlled conditions.
Methods - Long Term Soil Incubation

- Soils (0-10 cm) collected from Grassland, Cluster, Grove, and Drainage landscape elements

- Soils passed thru 4 mm sieve and moistened to 80% field capacity; aliquot measured for bulk organic C.

- 30 g soil incubated in 1-L vessels at 20, 25, & 30ºC.
Methods - Long Term Soil Incubation

- CO₂ trapped in NaOH and quantified by titration periodically.

- Pool sizes and MRTs for organic C pools determined by compartmental analyses of CO₂ kinetics.
Conceptual Model of Soil Organic Carbon

Active Pool
MRT < 1-10 yr

Slow Pool
MRT < 10-100 yr

Passive Pool
MRT ≈ 1000 yr
\[ C_t = C_a e^{-k_a t} + C_s e^{-k_s t} \]

- \( C_t \): total organic C at time t
- \( C_a \): carbon content of the active pool
- \( k_a \): rate constant for the active pool
- \( C_s \): carbon content of the slow pool
- \( k_s \): rate constant for the slow pool
- \( e \): the base of the natural logarithm
<table>
<thead>
<tr>
<th>Landscape</th>
<th>Active Pool</th>
<th></th>
<th>Slow Pool</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Residence</td>
<td>Mean Residence</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Time (days)</td>
<td>$C_a$ (gC/kg soil)</td>
<td>Residence (yrs)</td>
<td>$C_s$ (gC/kg soil)</td>
</tr>
<tr>
<td>Grassland</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30°C</td>
<td>103.9</td>
<td>1.02</td>
<td>10.87</td>
<td>5.35</td>
</tr>
<tr>
<td>25°C</td>
<td>70.5</td>
<td>0.98</td>
<td>12.06</td>
<td>5.40</td>
</tr>
<tr>
<td>20°C</td>
<td>109.8</td>
<td>0.90</td>
<td>22.43</td>
<td>5.47</td>
</tr>
<tr>
<td>Cluster</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30°C</td>
<td>123.3</td>
<td>1.16</td>
<td>13.08</td>
<td>7.70</td>
</tr>
<tr>
<td>25°C</td>
<td>63.6</td>
<td>1.04</td>
<td>15.77</td>
<td>7.81</td>
</tr>
<tr>
<td>20°C</td>
<td>123.1</td>
<td>1.01</td>
<td>21.65</td>
<td>7.84</td>
</tr>
<tr>
<td>Grove</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30°C</td>
<td>63.8</td>
<td>2.25</td>
<td>20.00</td>
<td>25.93</td>
</tr>
<tr>
<td>25°C</td>
<td>63.9</td>
<td>2.09</td>
<td>25.00</td>
<td>26.10</td>
</tr>
<tr>
<td>20°C</td>
<td>86.5</td>
<td>1.70</td>
<td>33.33</td>
<td>26.49</td>
</tr>
<tr>
<td>Drainage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30°C</td>
<td>72.7</td>
<td>2.45</td>
<td>25.00</td>
<td>35.40</td>
</tr>
<tr>
<td>25°C</td>
<td>56.5</td>
<td>1.90</td>
<td>33.33</td>
<td>35.95</td>
</tr>
<tr>
<td>20°C</td>
<td>90.1</td>
<td>1.77</td>
<td>50.00</td>
<td>36.08</td>
</tr>
</tbody>
</table>
Conclusions - Long Term Incubations

- Land uses can alter ecosystem carbon storage by changing species composition and the quantity and quality of organic matter inputs.
- Larger SOC in woodlands sustained respiration rates up to 180% greater than grasslands.
- Despite greater respiration, MRTs of SOC were larger in woodlands than grasslands.
- Increased MRTs and increased slow/recalcitrant pool sizes probably result from inputs of lignified woody tissues that decompose slowly.
Conclusions - Long Term Incubations

• Kinetic analyses showed slow/recalcitrant pools up to 600% larger in woodlands than grasslands.

• Estimates of pool sizes and flux rates varied with incubation temperature, indicating microbial sensitivity to temperature.

• Grassland-to-woodland conversion during the past century has been geographically extensive in grassland ecosystems worldwide, suggesting that changes in SOC storage and dynamics documented here could have significance for the global carbon cycle.