The First Steps to Sustainability:
Characterizing Plant Communities, Assessing CO2 Sequestration Rates, and Building a Model for Future Sustainability Projection
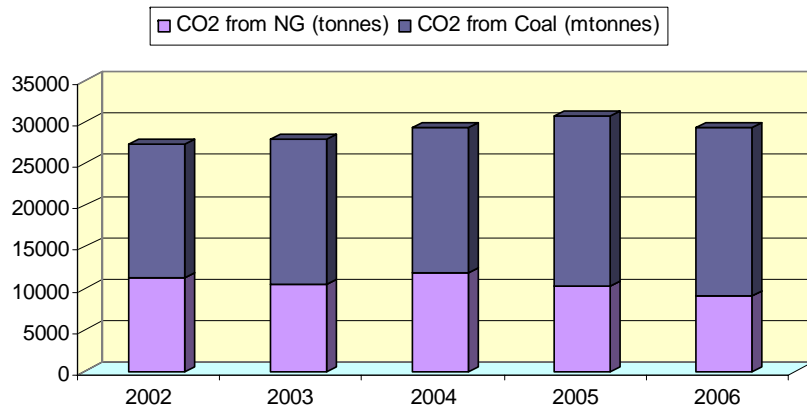
By Christine Prins

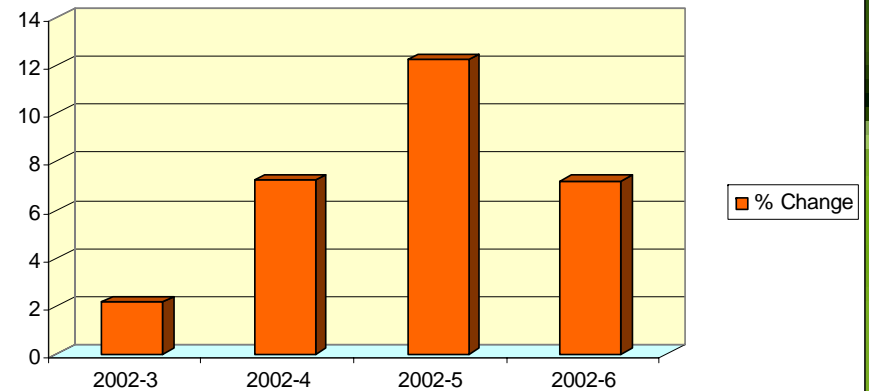Calvin College

August 2, 2008

Some Results from Dr. Piers…
April 20, 2007

- **Carbon Dioxide Emissions from Energy Use**

Carbon Dioxide Emissions (tonnes)

Legend: CO2 from NG (tonnes) ■ CO2 from Coal (mtonnes)

Years: 2002, 2003, 2004, 2005, 2006

% Change on CO2 Emissions (rel 2002)

Legend: ■ % Change

Categories: 2002-3, 2002-4, 2002-5, 2002-6

Our Experiment

- **Objective:**
  - Estimate amount of CO_2 Campus green space sequesters annually
  - Gather useful information for future green space planning
  - Compare our resulting estimate to Dr. Piers' estimated CO_2 output to move to a "carbon neutral" campus
  - Use the data gathered to generate a model for future estimations

Our Experiment

- **Hypothesis:**
  - CO_2 uptake rates will be approximately 30% of the estimated CO_2 output.
  - Based on the amount of green space comprising the campus area

The Design

- **Testing Level Specifications**
  - Plant Communities
  - Representative Plants
  - Replicates

The Design: Plant Communities

- Characterized by:
  - Sort of vegetation present
  - Canopy Cover
  - Amount of moisture available
  - Size of vegetation
  - Amount landscaping / lawn care

The Design: Plant Communities

1. **Maintained Lawn**:

   Fertilized and irrigated, mostly receive full sun with some shade cover, cut and manicured. Includes formal landscaping.

2. **Open Prairie Grassland**

   Direct sunlight, weeds, grasses and wildflowers. Appears to be first community after a major disturbance.

The Design: Plant Communities

3.   Secondary Grassland

    Intermediate between open prairie and forest edge. Has shrub and small tree cover. Receives mostly direct sunlight.

4.   Forest Edge

    Dense forest edge receiving direct sunlight on one side. Asymmetric tree cover, quite dense.

The Design: Plant Communities

5. **Early Successional Forest**
   Young forest, less organized and more dense than mature forests. Significant ground cover.

6. **Mature Forest**
   Older, more developed trees, less ground cover. Larger, more diverse trees and more organization from canopy down.

The Design: Representative Plants

- Chosen within the selected communities
  - Most abundant plants
  - In every community

The Design: Representative Plants

- Maintained Lawn:
  - *Poa pratensis* (Kentucky bluegrass)
- Open Prairie Grassland:
  - *Solidago Canadensis* (Canadian goldenrod)
  - *Fragaria virginiana* (Wild strawberry)
- Secondary Grassland
  - *Cornus serica* (Red-osier dogwood)
  - *Crataegus mollis* (Downy hawthorne)

The Design: Representative Plants

- Forest Edge:
  - *Rhamus cathartica* (Common buckthorn)
  - *Cornus racemosa* (Gray dogwood)
- Early Successional Forest:
  - *Acer saccharum* (Sugar maple)
  - *Fraxinus americana* (White ash)
- Mature Forest:
  - *Fagus grandifolia* (American beech)
  - *Quercus alba* (White oak)

The Design: Replicates

We chose 10 replicates for each representative species randomly around the campus

The Implementation

- **Series of Experiments**
  - Light and soil data
  - Initial testing of replicates
  - Light level experiment
  - LAI collection
  - CO_2 data collection with light levels
  - Creating Light use efficiency curves
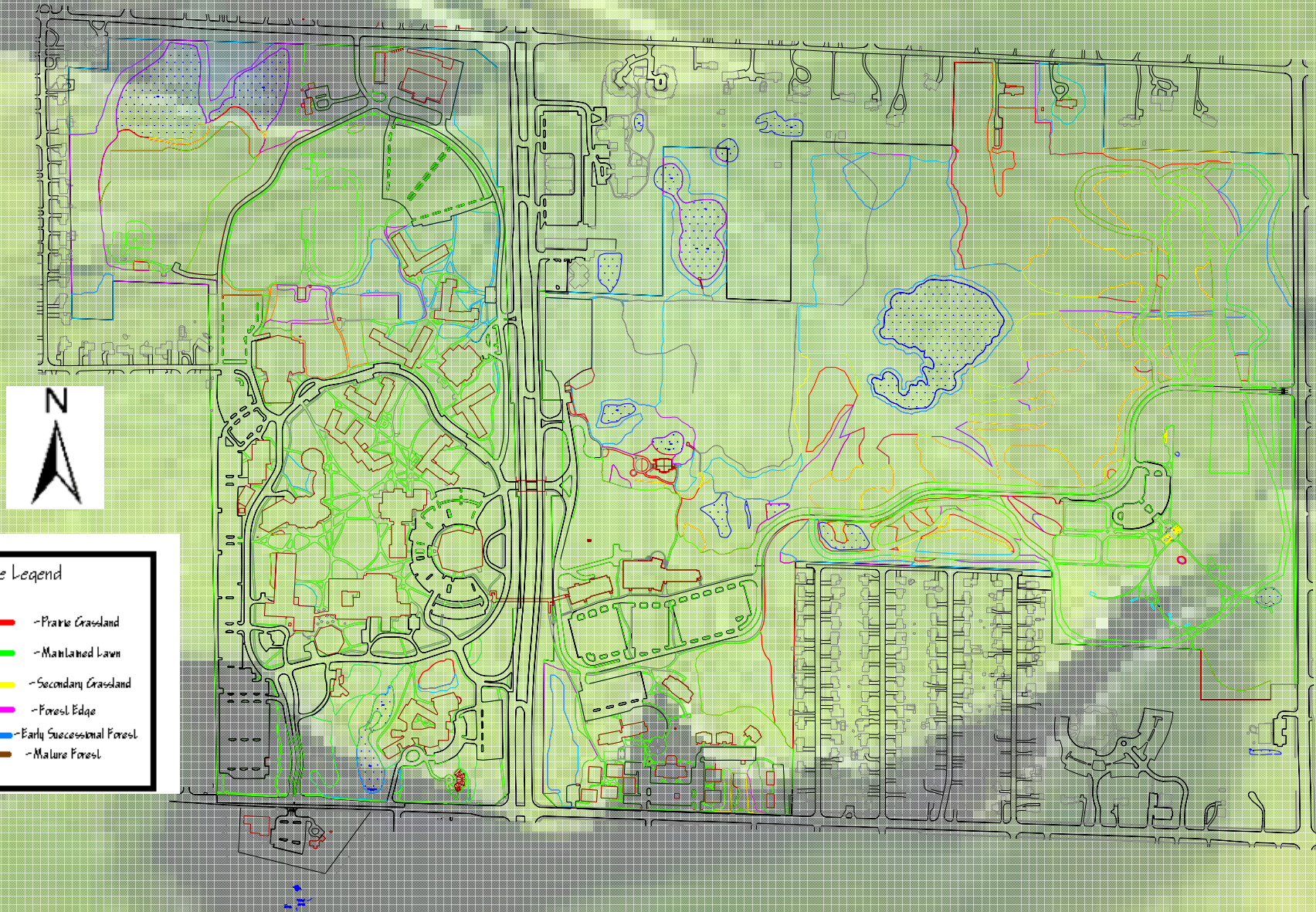 - Area estimation

LAI Photos

The Implementation

- **Series of Experiments**
  - Light and soil data
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Plant Communities of Calvin College

Figure Legend

- —Prairie Grassland
- —Maintained Lawn
- —Secondary Grassland
- —Forest Edge
- —Early Successional Forest
- —Mature Forest

The Results

- ## Community Comparison

SOURCE	DF	SS	MS	F	P
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REPLICATE (A)	9	3105.43	345.048	2.18	0.0219
JULIAN (B)	4	3111.60	777.900	4.93	0.0007
COMMUNITY (C)	5	15712.7	3142.54	19.90	0.0000
A*B	36	8239.57	228.877	1.45	0.0477
B*C	20	3224.20	161.210	1.02	0.4354
RESIDUAL	475	75022.7	157.943		
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TOTAL	549	108416			

The Results

- ## Species Comparison

SOURCE	DF	SS	MS	F	P
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REPLICATE (A)	9	2846.64	316.294	2.04	0.0335
JULIAN (B)	4	2984.51	746.128	4.81	0.0008
SPECIES (C)	10	17624.3	1762.43	11.37	0.0000
A*B	36	7552.94	209.804	1.35	0.0872
B*C	40	3528.92	88.2229	0.57	0.9848
A*B*C	450	69733.8	154.964		
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TOTAL	549	104271			

The Results:
Light Use Efficiency Curves

CO$_2$ Uptake as a Function of Light Level

SB: y = 2.335ln(x) - 13.64
R² = 0.765
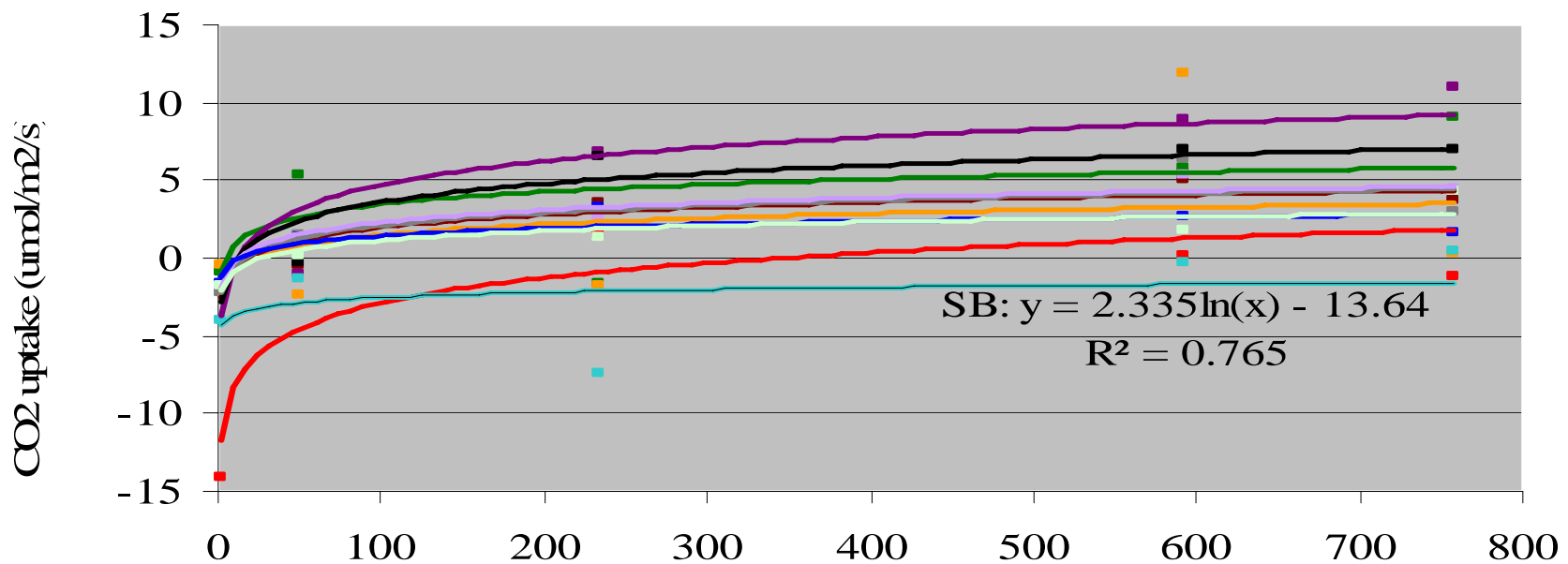
Model Building

- Putting it all together:
  - Light Intensity Data
  - Data inputted to LUE curves at defined light percentages
  - Adjusted for LAI
  - Summed and adjusted for units
  - Proportioned out according to canopy make-up
  - Multiplied by the area

The Total is……

- For the year of 2006 (the available light data)
- From Julian day 60 to 288

51.34771293 metric tons CO_2

Conclusions

- There are better and worse plant communities in terms of CO_2 Sequestration
- There are better and worse plants in terms of CO_2 Sequestration
- We have a long way to go to catch up with CO_2 emissions
- A model can be built to estimate the amount of CO_2 Sequestration at an annual basis.

Further Applications….

- **Green Space Planning**
- More plants studied and incorporated
- More data added to LUE curves
- Ongoing light data collection on campus

Green Space Planning

100% Buckthorn in the Edge

- Common Buckthorn is a non-native invasive species
- It is out-competing similar plants which are natural to the area.
- Without control, we will lose the other similar species completely.
- In this scenario, we adjusted the proportions of representative plants.
- 50:50 mix to a 100% Buckthorn and 0% Gray Dogwood.

	Amount of Carbon Sequestered per Year (Metric Tons)
50:50 Mix of Dogwood and Buckthorn	51.34771293
100% Buckthorn	53.23510423
Difference	**+1.8873913**

- This Scenario would give an increased amount of Carbon Sequestered per year.

100% Gray Dogwood in the Edge

- Gray Dogwood is a species that competes with Buckthorn
- If all the Buckthorn were to be removed as a restoration project, Dogwood would be the entirety of the Edge
- Part of this restoration project has begun
- In this scenario, we adjusted the proportions similar to the last scenario
- 50:50 mix to a 100% Gray Dogwood and a 0% Buckthorn

	Amount of Carbon Sequestered per Year (Metric Tons)
50:50 Mix of Dogwood and Buckthorn	51.34771293
100% Dogwood	49.46032164
Difference	**-1.8873913**

- Though this scenario would reinstate biodiversity, Carbon uptake rate would be diminished.

Open Prairie Grassland Instead of Maintained Lawn

- A Large Area of the Campus is made up of Maintained lawn
- Maintained lawn is expensive to keep up
- It requires constant mowing, watering, and fertilizing
- Some argue that heavily maintained lawns are not a wise use of water, minerals, or money.
- To model this scenario, we have replaced the area represented by maintained lawn with the amount of carbon fixed for the open prairie grassland.

	Amount of Carbon Sequestered per Year (Metric Tons)
With Maintained Lawn	51.34771293
With Prairie Replacing Maintained Lawn	51.18893322
Difference	**-0.15877971**

- This scenario suggests that the area occupied by maintained lawn is more effective at Carbon sequestration than the prairie grassland would be in that space.

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- Calvin College

Any Questions?