Measuring carbon in west-side permanent plots; aboveground, belowground, and in-between




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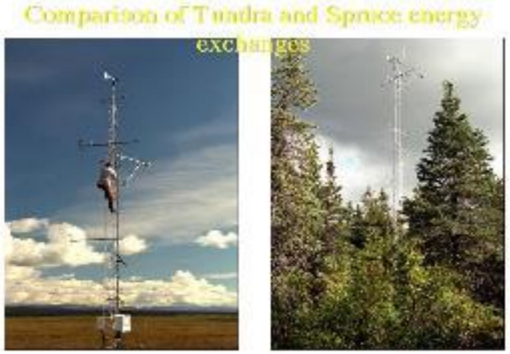
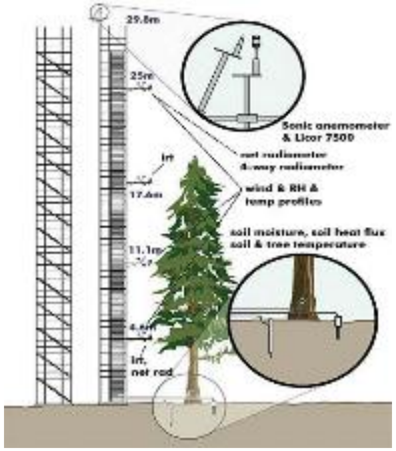
Carbon Measurement in Permanent Plots

- Some methods are complex – some are simple
- Complex tools require specialized knowledge and personnel
- Simple tools and techniques good for large novice groups.
- Build on forestry traditions
- Biometric approaches to C measurement are widespread



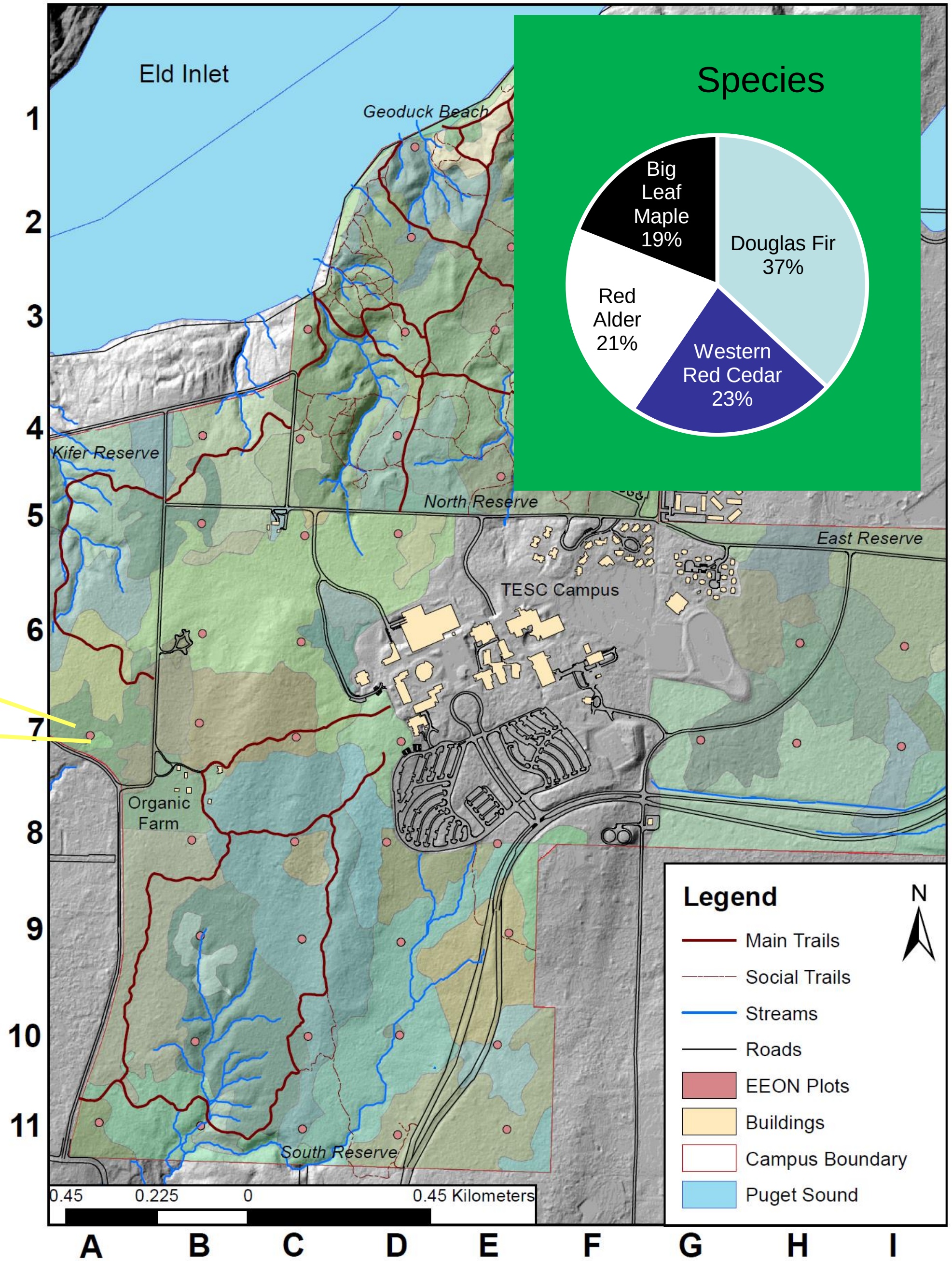


evergreen

TPA: 170 acre^{-1}
BA: ~300 ft^{2} acre^{-1}
SDI: ~450
MAI: 6 ft^{2} acre^{-1}
Top height 208 ft

http://blogs.evergreen.edu/eeon/files/panoramas/B10p/_flash/B10p.html

The Evergreen State College Forest Reserve Map

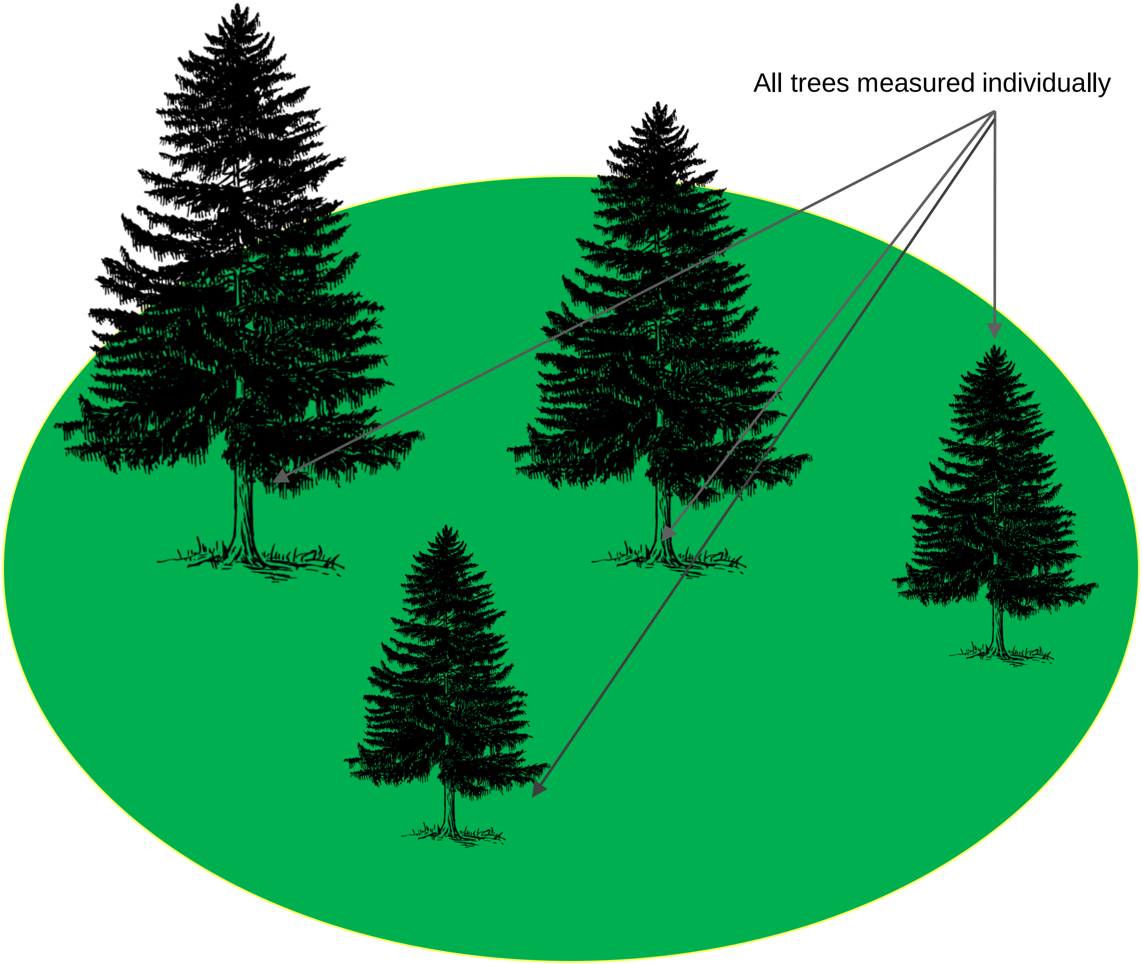


Authors: Jessica Andrade and Pauline Allen

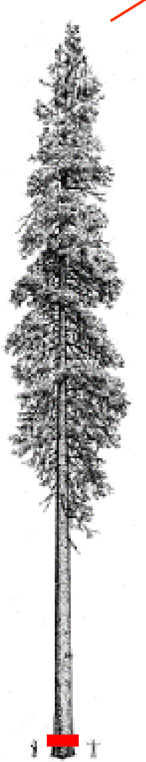
Plot Design

- 10 meter diameter plots (size for 10-20 trees per plot)
- Periodic biomass/carbon inventory (1-3 years)



Repeat measures allow estimation of carbon gain



Pseudotsuga menziesii

Aboveground Biomass =
$b + m*(\mathrm{DBH})^{c}$

Estimate ~46-50% of mass is carbon

Difference over time = carbon gain

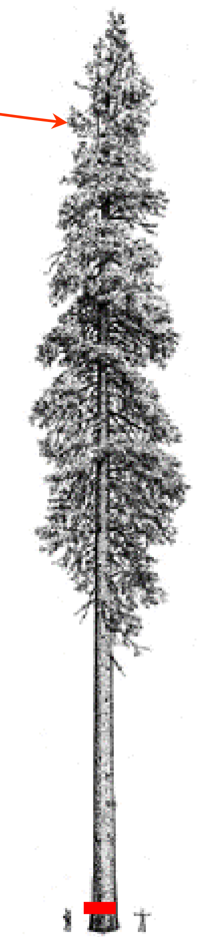
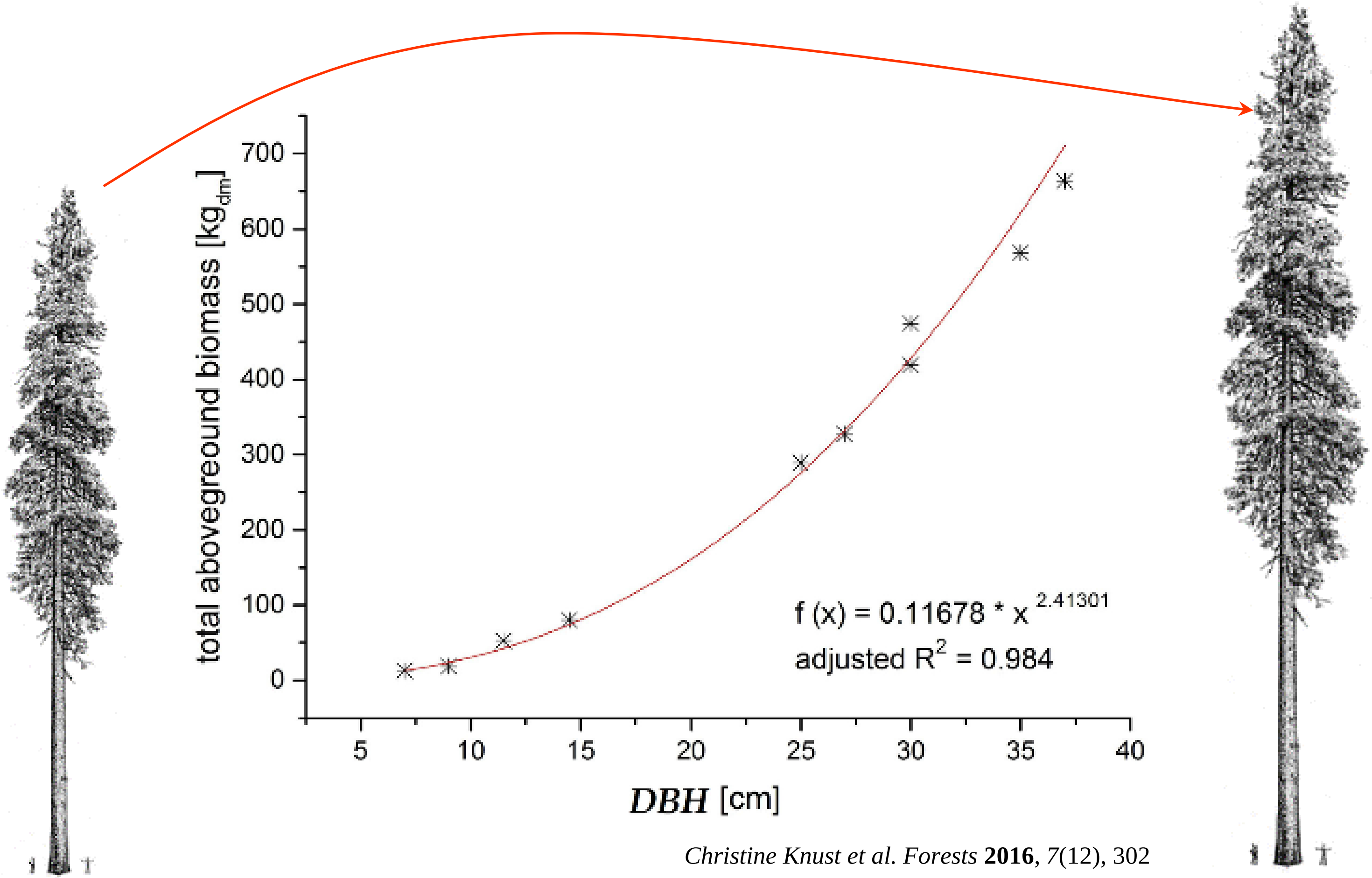


Image by Robert Van Pelt: www.forestgiants.com

- Biomass estimated from DBH
- 46-50% of Biomass = C
- Repeat measures allow estimation of C gain



Christine Knust et al. Forests **2016**, *7*(12), 302

Image by Robert Van Pelt: **www.forestgiants.com**

Forest Science 49(1) 2003

National-Scale Biomass Estimators for United States Tree Species

Jennifer C. Jenkins, David C. Chojnacky, Linda S. Heath, and Richard A. Birdsey

ABSTRACT. Estimates of national-scale forest carbon (C) stocks and fluxes are typically based on allometric regression equations developed using dimensional analysis techniques. However, the literature is inconsistent and incomplete with respect to large-scale forest C estimation. We compiled all available diameter-based allometric regression equations for

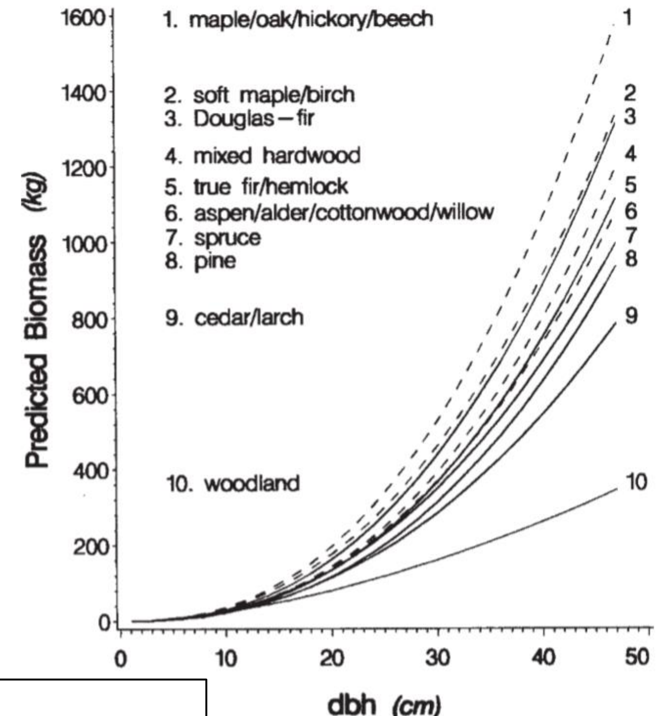


Table 4. Parameters and equations* for estimating total aboveground biomass for all hardwood and softwood species in the United States.

	Species group	Parameters β_0	Parameters β_1	Data points†	Max ††dbh cm	RMSE§ log units	R^2
Hardwood	Aspen/alder/cottonwood/willow	–2.2094	2.3867	230	70	0.507441	0.953
	Soft maple/birch	–1.9123	2.3651	316	66	0.491685	0.958
	Mixed hardwood	–2.4800	2.4835	289	56	0.360458	0.980
	Hard maple/oak/hickory/beech	–2.0127	2.4342	485	73	0.236483	0.988
Softwood	Cedar/larch	–2.0336	2.2592	196	250	0.294574	0.981
	Douglas-fir	–2.2304	2.4435	165	210	0.218712	0.992
	True fir/hemlock	–2.5384	2.4814	395	230	0.182329	0.992
	Pine	–2.5356	2.4349	331	180	0.253781	0.987
	Spruce	–2.0773	2.3323	212	250	0.250424	0.988
Woodland‖	Juniper/oak/mesquite	–0.7152	1.7029	61	78	0.384331	0.938

* Biomass equation:

$bm = \text{Exp}(\beta_0 + \beta_1 \ln dbh)$

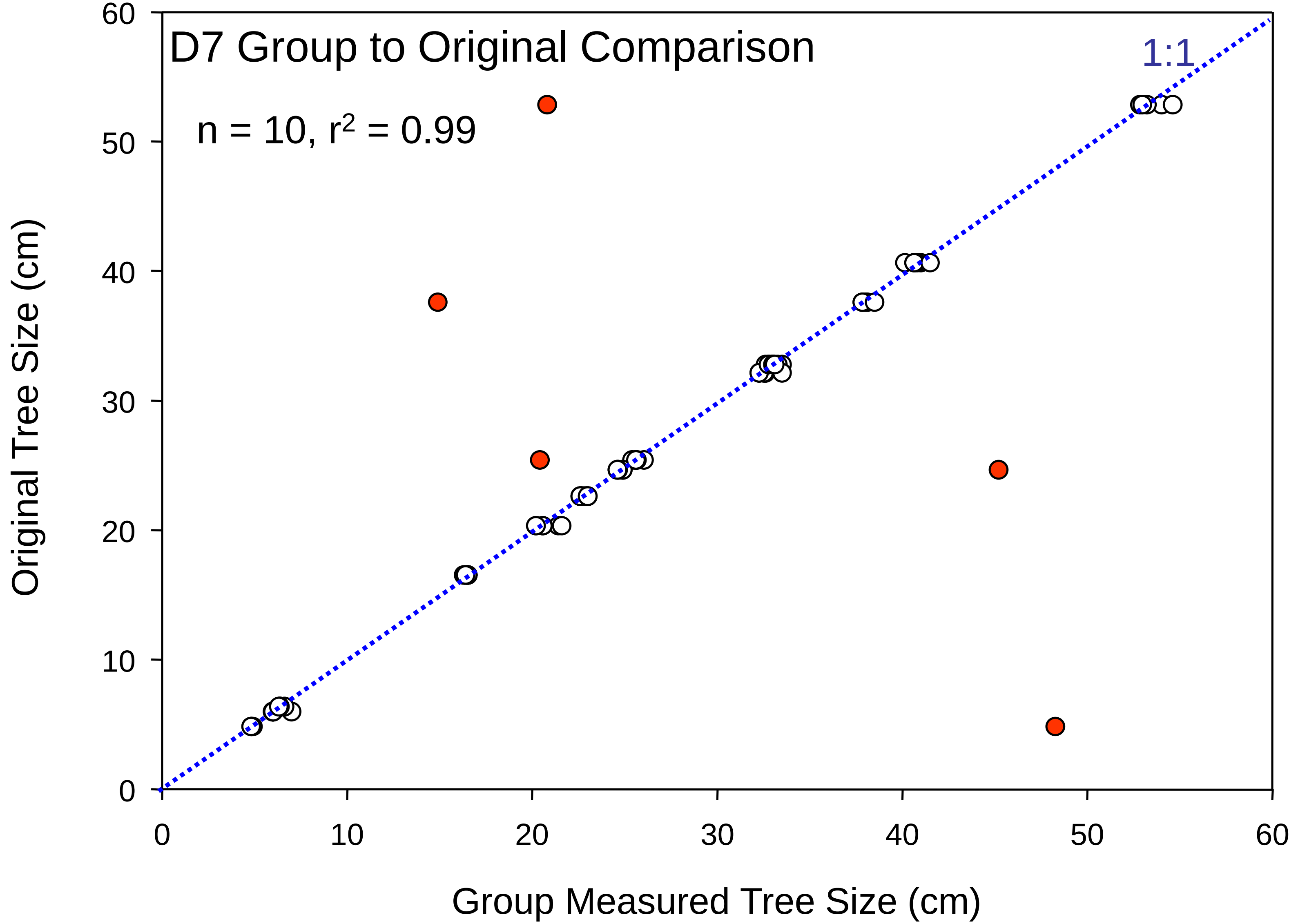
where

bm = total aboveground biomass (kg) for trees 2.5cm dbh and larger

dbh = diameter at breast height (cm)

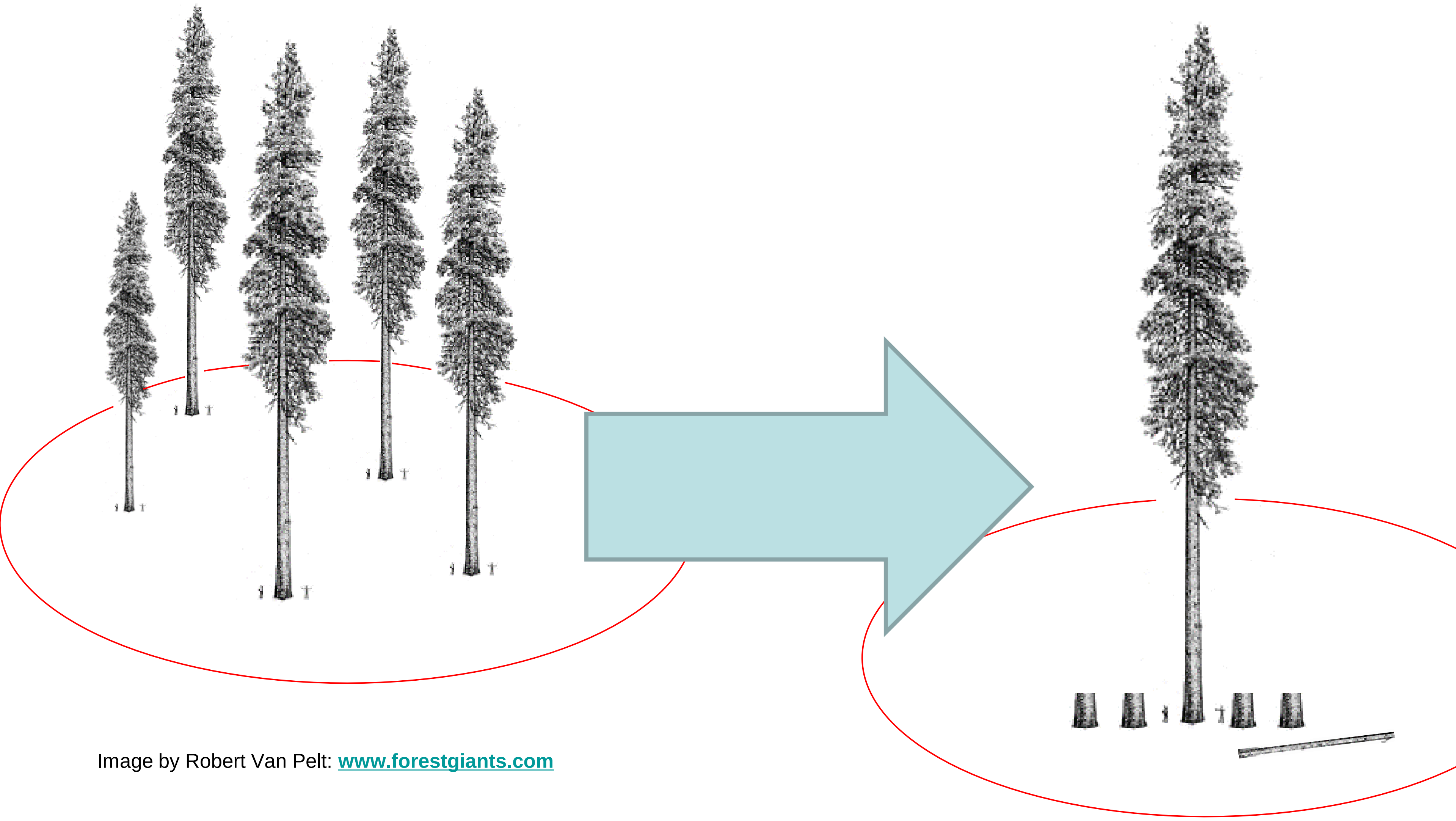
Exp = exponential function

ln = natural log base "e" (2.718282)



- Most are errors of measurement units
- Most groups made errors
- Few errors that are not gross mistakes (mostly 2.54 x)

Repeat measures allow estimation of carbon gain



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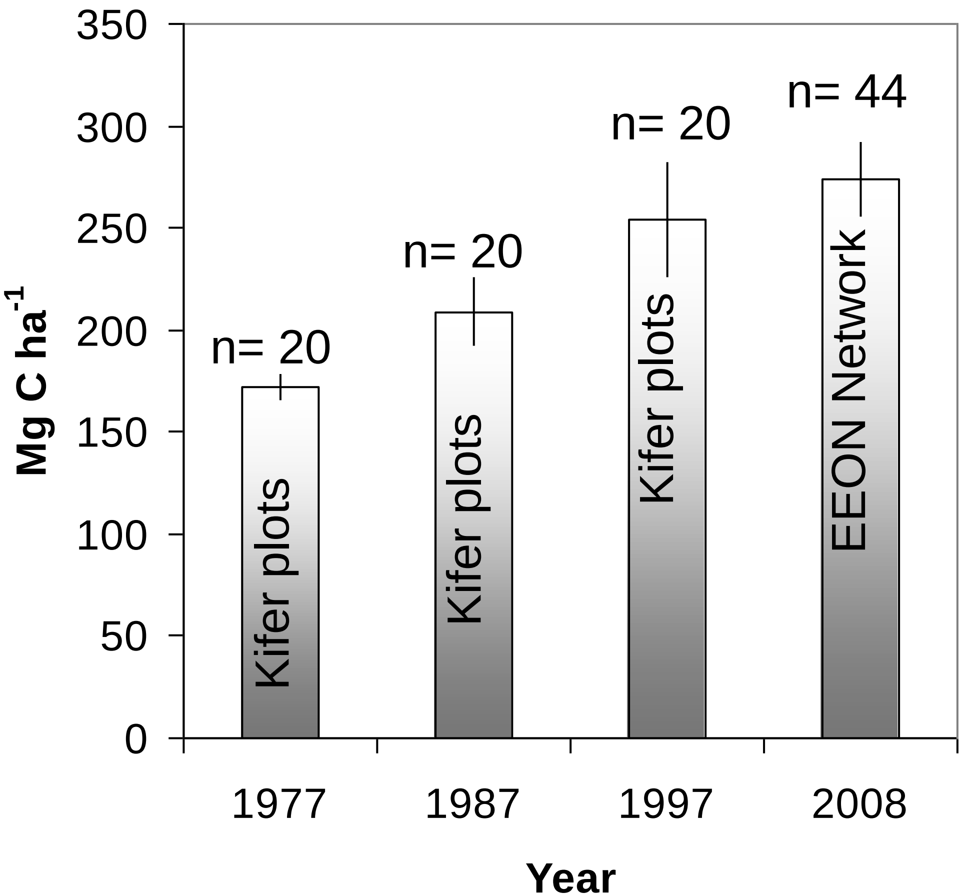
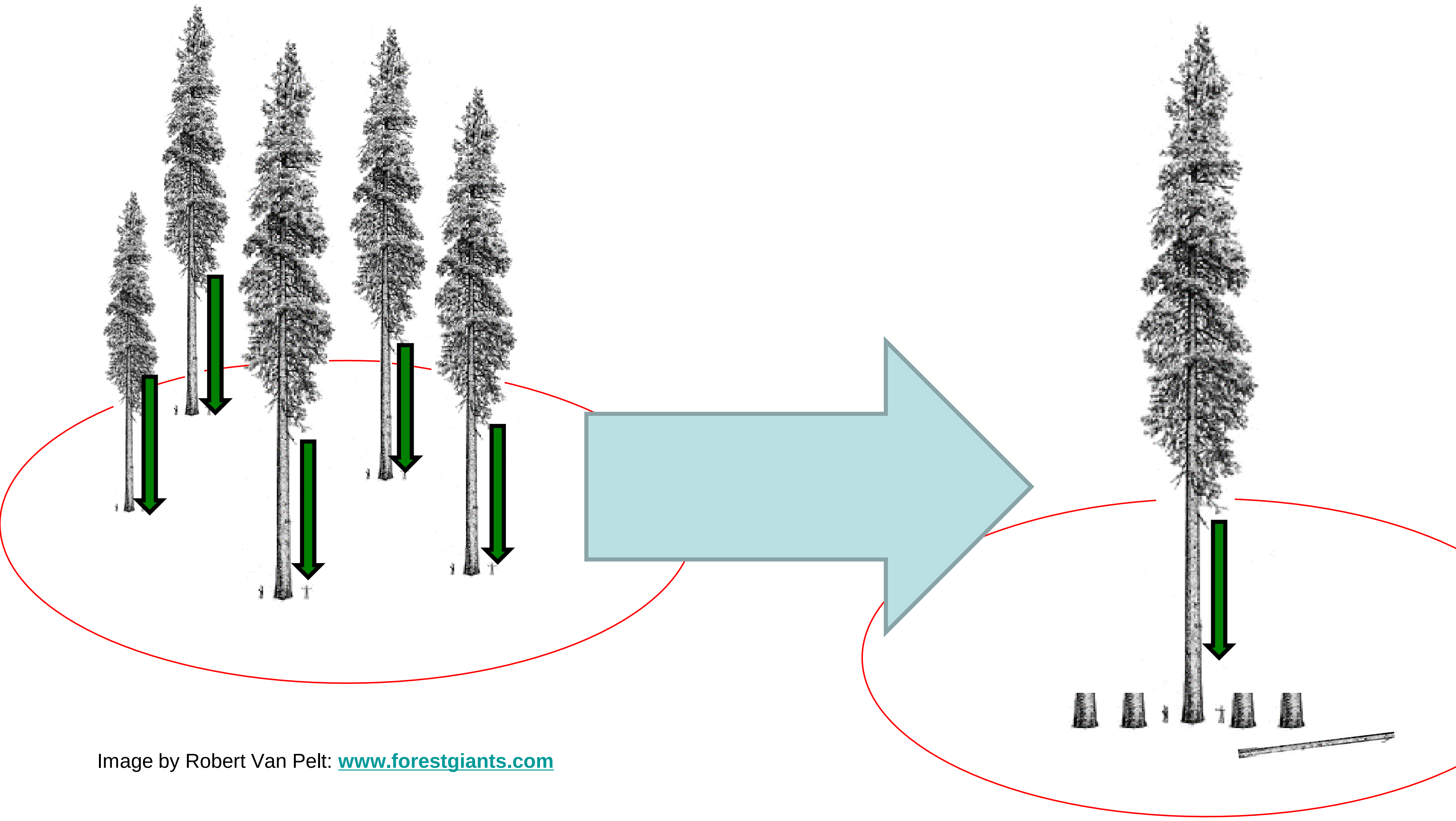


Figure 1. Carbon storage in a second growth forest over time in tons (Mg) per hectare. For years 1977-1997, measurements are based on a sample size of 20 plots over ~50 ha. The 2008 data covers a 300 ha area, and consists of measurements from 44, 314 m^2 plots. All data is from curriculum-integrated student measurements in forest ecology courses beginning in 1977. Bars represent one standard error from the mean.

Repeat measures allow estimation of carbon gain



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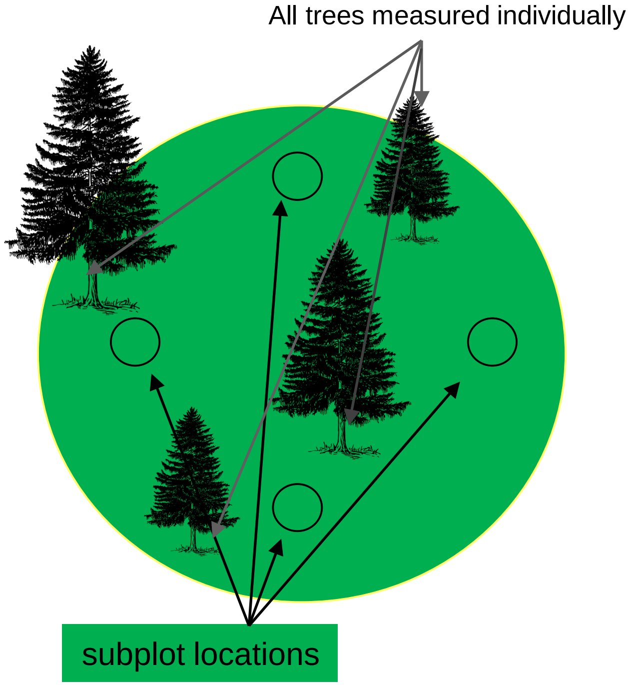
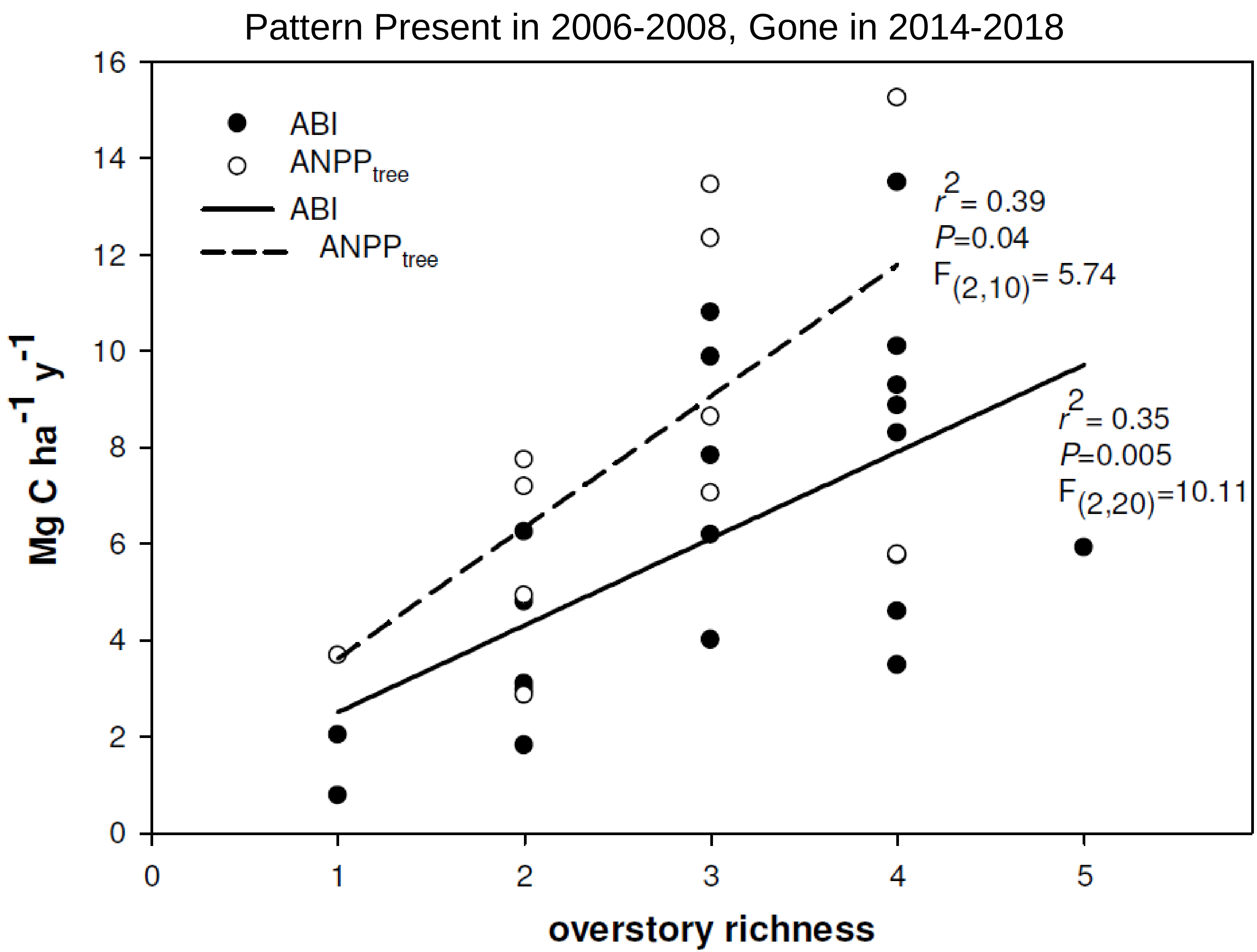
Plot Design

- 10 meter diameter plots
- Periodic biomass/carbon inventory (1-3 years)
- Litter-fall collected and added to tree biomass increment for ANPP estimation

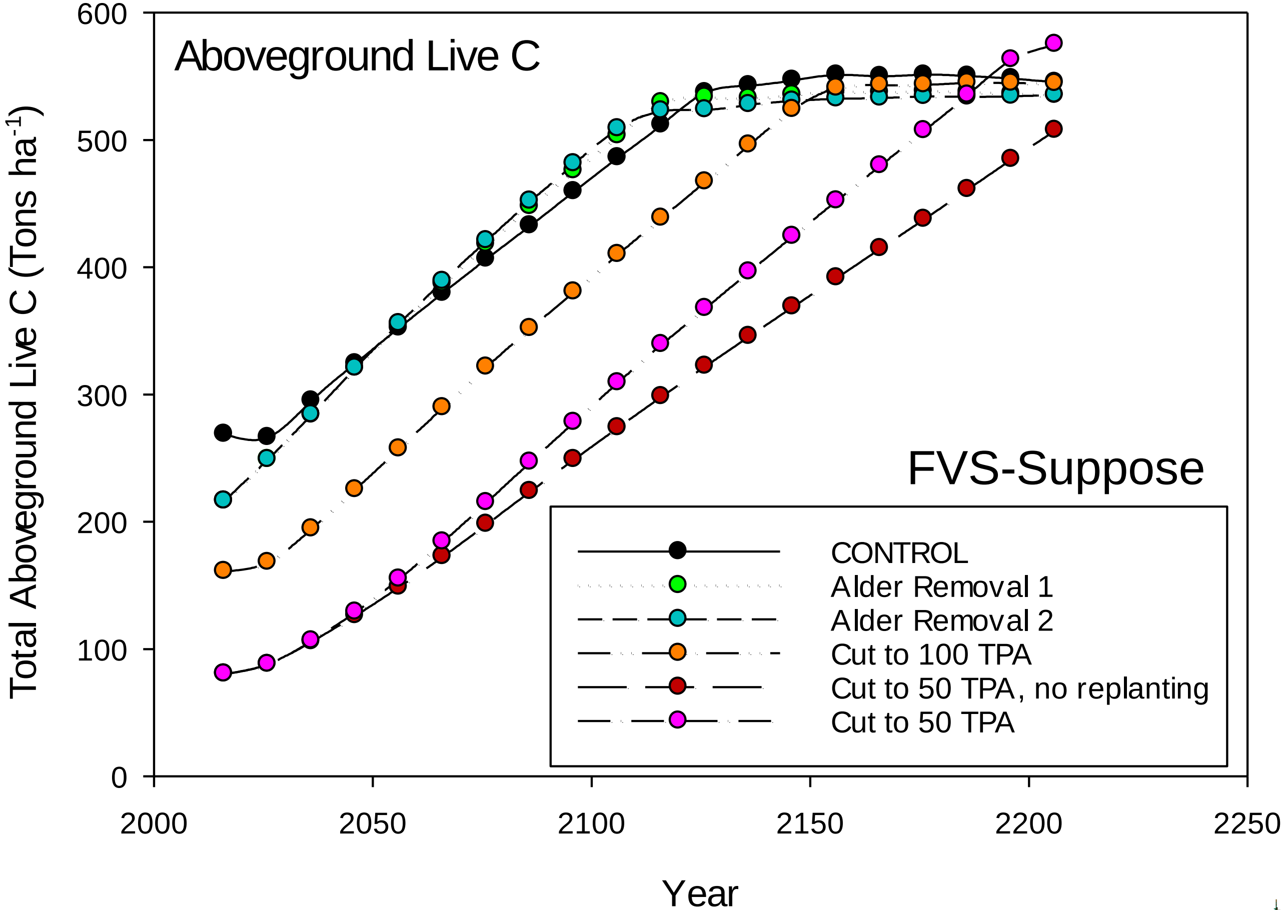


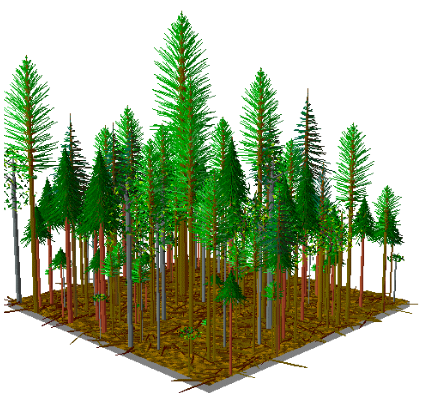


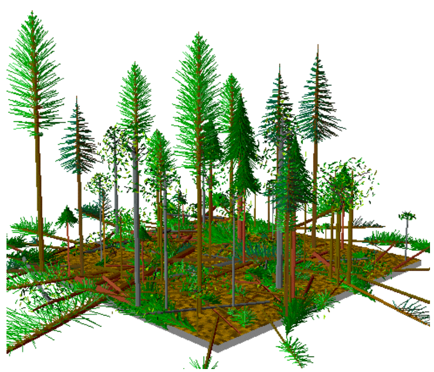


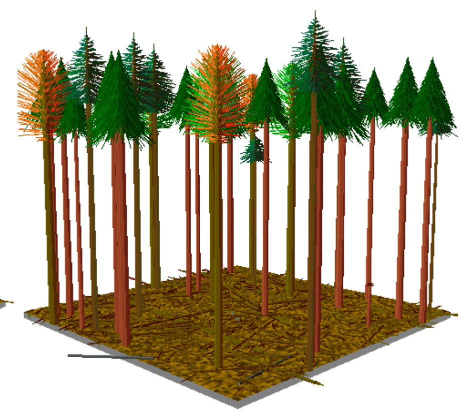

Pattern Present in 2006-2008, Gone in 2014-2018
ABI
ANPPtree
ABI
ANPPtree
r2= 0.39
P=0.04
F(2,10)= 5.74
r2= 0.35
P=0.005
F(2,20)=10.11
Mg C ha-1 y-1
overstory richness
0
2
4
6
8
10
12
14
16
0
1
2
3
4
5

15,621 to 50,742 merchantable BD ft removed

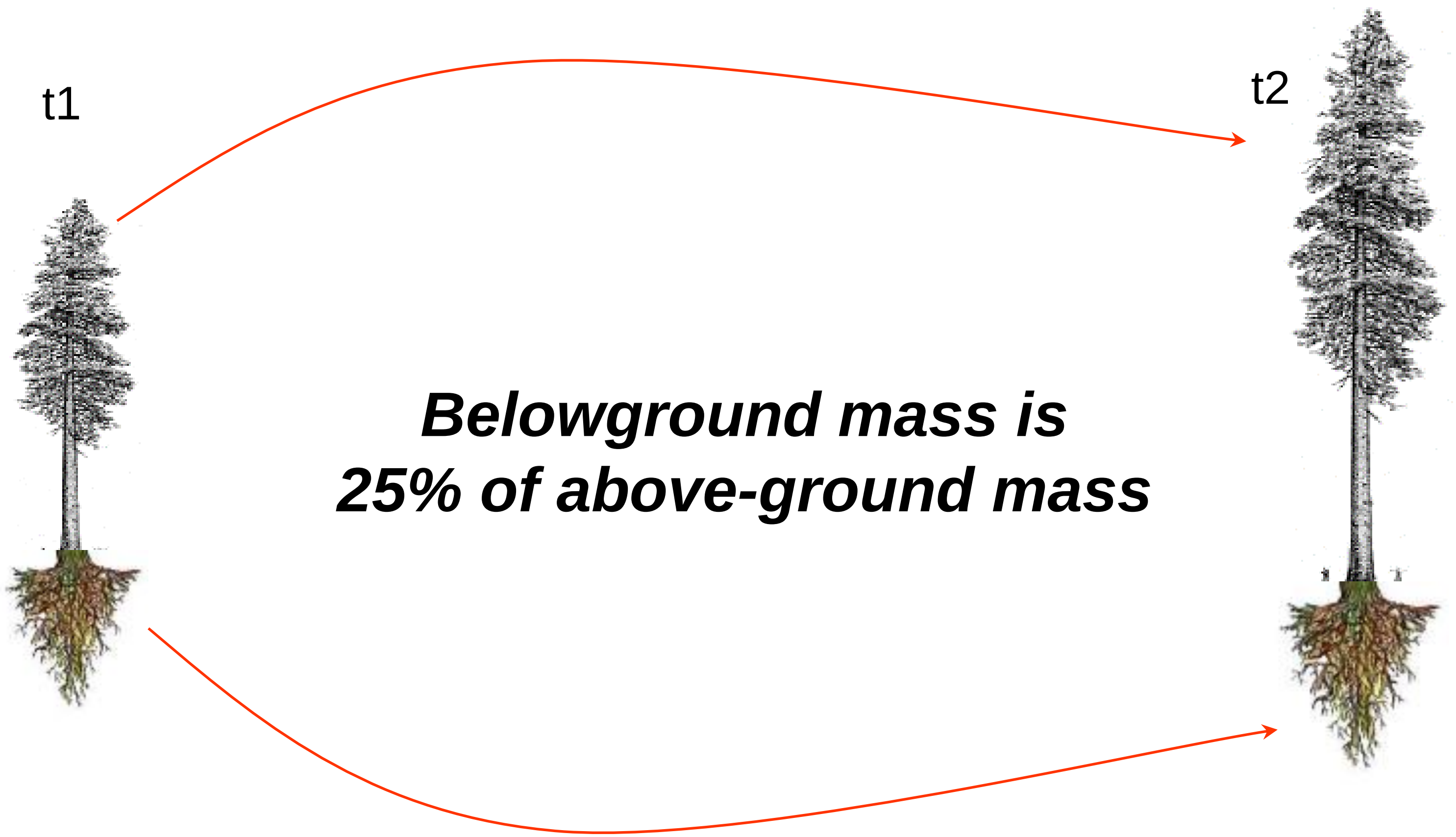






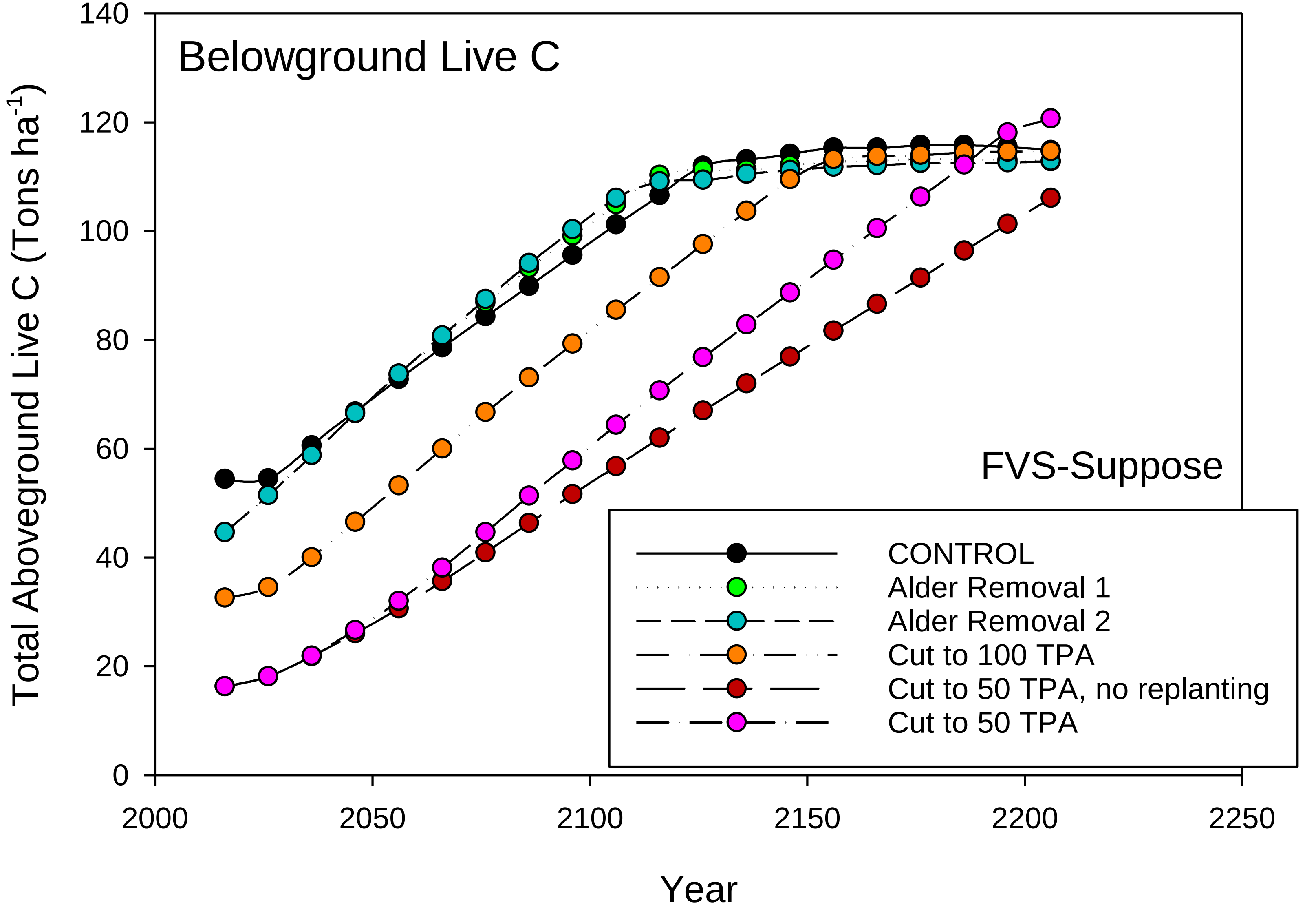


Belowground Assumptions



Belowground mass is 25% of above-ground mass

Image by Robert Van Pelt: **www.forestgiants.com**



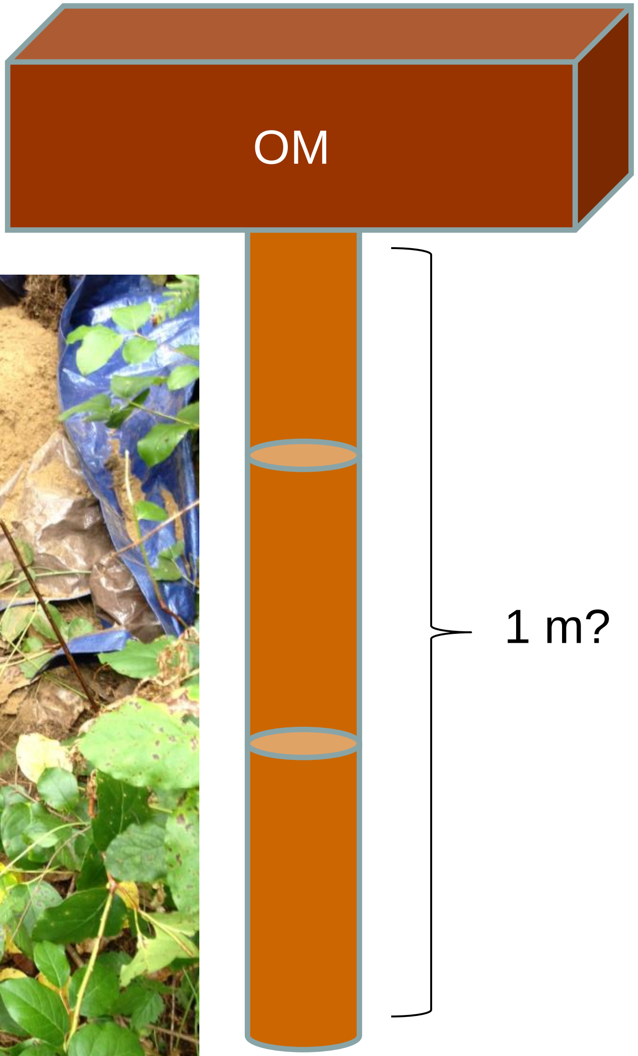
Belowground Live C
FVS-Suppose
Total Aboveground Live C (Tons ha-1)
Year
0
20
40
60
80
100
120
140
2000
2050
2100
2150
2200
2250
CONTROL
Alder Removal 1
Alder Removal 2
Cut to 100 TPA
Cut to 50 TPA, no replanting
Cut to 50 TPA

Woody Debris Assumptions

http://dharmablog.everyday-beat.org/page/4

Soil C – Thor's Hammer Method

- Infrequent, intensive sampling
- % C measured using elemental analysis
- Very depth-dependent



IRGA

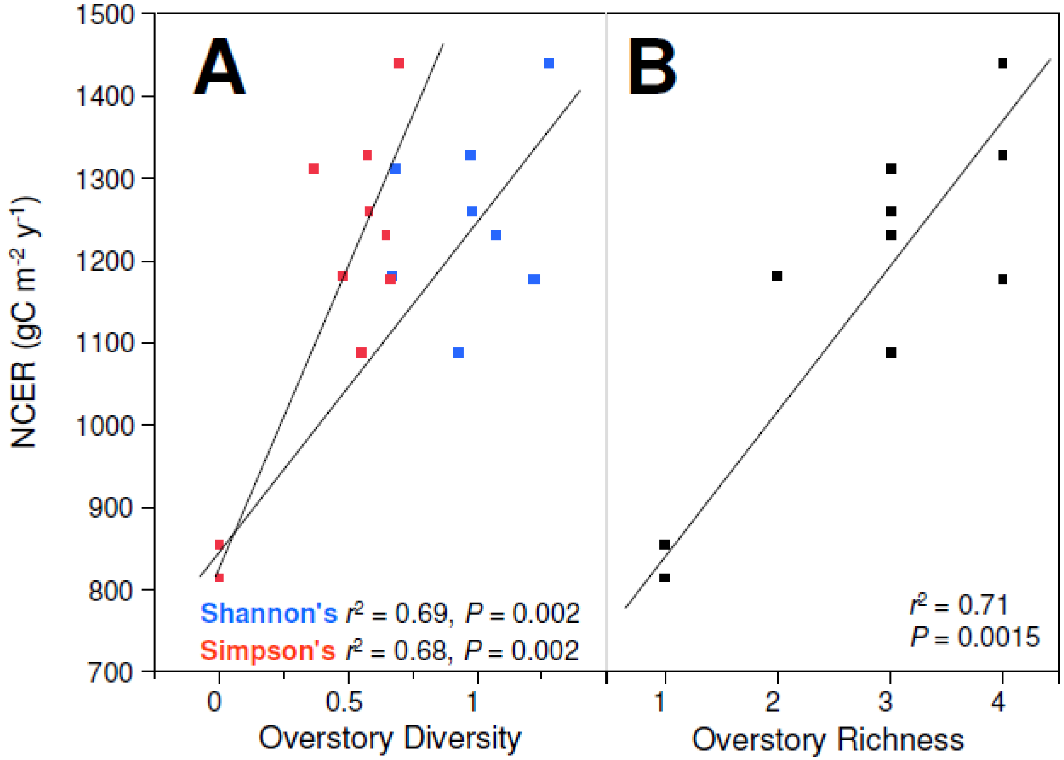
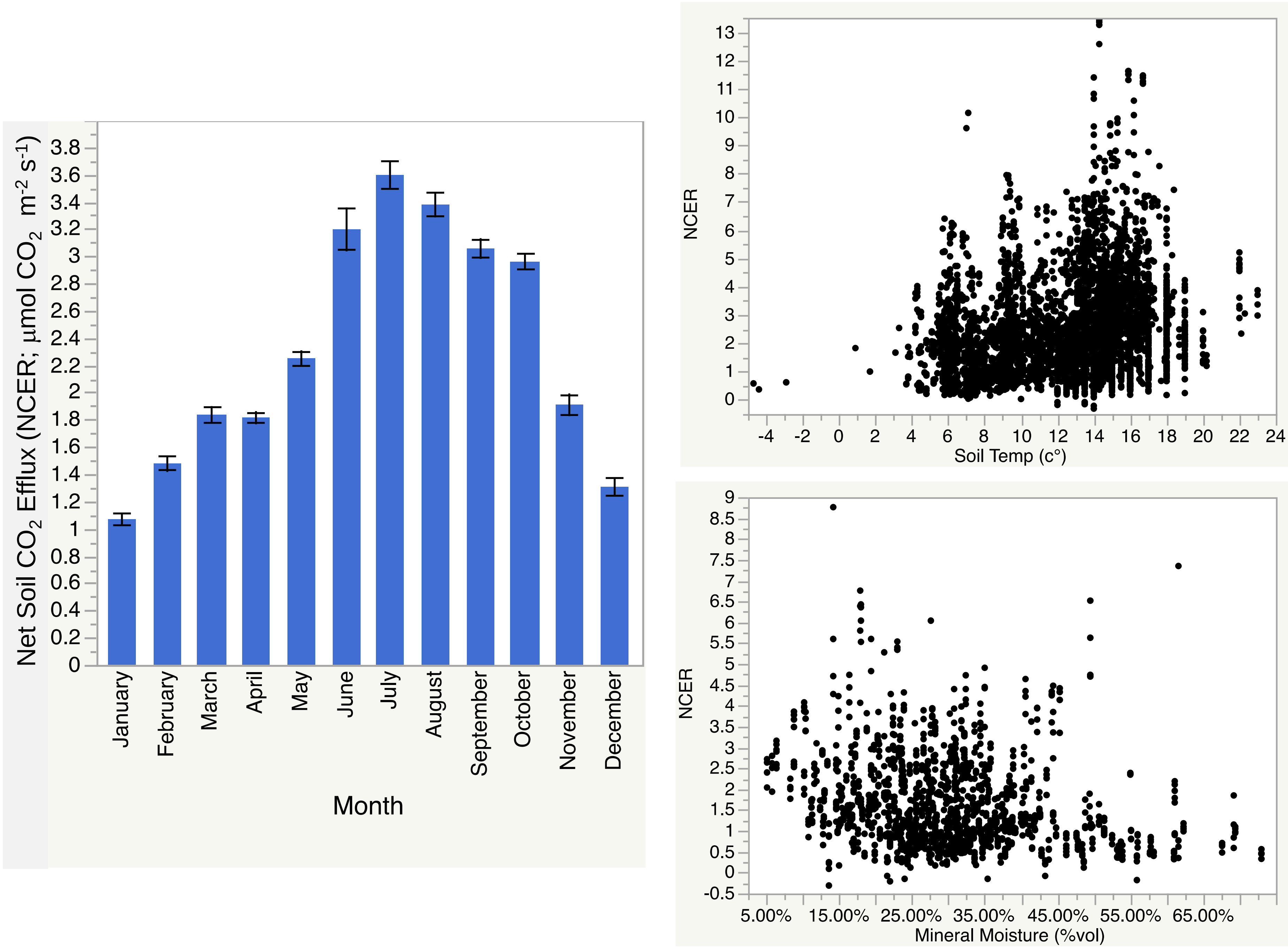
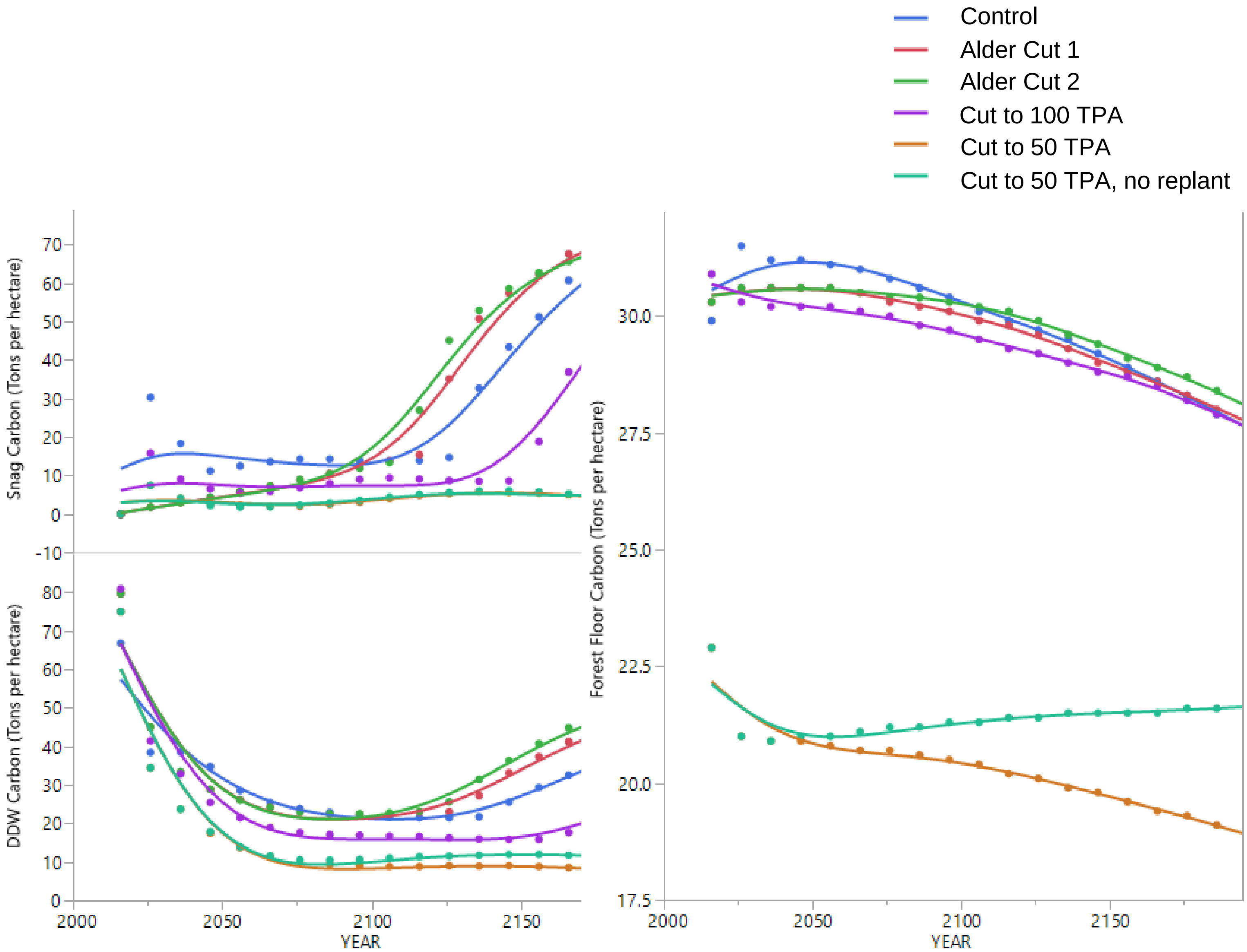


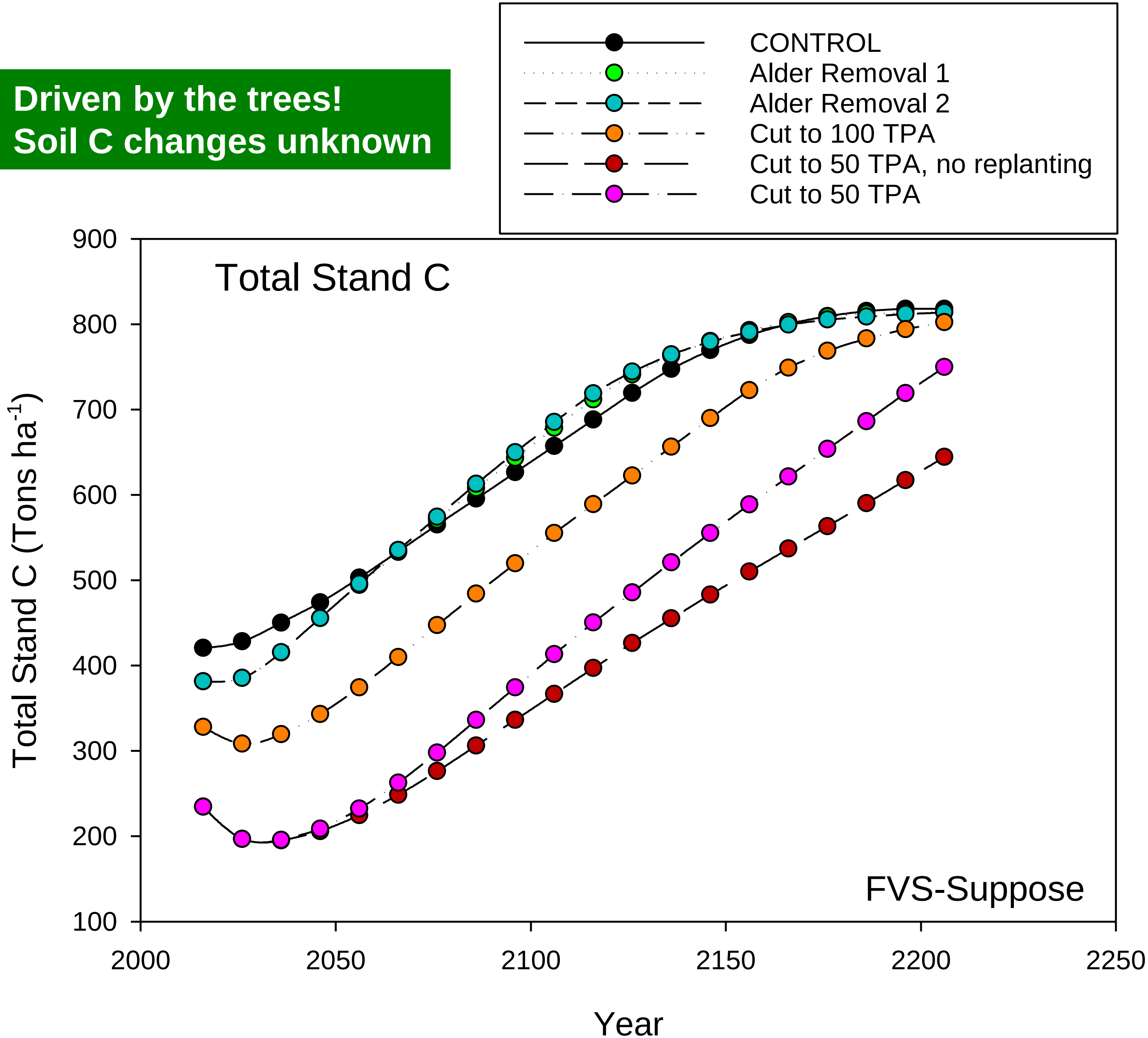
Figure 5. Positive relationships between NCER and overstory diversity represented by Shannon's and Simpson's diversity indices (**A**), and overstory richness (**B**). Here the 5 most abundant tree species are represented.


Net Soil CO_2 Efflux (NCER; µmol CO_2 m^{-2} s^{-1})
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
January
February
March
April
May
June
July
August
September
October
November
December
Month
NCER
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-4
-2
0
2
4
6
8
10
12
14
16
18
20
22
24
Soil Temp (c°)
NCER
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
5.00%
15.00%
25.00%
35.00%
45.00%
55.00%
65.00%
Mineral Moisture (%vol)


Control
Alder Cut 1
Alder Cut 2
Cut to 100 TPA
Cut to 50 TPA
Cut to 50 TPA, no replant
Snag Carbon (Tons per hectare)
DDW Carbon (Tons per hectare)
Forest Floor Carbon (Tons per hectare)
YEAR
YEAR
2000
2050
2100
2150

FVS-Suppose

- **Driven by the trees!**
- **Soil C changes unknown**



Forests And Carbon

Permanent plots - A Critical Component

- Accounting for live tree fluxes is easy and repeatable in permanent plots, and can be matched with DWD and soil C measurements
- Local permanent plot networks can increase mechanistic understanding
- Tree pools are <u>the</u> big measurable pool

Effects on C through forest practices?

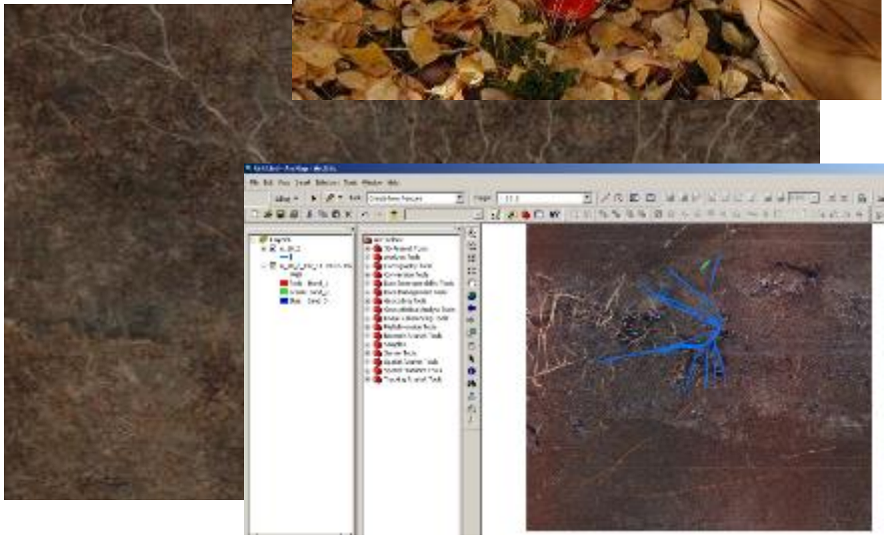
- Diversity Matters
- Species Matter
- Recovery of lost C after harvests?

Acknowledgements

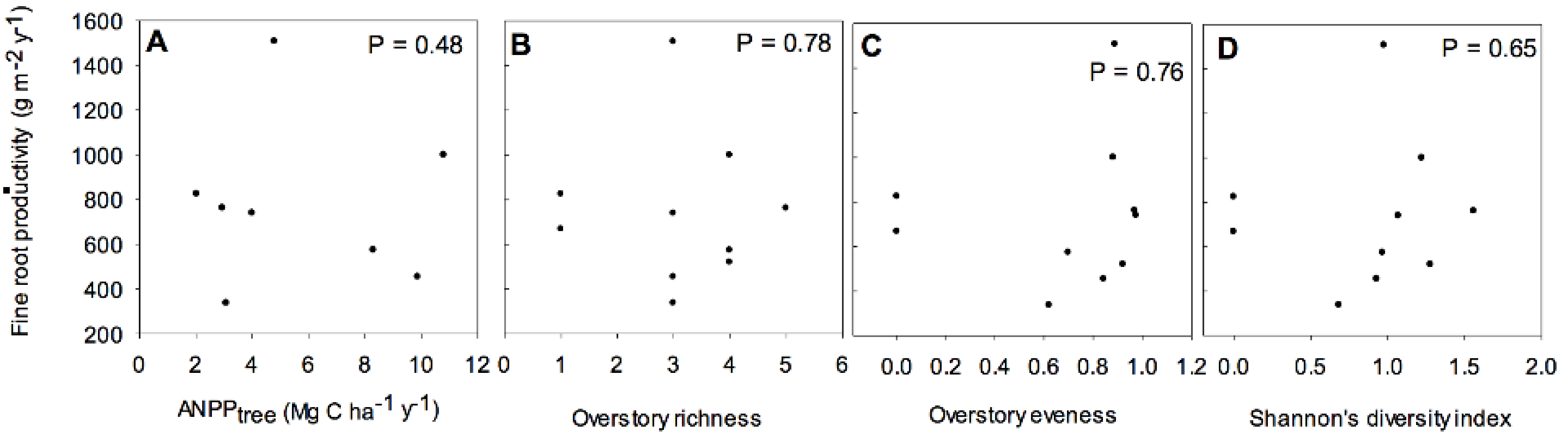
- The Evergreen E3 lab and over 100 undergraduate students working in the EEON project since 2006 have made this work possible.
- EEON lab managers and project managers who have made major contributions include: Kate Halstead, Pat Babbin, Justin Kirsch, Alexandra Kazakova, Liam Mueller, Erik Rook, Tom Otto, Adam Martin, Leighton Olive, Andy Berger, Levi Travis, Ruth Mares, Claire Cook, Sidney Baker, Gabe Chavez, Mathew Brousil, Chile Hunt, Chris Shipway, Christina Muller-Shinn, Irene Gribble, and Anchal Rikhi.
- Evergreen faculty who have also contributed significantly include Paul Butler, Rob Cole, Paul Przybylowicz, Alison Styring, Abir Biswas, and Carri LeRoy.
- This work was supported by generous support from Evergreen sponsored research grants and funding from the Evergreen Foundation.




Minirhizotron



- 44 tubes (0-24 cm) measured monthly
- Field measurement requires single dedicated researcher



Multiple Methods

- Values From the Carbon Literature (highly variable) fron ~0-8 Tons $ha^{-1}yr^{-1}$
- Regional Carbon Sequestration Models
  - COLE ~ 1 Tons ha^{-1} yr^{-1}
  - Standcarb 2.0
  - LMS and FVS
  - Direct Measurement
  - Integration over stand types
  - Use of average values (w/ error term)