Influence of C4 Vegetation on 13CO2 Discrimination and Isoforcing in the Upper Midwest, United States

M. Chen1, T.J. Griffis1, J.M. Baker1,2, S.D. Sargent3, M. Erickson1, J. Corcoran1, and K. Billmark1

1. Department of Soil, Water and Climate, University of Minnesota, St. Paul, MN 55108, USA
2. United States Department of Agriculture-Agriculture, Research Service, St. Paul, MN 55108, USA
3. Campbell Scientific Inc., Logan, Utah, USA

Introduction

Agricultural crops with a C4 photosynthetic pathway rapidly expanded across North America as early as 800 A.D. Their distribution continues to expand globally as demands for food and biofuel production increase. These systems are highly productive, having a significant impact on carbon and water exchange between the land and atmosphere. Here, we investigate the relative impact of agricultural C4 vegetation on the local and regional CO2 biosphere-atmosphere exchange and on the atmospheric isotope forcing in the Upper Midwest, United States. We address three questions:

1. What is the relative importance of C4 and C3 species to the regional CO2 budget?
2. How do these different photosynthetic pathways influence the regional biosphere atmosphere isotope discrimination?
3. To what extent do changes in C4 vegetation impact atmospheric isotope forcing and the isotopic signature of the atmosphere?

Research Site and Land Use History

Field-scale measurements of isotopic CO2 exchange over C4 and C3 systems [Griffis et al., 2005, 2007, Zhang et al., 2008], within close proximity to the tower, were used to provide estimates of the isotopic fractionation for the individual C4 and C3 components:

\[ \delta_{\text{rat}} = \frac{R_{\text{target}} - 1}{R_{\text{source}} - 1} \times 1000 \]  

where \( R \) represents the weight specific isotopic ratio of the source or target plant and \( \delta \) is the deviation of the ratio from standard mean ocean water (SMOW).

Remote Sensing Monitoring Land Use Change

Figure 3. Climatography June and July 2007 were wet and dry. Although more precipitation occurred in August and September, the U.S. Drought Monitor classified much of the region in the moderate drought category with significant depletion of soil water content. Summer 2007 was slightly cooler and significantly drier compared to 2008. However, due to adequate stored soil water prior to the growing season, there was no significant drought in 2008.

Table 1. Comparison of land change between 2007 and 2008 within footprint show the impact of land-use change on CO2 exchange.

<table>
<thead>
<tr>
<th>Land Use</th>
<th>2007 %</th>
<th>2008 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upland prairie</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>Wetland</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Agricultural</td>
<td>40</td>
<td>50</td>
</tr>
</tbody>
</table>

Community Land Model (CLM) and Future Work

NCAP Community Land Model (CLM) is the land surface component of Community Climate System Model (Borlaug et al., 1991, Bonan, 1998, Dai et al., 2003, Zeng et al., 2002) CLM simulates integrated carbon cycle and stable carbon isotope cycles. Here we modified to simulate dynamics of C4 discrimination and to account explicitly for canopy kinetic fractionation [Lee et al., 2009].

In the future, we would like to use this model to study land use versus climate variations on biosphere-atmosphere 13C discrimination within this heterogeneous landscape, and we also study C4/CO2 discrimination.

Acknowledgements

We express our sincere thanks to Jeremy Smith and Bill Breiner for their technical assistance in the lab and at the field site. Funding for this research has been provided by the National Science Foundation, ATEC/1065449 (T.G.) and by the Office of Energy Research (DE-SC0000900). DERM4847 (T.G.) and Tom Nelson for providing logistical support for the tower. Paul and Barbara Driessen for the use of their lab space, and Dr. John Weis, University of Wisconsin, for all the tower flux measurements and isotopic analysis.

Table 2. Biophere-Atmosphere 14CO2 Discrimination and Flux Partitioning

<table>
<thead>
<tr>
<th>Component</th>
<th>CO2 Flux</th>
<th>14CO2 Flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>C3</td>
<td>0.5</td>
<td>0.3</td>
</tr>
</tbody>
</table>

References

[Griffis et al., 2005, 2007, Zhang et al., 2008]
[Lee et al., 2009]
[Griffis et al., 2005, 2007, Zhang et al., 2008]
[Lee et al., 2009]