Oregon State University

Vegetation Management Research Cooperative

VMRC

Long-term Effects of Vegetation Management on Biomass Stock and Aboveground Net Primary Productivity of Four Coniferous Species in the PNW

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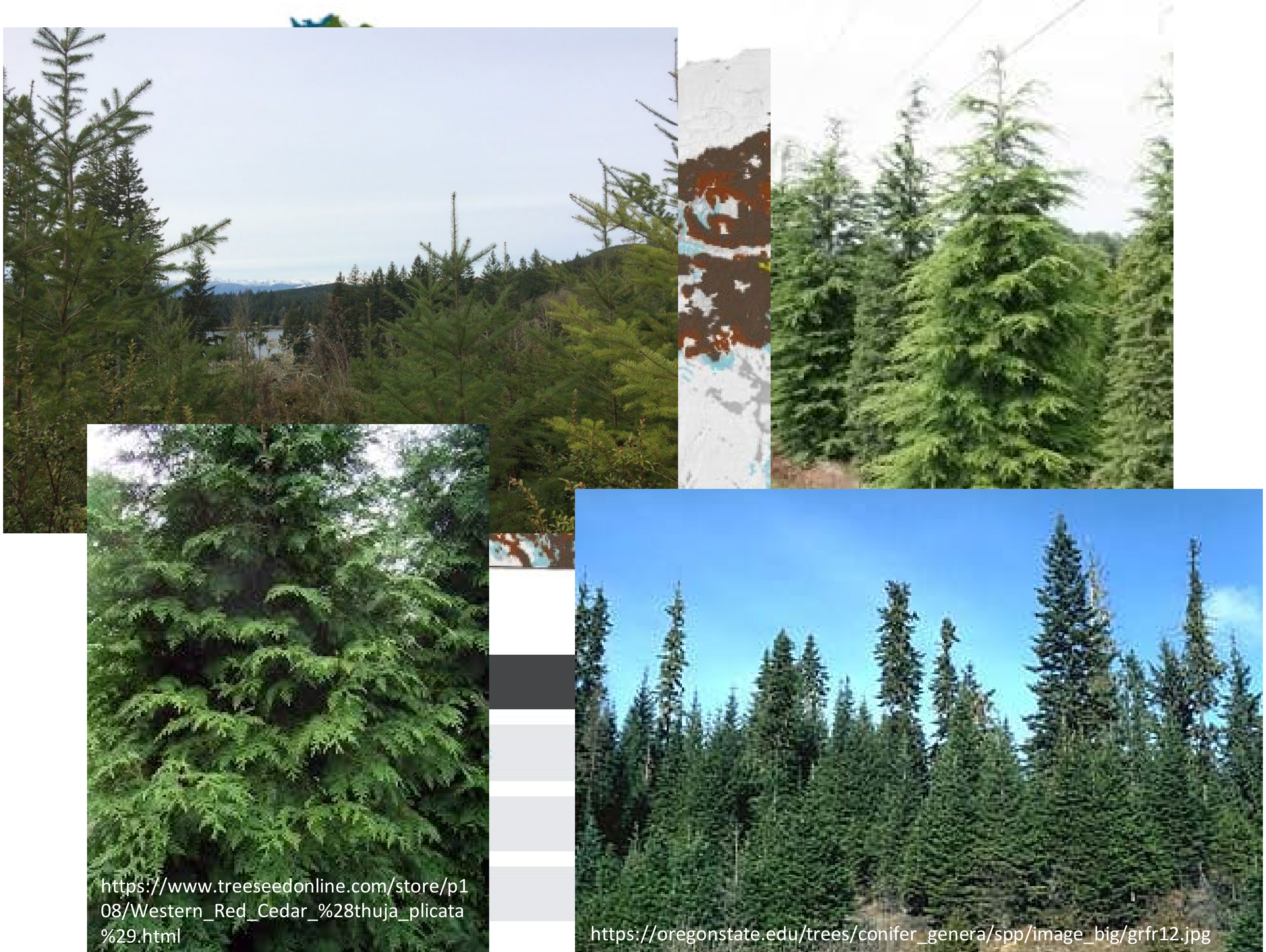
Presentation Outline

- Introduction
- Research Focus
- Hypotheses
- Methodology
- Research Findings
- Conclusion

Introduction

- 47% of Oregon is forested[10]
  - 34% in held by private landownders
- >$12 billion to Oregon's economy[10]
  - Leader in softwood lumber and plywood production
- Improve water quality, provide habitat, biodiversity on the landscape, carbon sequestration

Introduction



Introduction

- Forest vegetation management (FVM) is an integral part of reforestation in the PNW[5, 6, 12]
- Early control of competing vegetation reduces competition for light, water, and nutrients[8]
- Most studies have focused on short-term responses of FVM[2]


Forest Biomass

- Forests in PNW have the largest amount of storage carbon of US forests[1]
- FVM has been reported to increase growth rates and biomass accumulation in forests in other parts of the world[4, 9, 13]

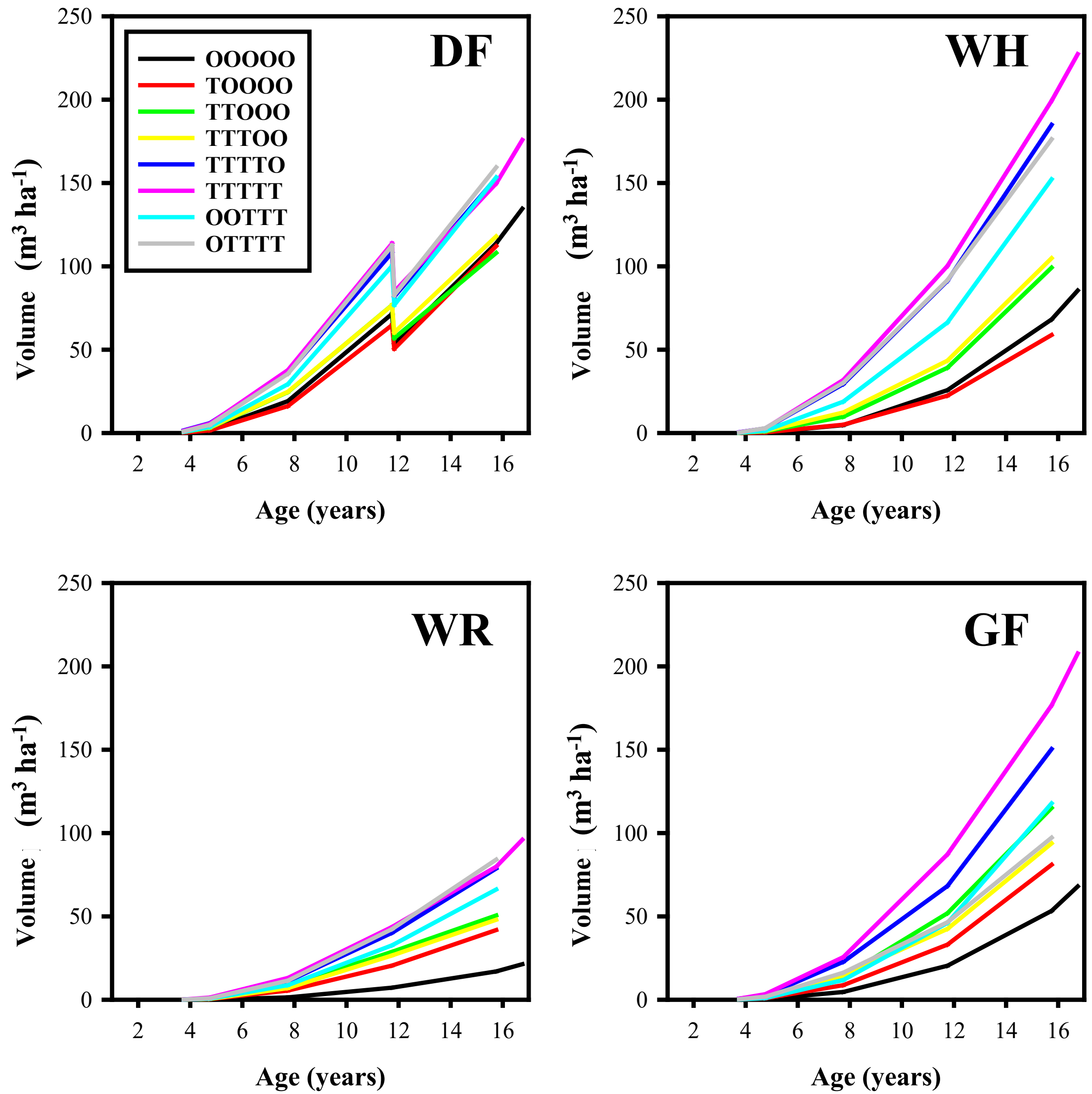
Net Primary Productivity

- Net Primary Productivity (NPP) is an important variable of terrestrial ecosystems and a key component of the global carbon cycle[6]

- NPP improves our understanding of the impact that management practices can have on forest production and carbon sequestration[14]

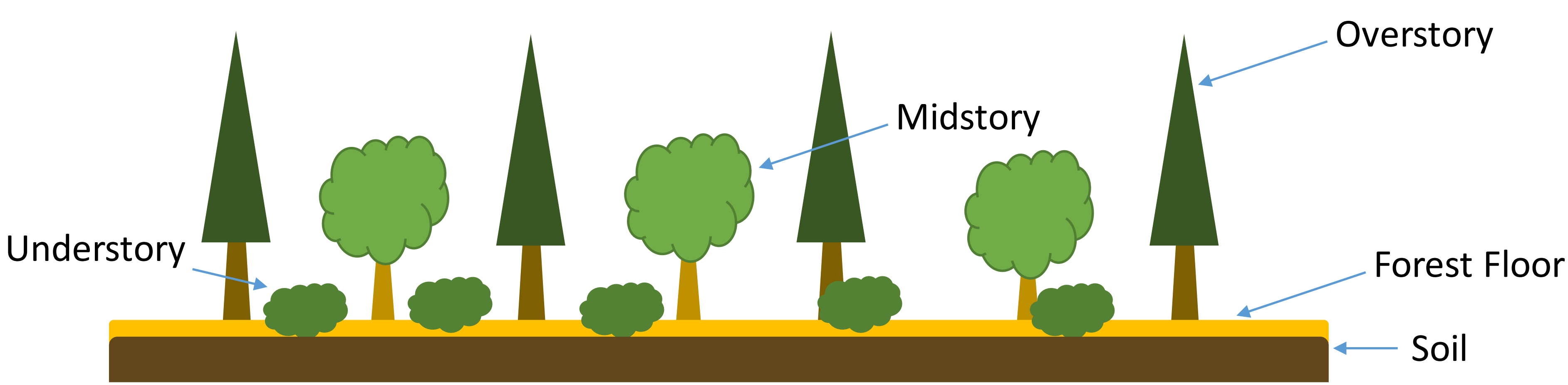
Research Focus

- The VMRC has information on the effects of FVM at the tree level (dbh, height) and stand level (survival, basal area, volume), but not on the long-term effect on biomass accumulation and NPP of the whole ecosystem



Research Focus

- Quantify biomass stock and NPP of the whole ecosystem on 4 conifer species at age 16 years, growing under contrasting FVM treatments in 2 sites in the PNW.
  - Including total tree biomass, competing vegetation (midstory and understory), forest floor, coarse woody debris, and top soil.
  - Only above-ground NPP (ANPP) was measured.



Hypotheses for Biomass Stock

At age 16, 11 years after vegetation management ended:

1. Trees growing on **plots that had sustained elimination of competing vegetation** during the first 5 years after planting will have **higher total and component biomass stock**.

2. Tree **response** in above ground biomass stock to vegetation management **differs between species and sites**.

Hypotheses for Biomass Stock

At age 16, 11 years after vegetation management ended:

3. **In plots without vegetation control, understory and midstory vegetation play a major role in terms of biomass stock**, partially counteracting the positive effects of vegetation management.

4. **Ecosystem biomass stock (Crop Trees + Understory + Midstory + Forest Floor) is larger in treated plots**, and the **response** in above ground biomass stock to vegetation management **differs between species and sites**.

5. **Top soil biomass does not differ** among FVM treatments.

Hypotheses for ANPP

We hypothesize that 10-11 years after vegetation management ended:

1. Trees growing on **plots that had sustained elimination of competing vegetation** during the first 5 years after planting will have **higher total and component ANPP**.

2. The **response** in ANPP to vegetation management **differs between species and sites**.

Hypotheses for ANPP

We hypothesize that 10-11 years after vegetation management ended:

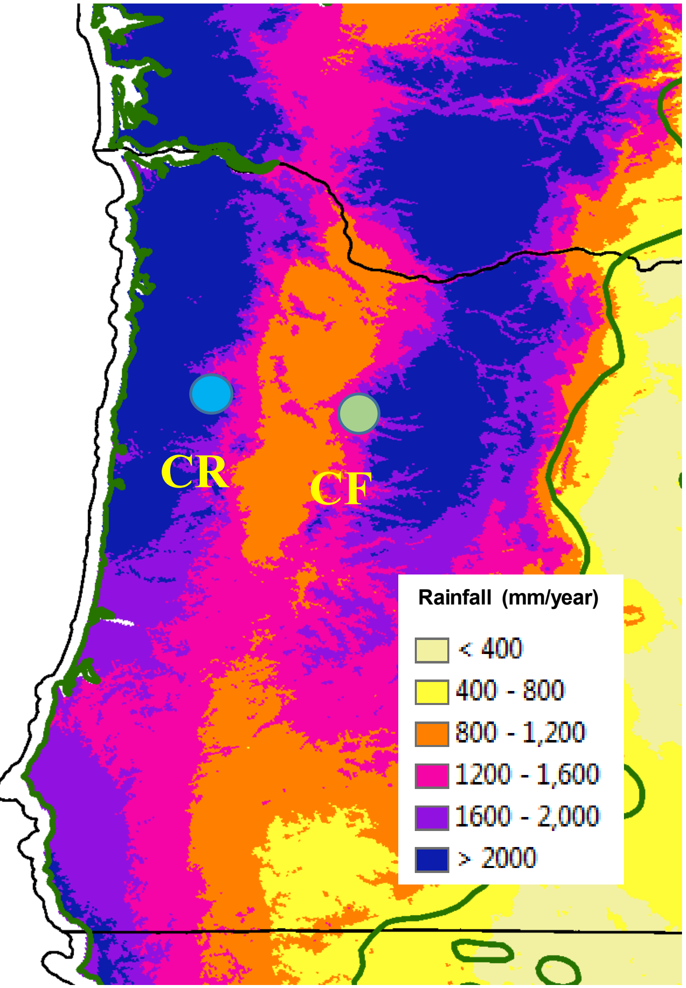
3. **In plots without vegetation control, understory and midstory vegetation play a major role** in the ecosystem ANPP ($ANPP_E$).

4. **$ANPP_E$ is larger in vegetation management treated plots**, and the **response differs between species and sites**.

Methods

- Site and Treatments Description
- Biomass Sampling
  - Overstory Trees
  - Midstory + Volunteers
  - Understory
  - Forest Floor
  - Thinning Residues
  - Fine Roots
  - Soil Organic Matter
  - Litterfall

Site Description



Planting density: 10’ x 10’

Plot Size: 80’ x 80’
(36 measurement trees)

Coast Range (CR)

Study ID: CPT01
Institution: Starker Forests
State: OR
County: Benton
Planting year: 2000

Soil Series: Preacher-Bohannon complex
Soil Texture: Fine-loamy

Mean annual temp.: 11.1 C
Annual rainfall: 1707 mm

Species:
- Douglas-fir
- Western hemlock
- Western redcedar
- Grand fir

Cascade Foothills (CF)

Study ID: CPT02
Institution: Cascade Timber
State: OR
County: Linn
Planting year: 2001

Soil Series: Bellpine

Soil Texture: silty-clay-loam

Mean annual temp.: 12.4 C
Annual rainfall: 1179 mm

Species:
- Douglas-fir
- Western redcedar

Container seedling: Styro 15

Treatments Description

The VMRC's Critical Period Threshold (CPT) studies represent a unique opportunity to look at the response of different coniferous species at different sites in Western Oregon.

Treatment	Fall SP	SR1	SR2	SR3	SR4	SR5
OOOOO	SP	O	O	O	O	O
TOOOO	SP	T	O	O	O	O
TTOOO	SP	T	T	O	O	O
TTTOO	SP	T	T	T	O	O
TTTTO	SP	T	T	T	T	O
TTTTT	SP	T	T	T	T	T
OTTTT	SP	O	T	T	T	T
OOTTT	SP	O	O	T	T	T

Control (C): Only Fall Site Prep

Vegetation Management Treatment (VM): Fall Site Prep + 5 years of Spring Release

- 2 sites
- Complete randomized block design
- 4 replications

Biomass Stock and ANPP

- Biomass Stock ($Mg\ ha^{-1}$)

  Aboveground (overstory + midstory + understory)

  + fine roots

  + forest floor

  + soil organic matter (SOM)

- ANPP ($Mg\ ha^{-1}\ yr^{-1}$) (2016 –2017)

  Δ AG Biomass (overstory + midstory + understory)

  + Litterfall

AG Biomass

- **Overstory: (Crop Trees)**

  - Determine species-specific AG biomass functions
    - Fell **four** trees for each species and treatment on each site (8 trees per species per site):
      - 1 from DBH percentile 1^{th} - 25^{th},
      - 1 from DBH percentile 25^{th} - 50^{th}
      - 1 from DBH percentile 50^{th} - 75^{th}
      - 1 from DBH percentile 75^{th} - 99^{th}

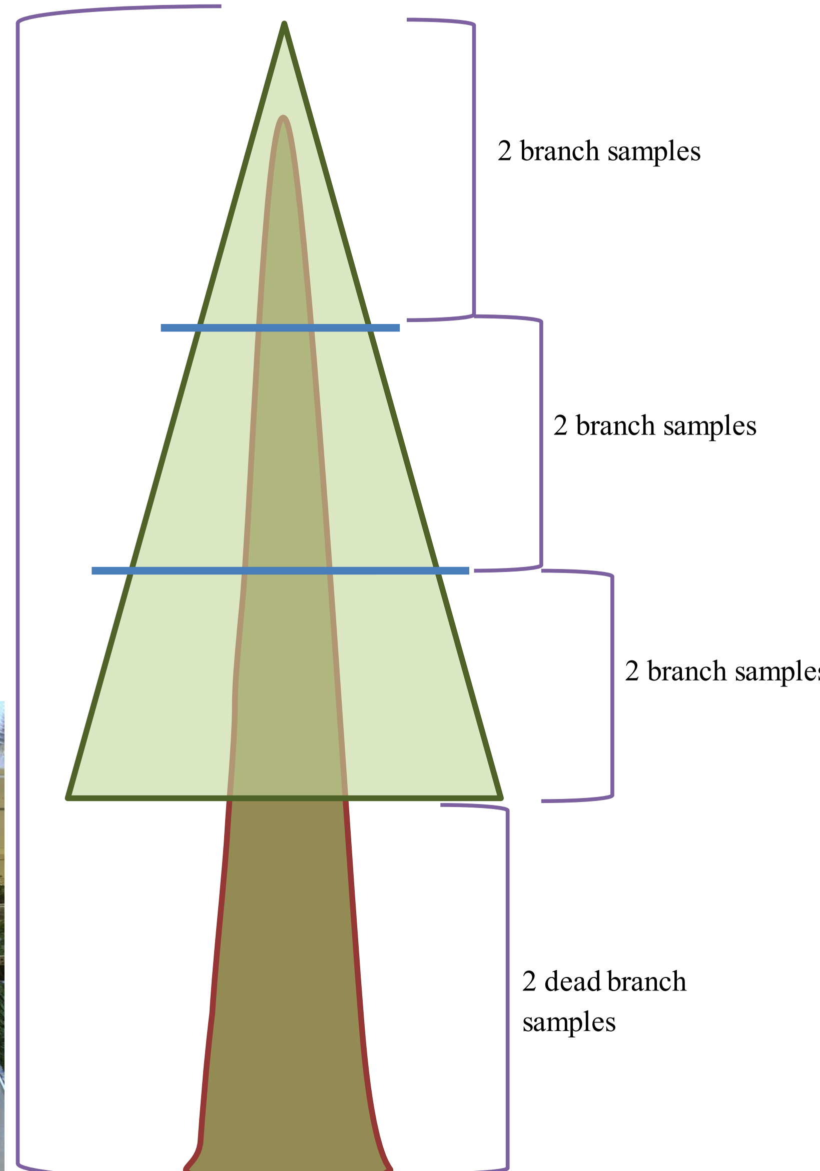
    - 1 tree selected from buffer row on each plot

    - Foliage, Branch, Stemwood, Bark

AG Biomass

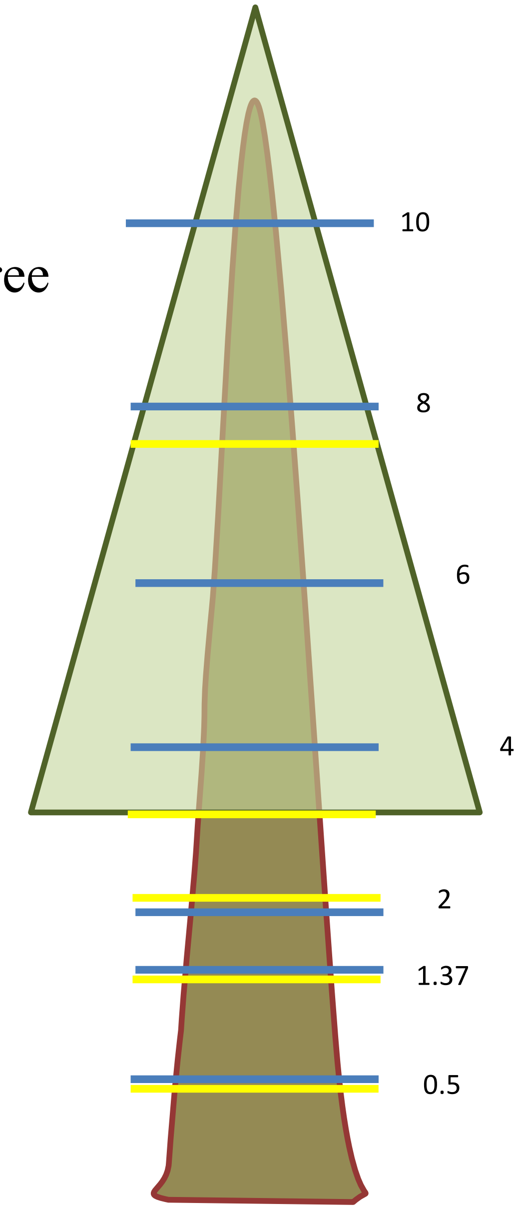
- **Overstory**: Continued
  - **Crown biomass**: Measure diameter and position of all branches and take 2 samples from each third of the crown

Measured diameter of all branches



AG Biomass

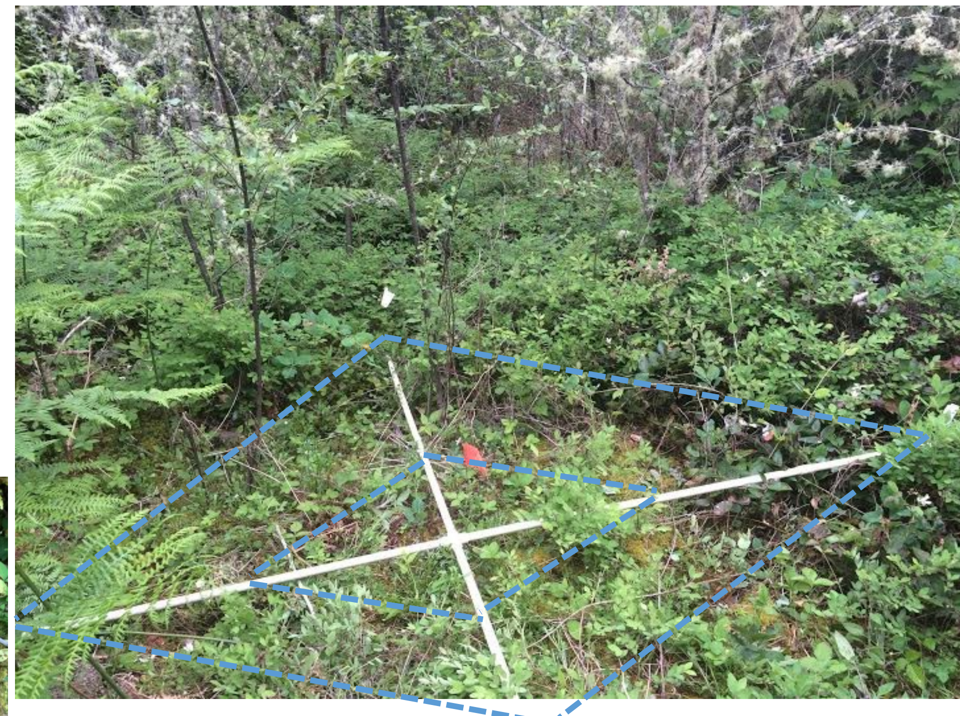
- **Overstory**: Continued
  - **Stem Volume**: Measure stem diameter and bark thickness every 2 m along the stem
  - **Wood and bark SG**: Cut and measure 5 disks on each tree



AG Biomass

- **Mid-story**: 6 subplots of 2 x 2m (7% plot area) for two growing seasons
  - Measure DBH on all stems > 1.5 m height
  - Use reported biomass functions (cherry, red alder, hazel,…..)
  - Develop species-specific biomass functions for cascara buckthorn (sample 7 trees).
  - For hardwood volunteers (> 10 cm DBH) outside subplot: measure DBH on all trees.
- **Understory**: 6 clip plots of 0.6 x 0.6 m per plot
  (for vegetation <1.5 m)
  - Biomass and cover% for each living form (moss, grass, fern, forb, and shrub)





All biomass sampling: During Summer 2016 and 2017

AG Biomass

- Forest floor: collecting OM layer
  - (Oa and Oi) in 0.6m x 0.6m square

- Belowground biomass: (at the center of each clip plot)
  - Fine roots: 6 pvc-cores per plot (5 cm diameter x 20 cm depth)
  - Soil: Use same 6 samples used for fine roots

AG Biomass

- As Douglas-fir was thinned at age 12 years on both sites:
  - Pre-commercial thinning residues
    - Crown: In forest floor clip plots
    - Stem: Using volume estimated with inventory at thinning time (Vt) and current wood density of those thinned stems (WDt) after 4-5 years on the ground.
      - Sample 10 logs
    - Determine stem biomass of thinned trees using WDt and Vt

Litterfall

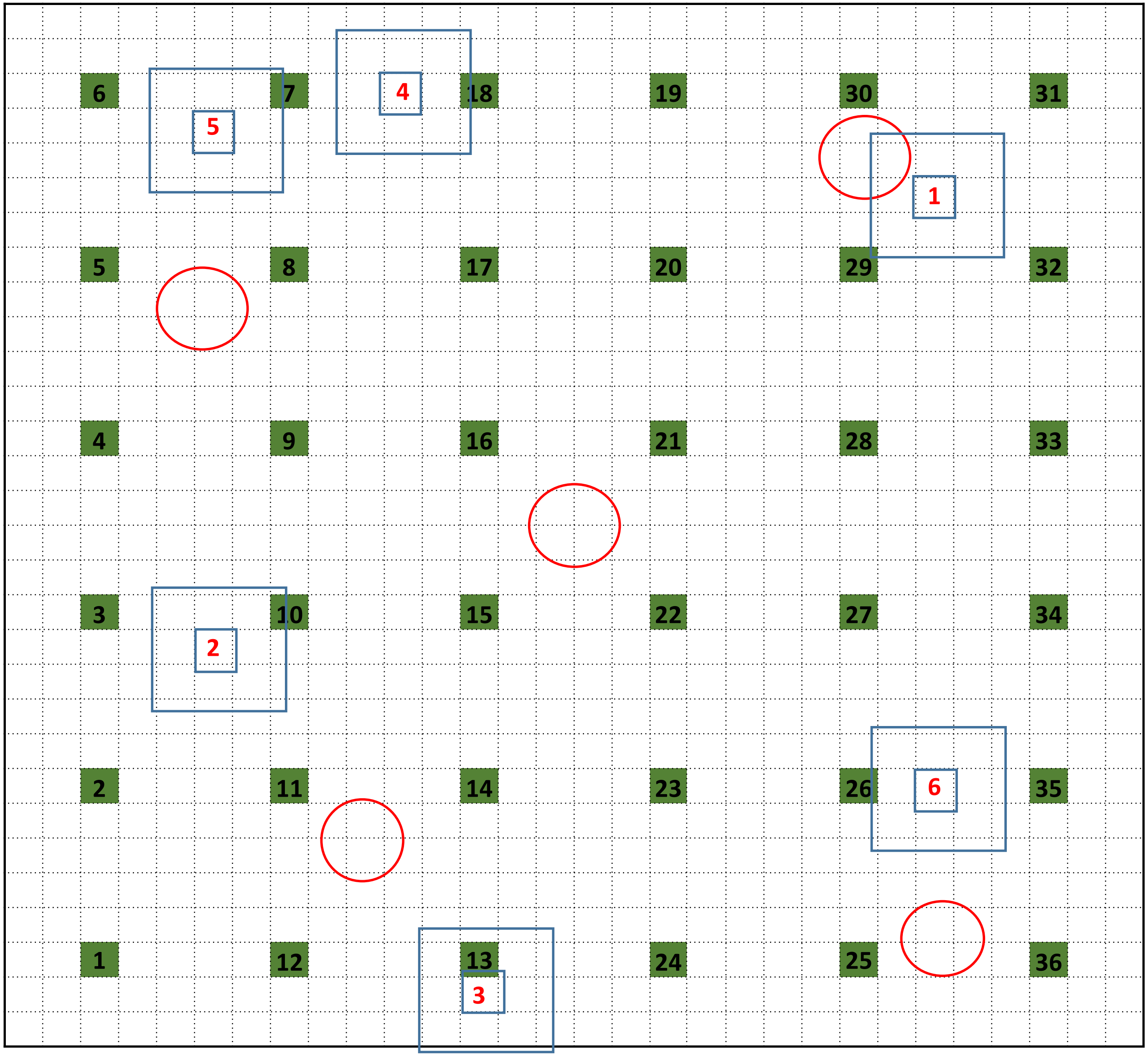
- Set up: February/ March 2016
- 5 traps in each plot:
  - 140 at CR,
  - 80 at CF
- Collected monthly
- Trap size: 0.5 m^2

(80 cm diameter)

Leaf Area Index

- Leaf area index (LAI) describes canopy density
- Leaf area estimated using specific leaf area and dry weight of foliage from collected branch samples
- Projected LAI estimated using developed leaf area equations

Example of selection of measurement points



Litterfall traps
Random selection of 5 points on each plot
1 trap per quarter + 1 trap at the center of the plot

Midstory, Understory, Forest Floor and Soil:
Random selection of 6 points on each plot

- Flagged Center and Corners of 2x2 m plot

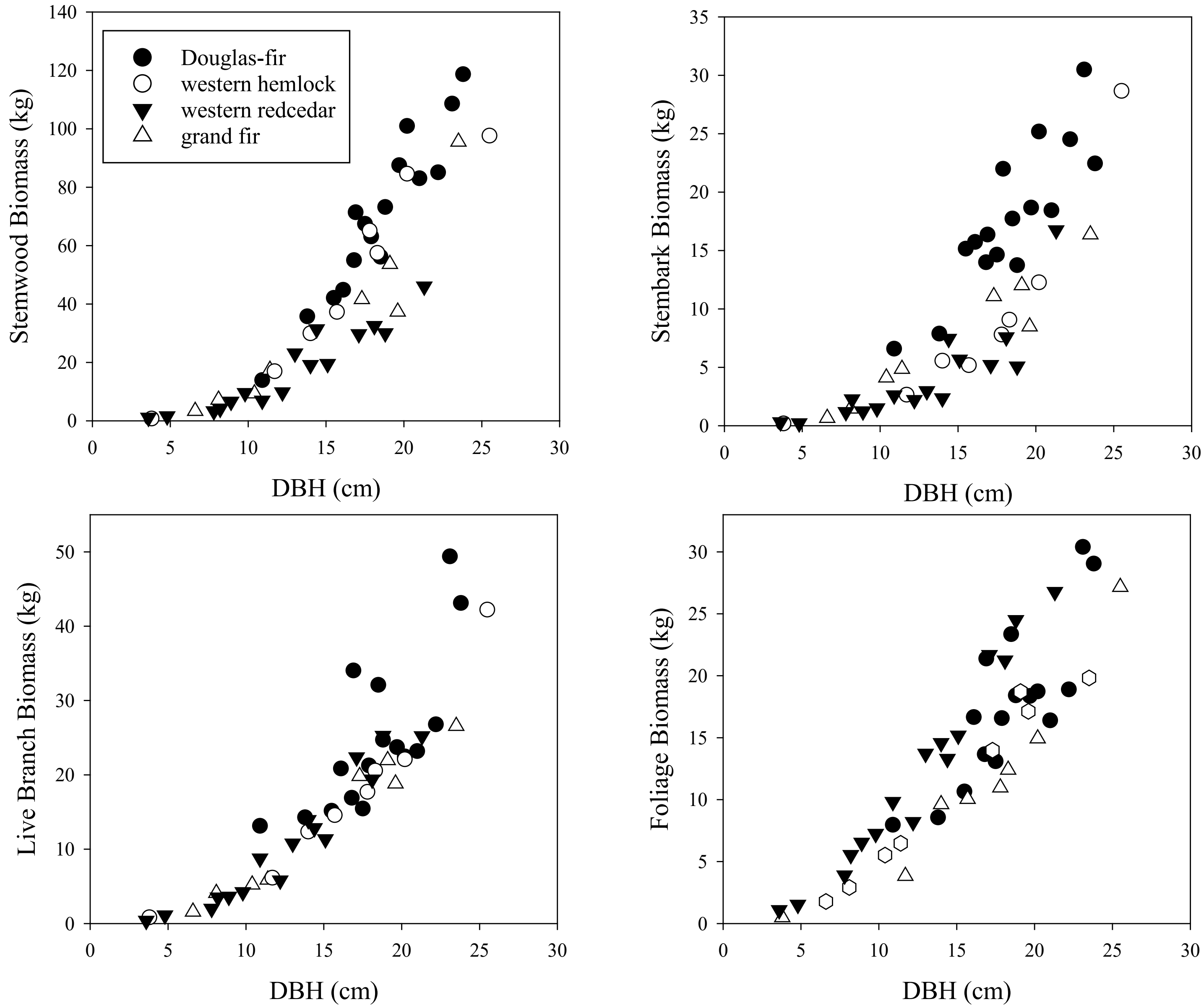
Measurement Tree

Results

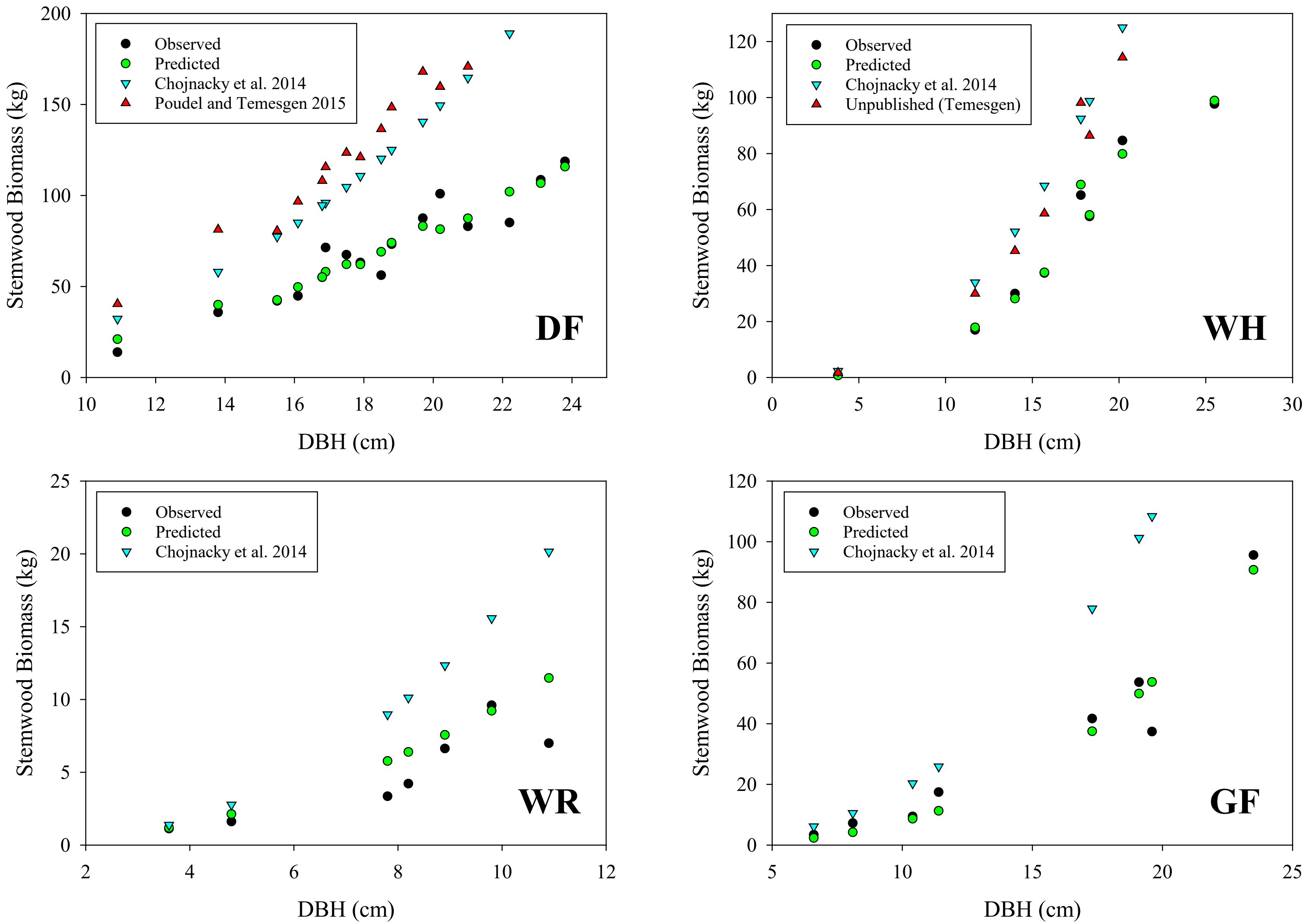
- Equations
- Stem Volume Production
- LAI
- Tree Biomass
- Ecosystem Biomass
- Tree ANPP
- Ecosystem ANPP

Biomass, Volume, and Leaf Area Functions

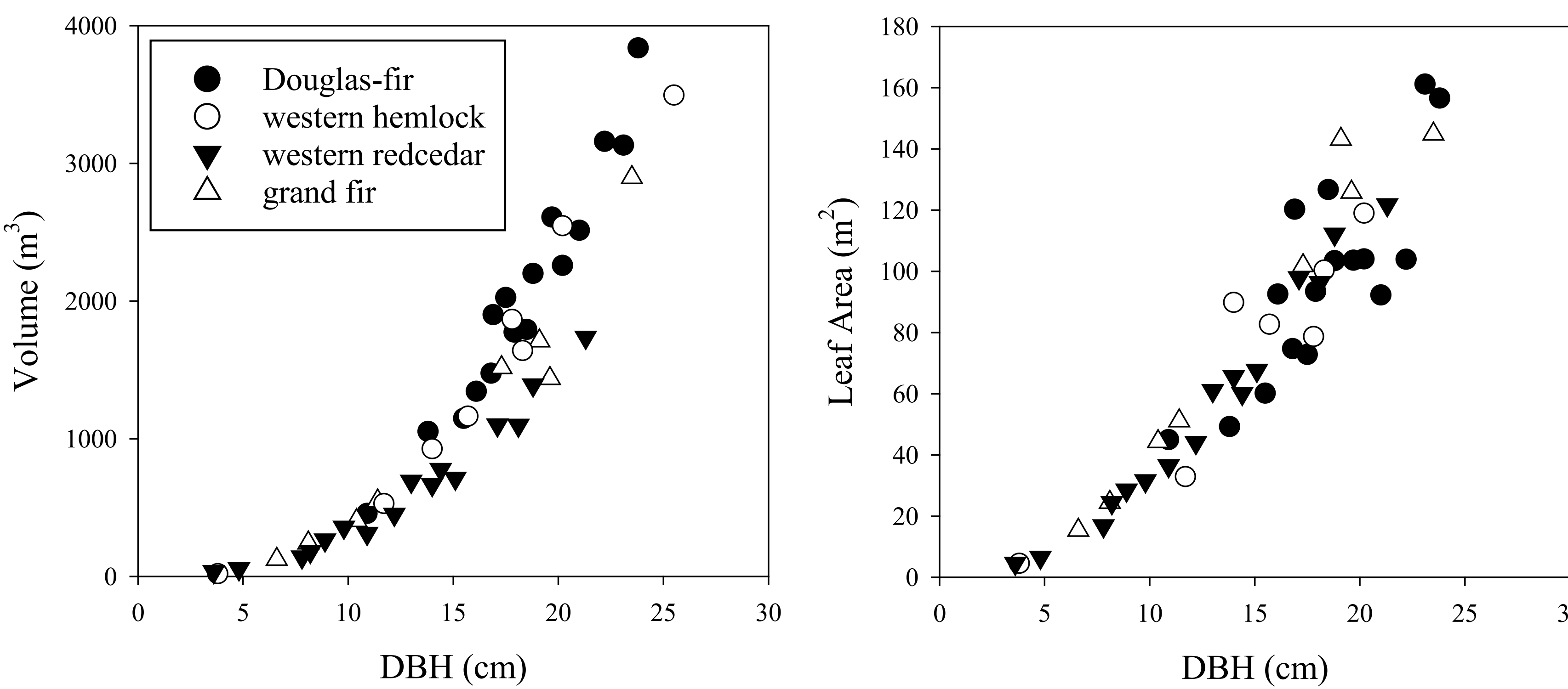
Biomass Allometry



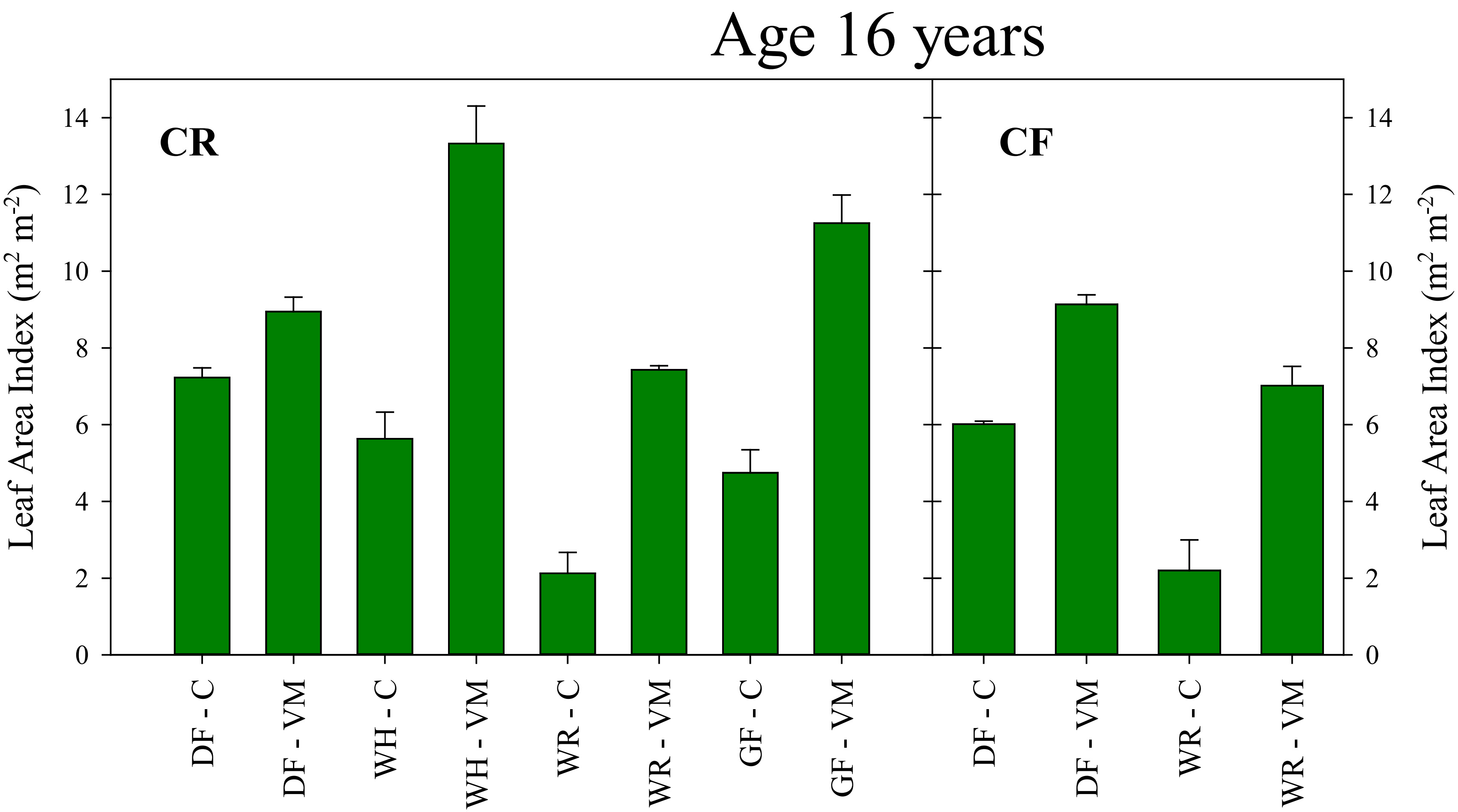
Biomass Equations



Volume and Leaf Area

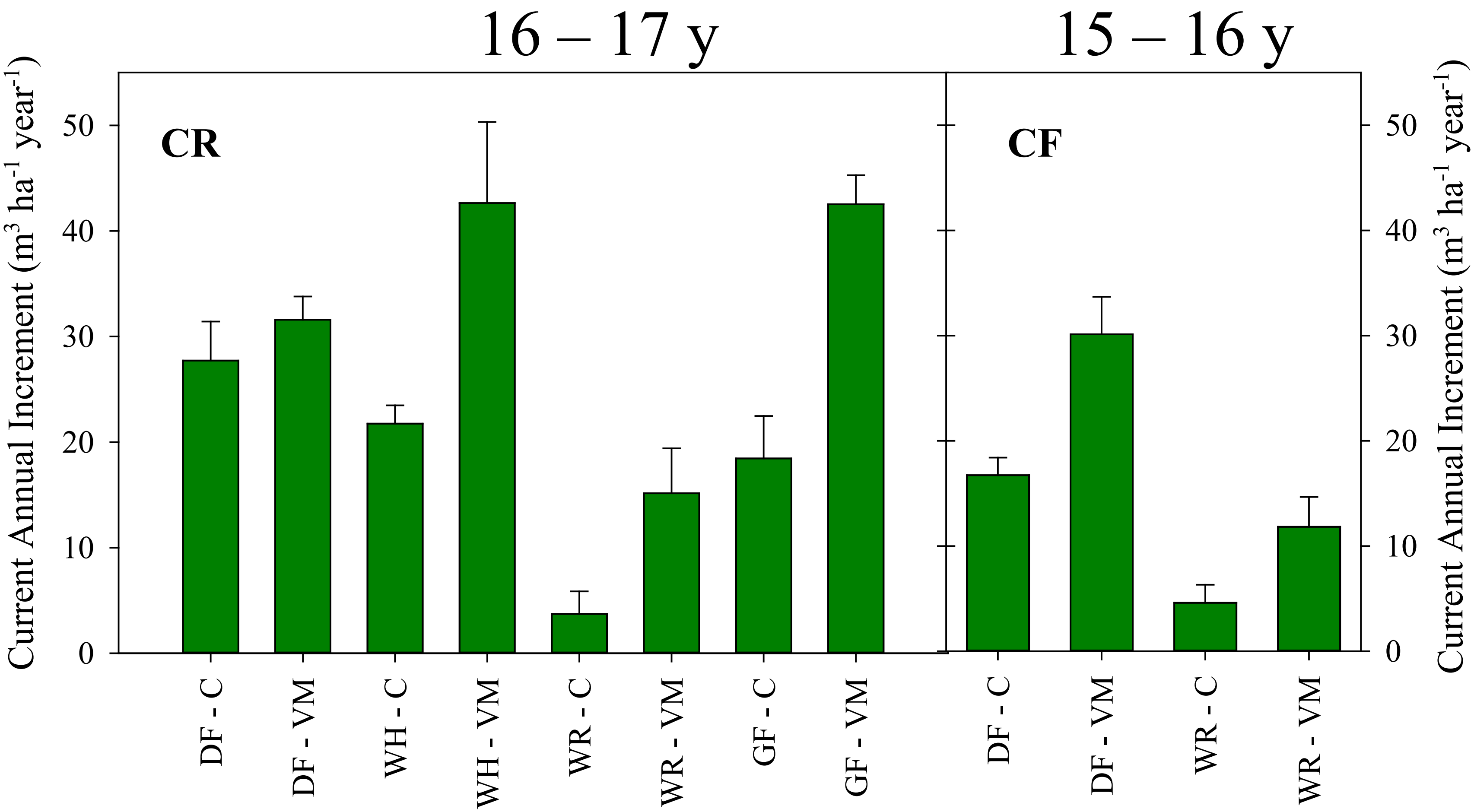


Projected LAI ($m^2\ m^{-2}$)



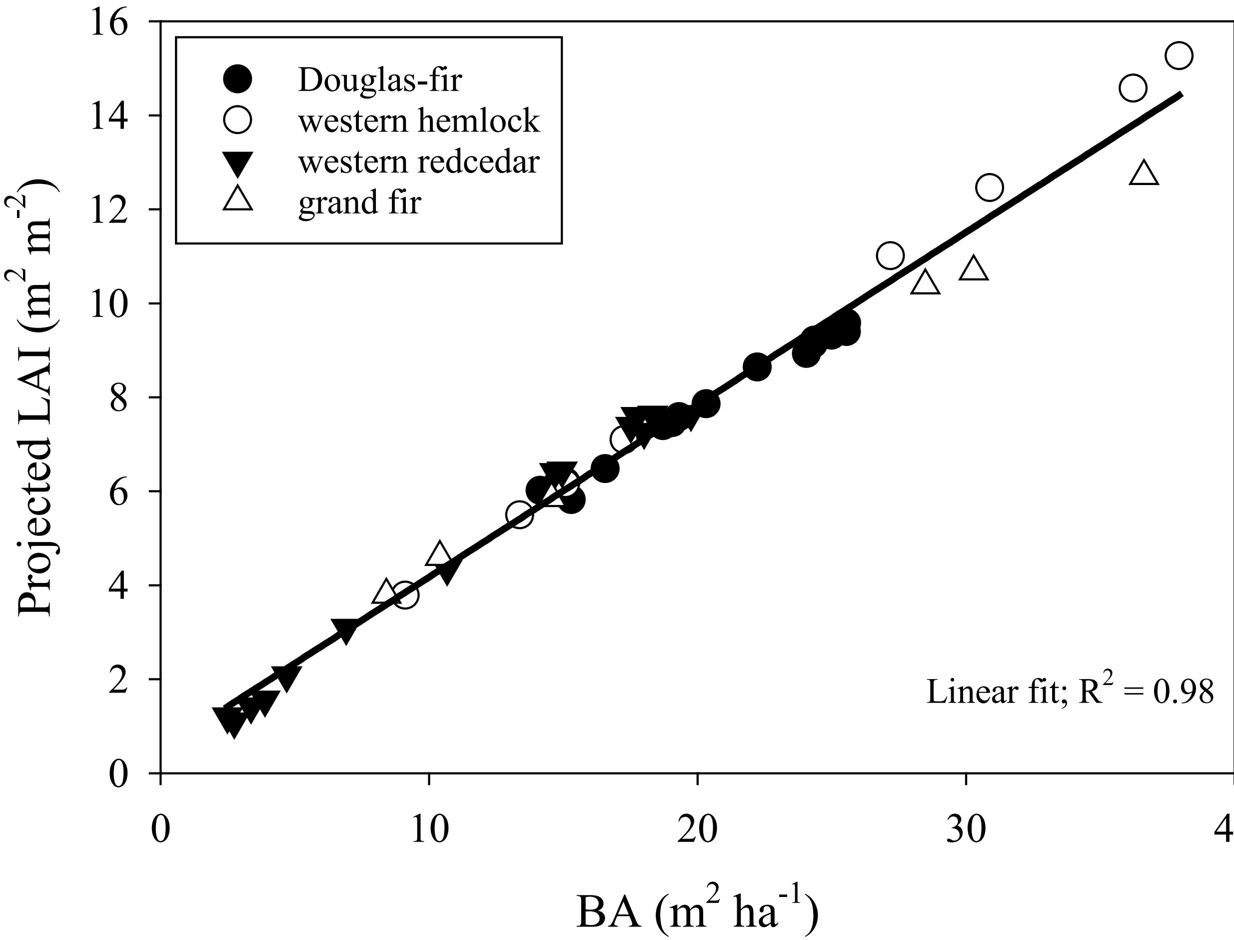
Site	CR				CF	
Species	DF	WH	WR	GF	DF	WR
T-Test Treatment	**0.009**	**0.001**	**0.001**	**0.002**	**<0.0001**	**0.002**

Volume Production (CAI, $m^3\ ha^{-1}\ year^{-1}$)



Site	CR				CF	
Species	DF	WH	WR	GF	DF	WR
T-Test Treatment	0.403	**0.038**	0.075	**0.008**	**0.015**	0.072

BA and LAI Relationship

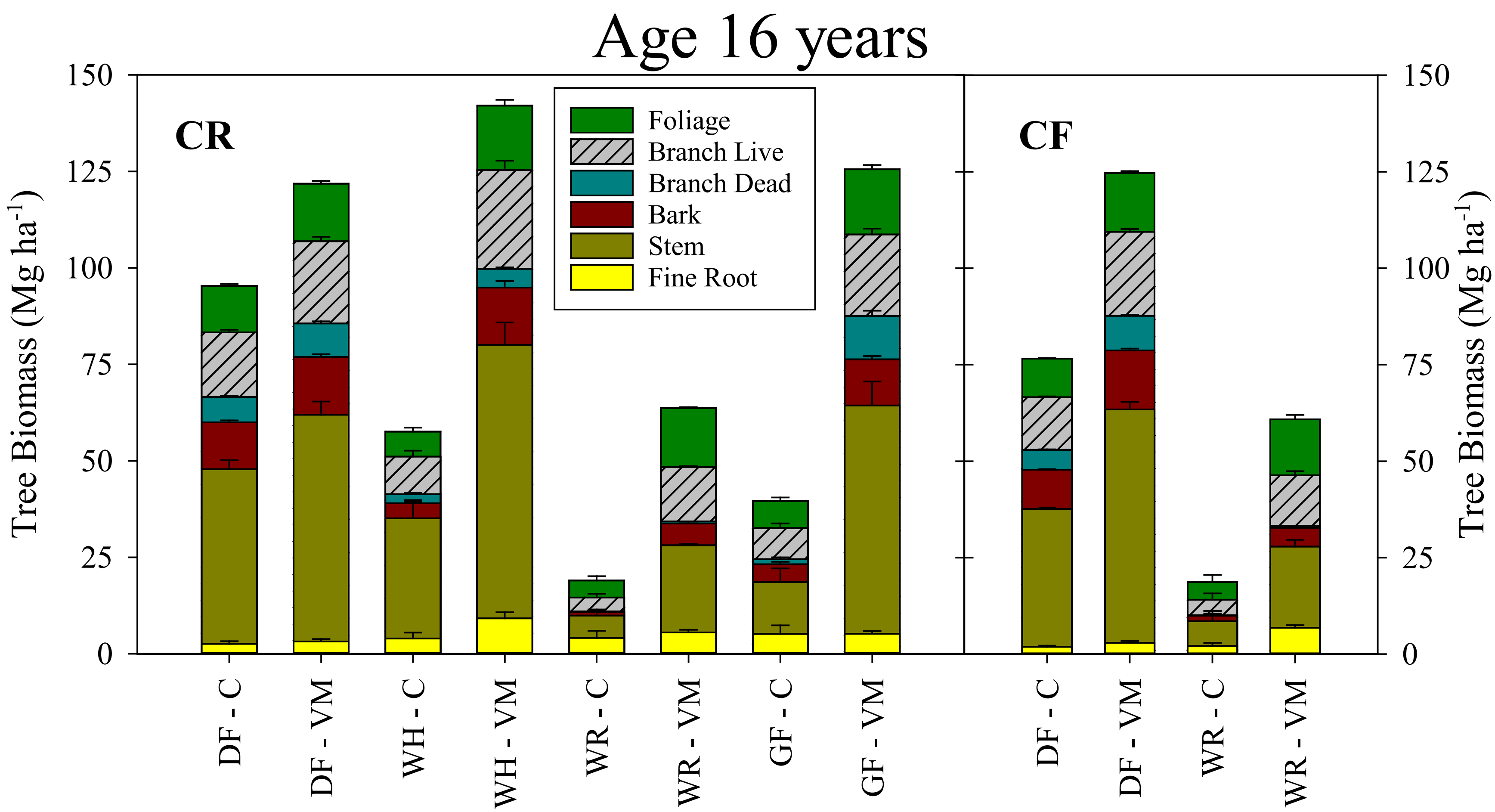


Model	Parameter	Parameter Estimate	SE	R^2	RMSE
$LAI = a + b \cdot BA$	a	0.5038	0.1463	0.98	0.428
	b	0.3670	0.0073		

Results

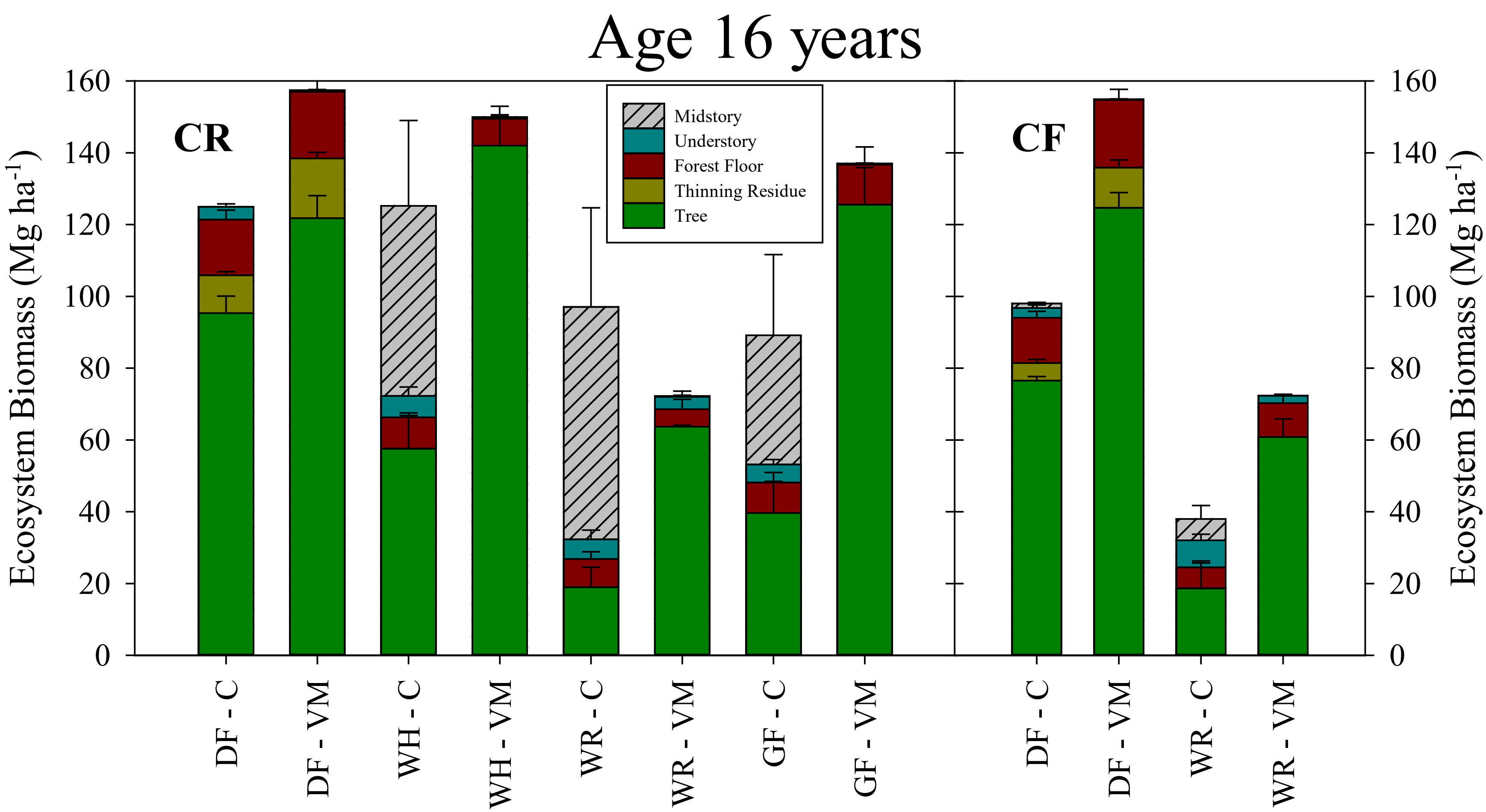
Biomass Stock

Crop Tree Stand Biomass (Mg ha^{-1})



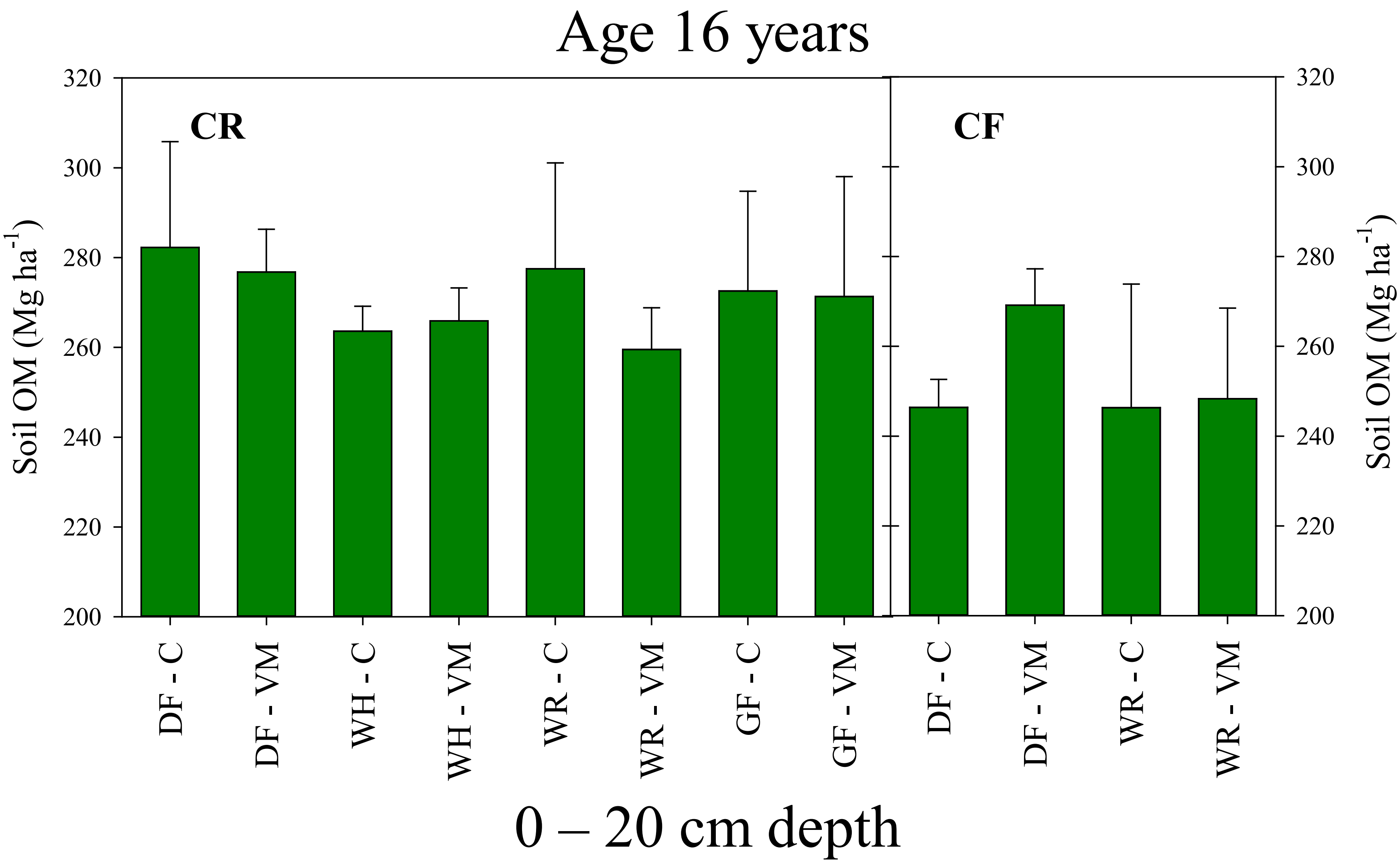
Site	CR				CF	
Species	DF	WH	WR	GF	DF	WR
T-Test Treatment	**0.009**	**0.001**	**0.001**	**0.003**	**<0.0001**	**0.002**

Ecosystem Biomass (Mg ha^{-1})



Site	CR				CF	
Species	DF	WH	WR	GF	DF	WR
T-Test Treatment	**0.005**	0.281	0.282	0.133	**<0.0001**	**0.016**

Soil Organic Matter (Mg ha^{-1})

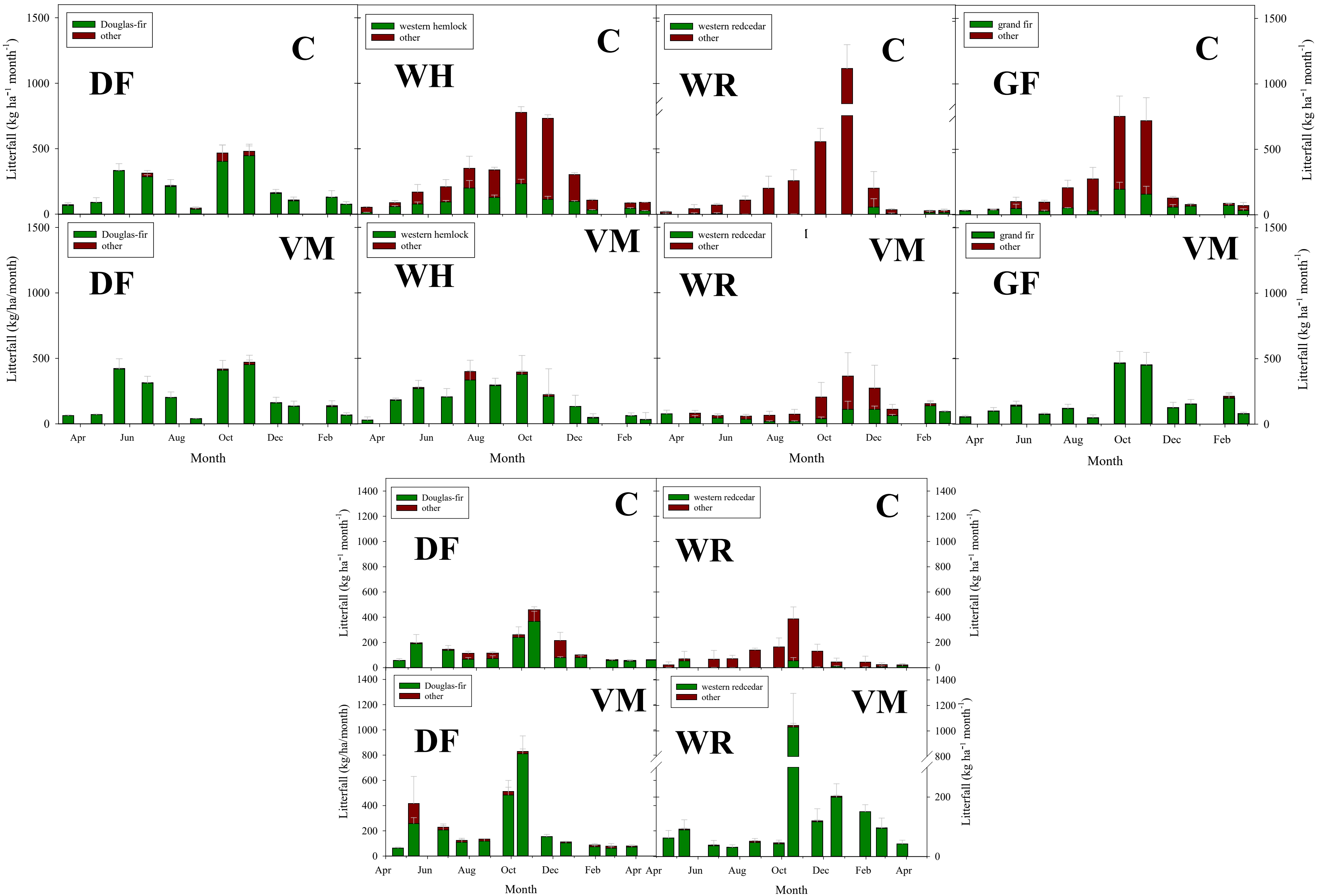


Site	CR				CF	
Species	DF	WH	WR	GF	DF	WR
T-Test Treatment	0.836	0.810	0.518	0.974	**0.067**	0.955

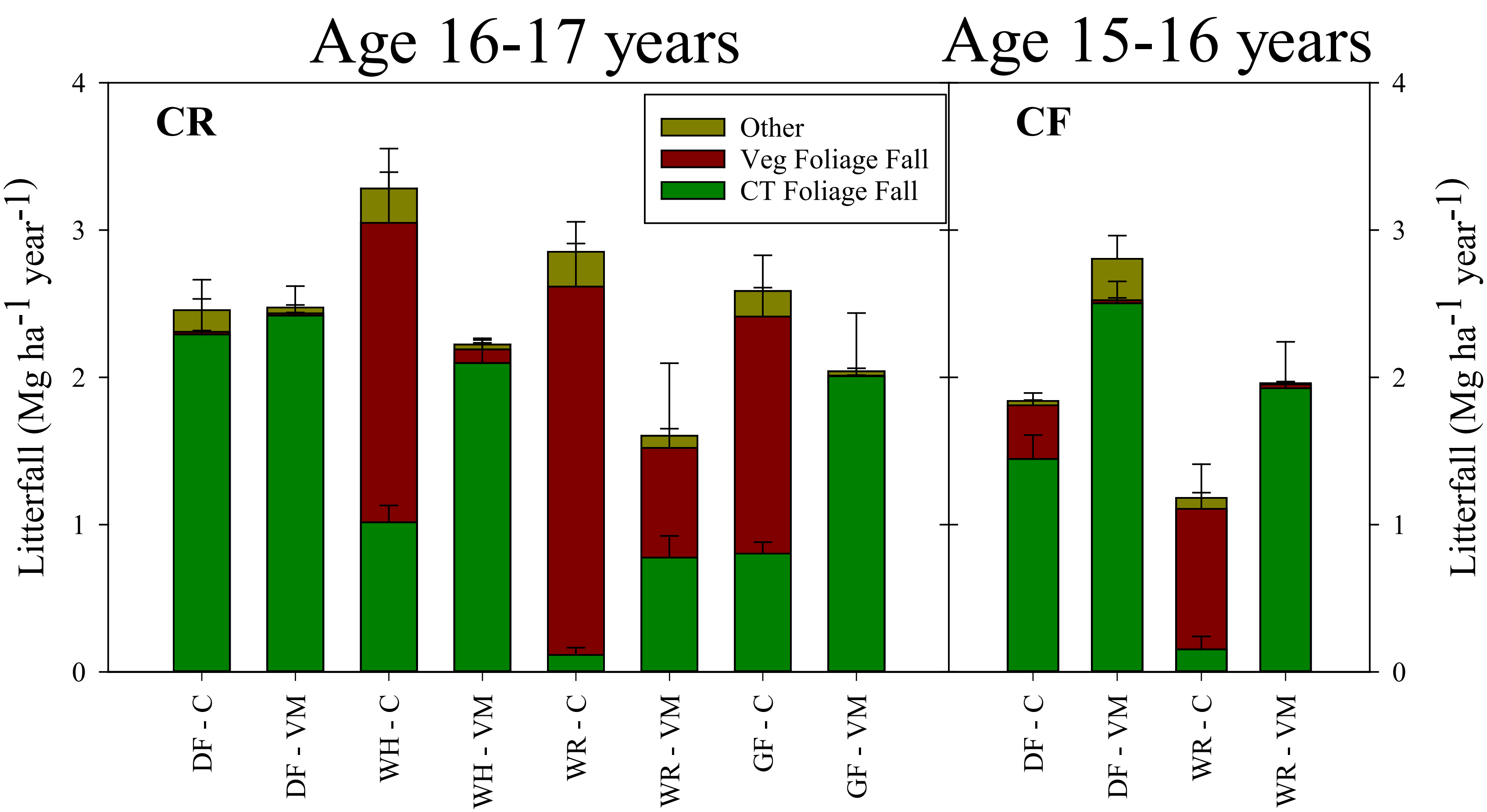
Results

ANPP

Litterfall Dynamics (kg ha^{-1} month^{-1})

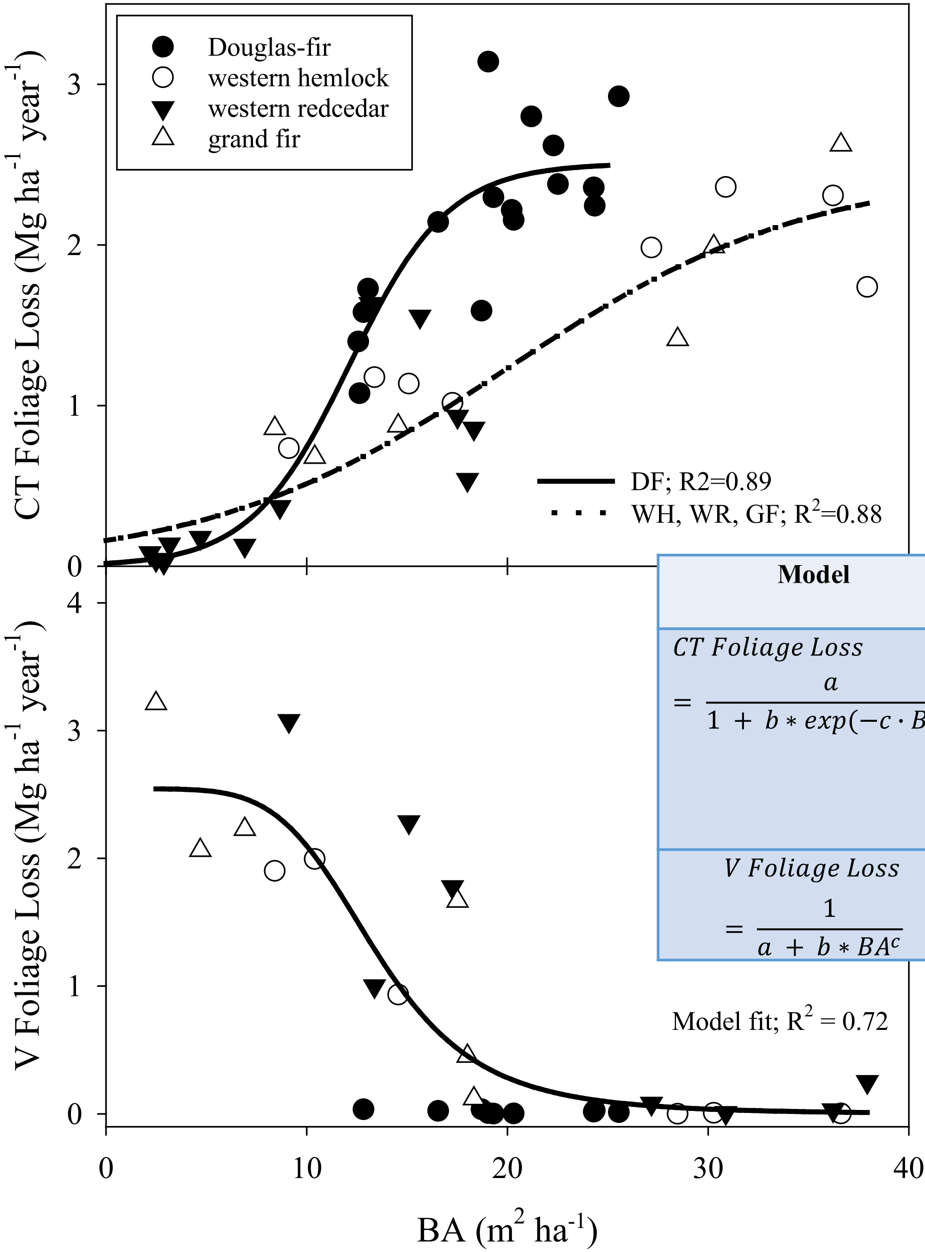


Total Litterfall (Mg ha^{-1} year^{-1})



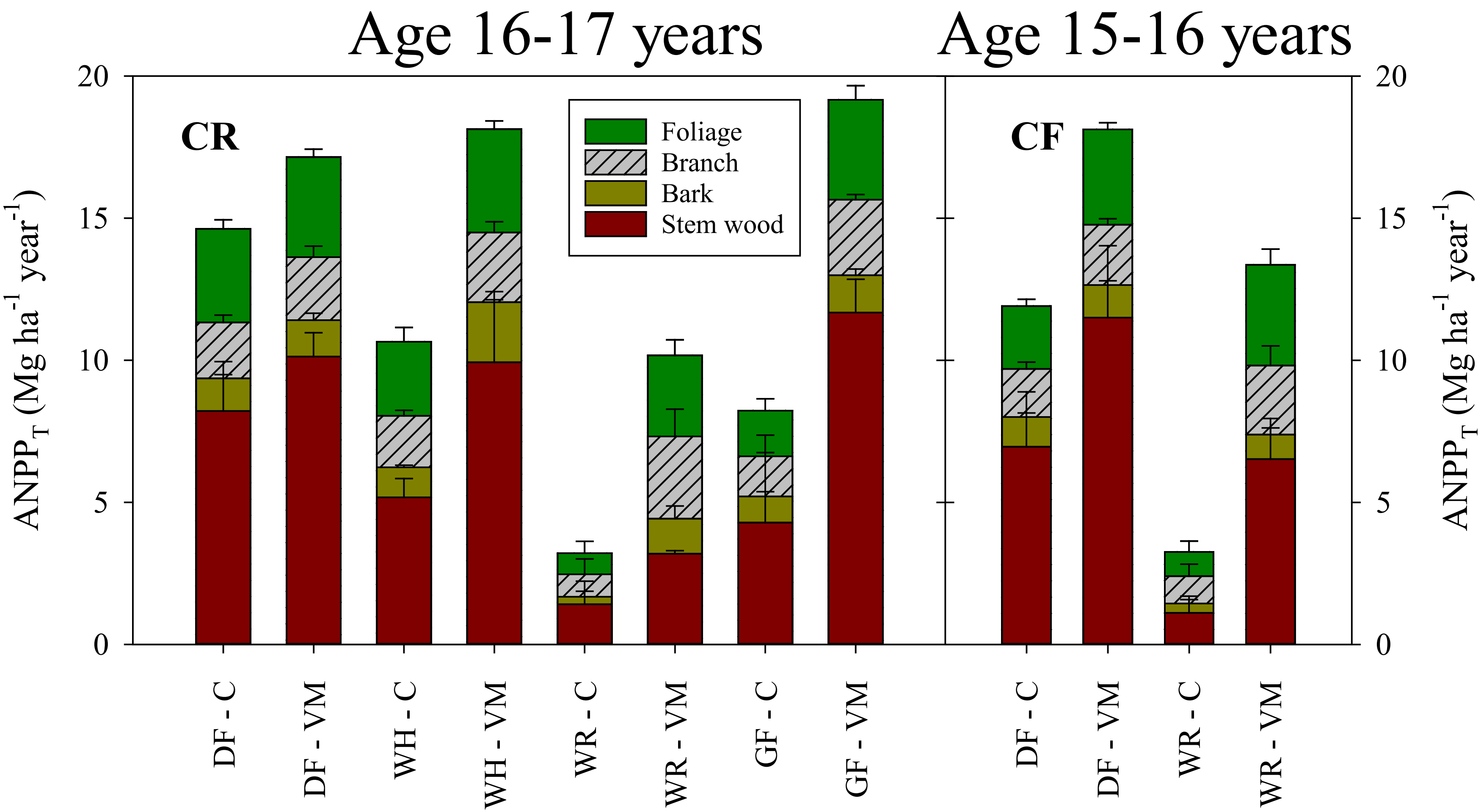
	CR				CF	
T-Test Treatment	DF	WH	WR	GF	DF	WR
CT Foliage Fall	0.766	**0.001**	**0.008**	**0.026**	**0.002**	**0.001**
Total LF	0.996	**0.034**	0.114	0.329	**0.012**	0.178

Litterfall and BA Relationships



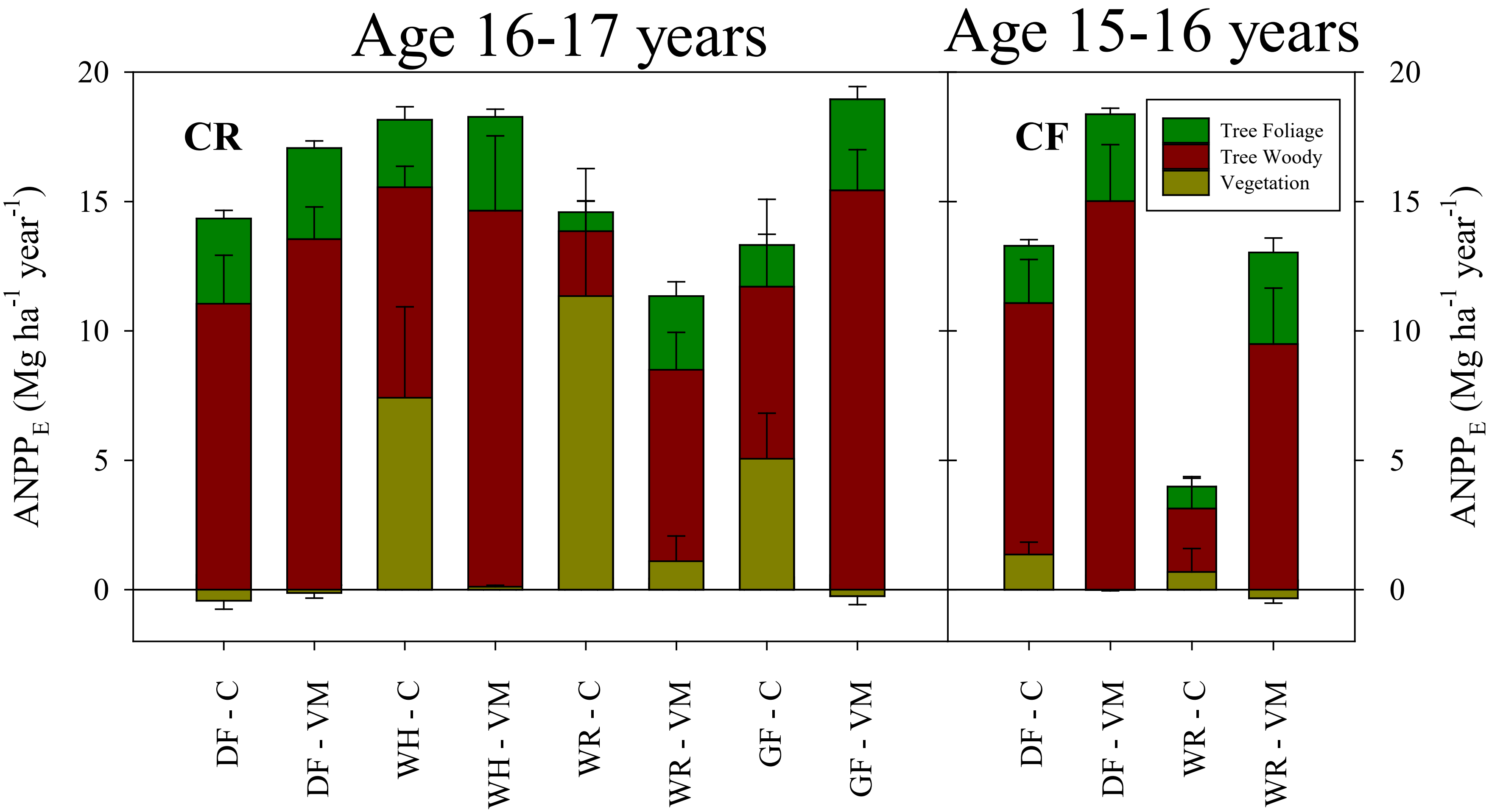
Model	Species	Parameter	Parameter Estimate	SE	R^2	RMSE
$CT\ Foliage\ Loss = \frac{a}{1 + b * exp(-c \cdot BA)}$	DF	a	2.5086	0.1473	0.89	0.578
		b	137.0973	0.0540		
		c	0.4057			
	WH WR GF	a	2.4676	0.1473	0.88	0.544
		b	14.3036	0.0540		
		c	0.1329			
$V\ Foliage\ Loss = \frac{1}{a + b * BA^c}$	All	a	0.3931	0.0538	0.72	0.770
		b	0.000000495	0.00000029		
		c	5.2279	2.1439		

Crop Tree ANPP (Mg ha^{-1} year^{-1})



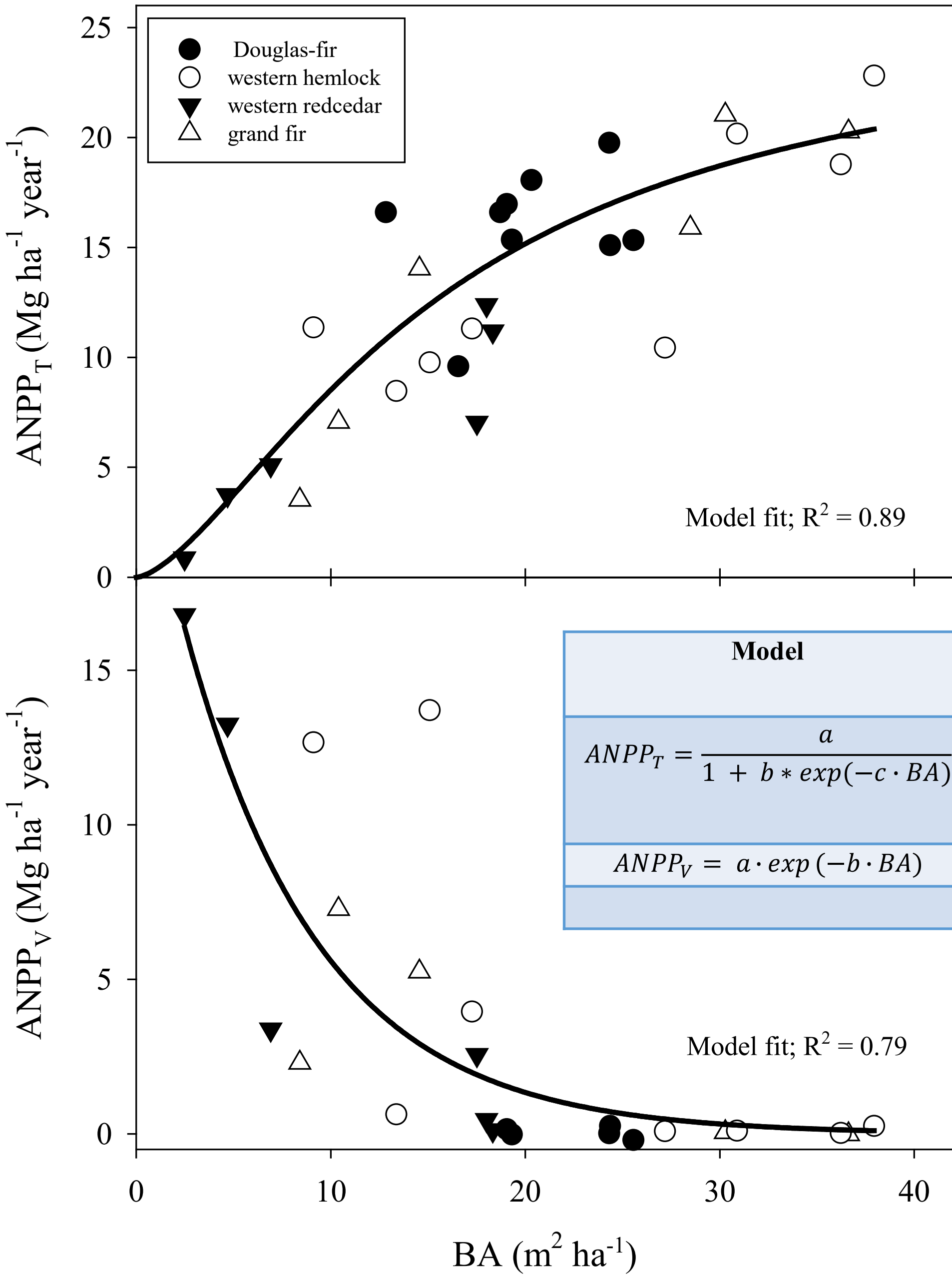
Site	CR				CF	
Species	DF	WH	WR	GF	DF	WR
T-Test Treatment	0.279	**0.031**	**0.028**	**0.036**	**0.022**	**0.008**

Whole Ecosystem ANPP (Mg ha^{-1} $year^{-1}$)



Site	CR				CF	
Species	DF	WH	WR	GF	DF	WR
T-Test Treatment	0.252	0.966	0.369	0.263	**0.061**	**0.024**

BA and ANPP Relationships



Model	Parameter	Parameter Estimate	SE	R^2	RMSE
$ANPP_T = \dfrac{a}{1 + b * exp(-c \cdot BA)}$	a	25.603	6.310	0.89	3.027
	b	-1.542	0.479		
	c	15.688	5.575		
$ANPP_V = a \cdot exp(-b \cdot BA)$	a	23.5255	4.8486	0.79	3.085
	b	0.1435	0.0288		

Summary

At age 15-17 years:

- H1: With sustained FVM treated plots will have higher total component biomass stock and ANPP
  - Accepted: Higher tree biomass stock
  - Partially Accepted: Higher tree ANPP ($ANPP_T$) with the exception of Douglas-fir at the CR site

Summary

At age 15-17 years:

- H2: Tree response to FVM differs between species and site.
  - Partially Accepted: Crop tree biomass stock differed between species, but not sites.
  - Partially Accepted: $ANPP_T$ differed between species and differed between sites for Douglas-fir.

Summary

At age 15-17 years:

- H3: Midstory and understory partially counteract response to FVM.
  - Partially Accepted: midstory + understory played a major role in biomass stock and $ANPP_E$
    - Except Douglas-fir stands

Summary

At age 15-17 years:

- H4: Ecosystem biomass stock and ANPP is higher with FVM, and response differs between species and sites.
  - Partially Accepted: No difference in ecosystem biomass stock between treated and control plots of western hemlock, western redcedar, and grand fir on CR site
    - Ecosystem biomass stock differed between species, not sites
  - Partially Accepted: No difference in $ANPP_E$ for all species at both sites, with the exception of western redcedar on the CF site
    - $ANPP_E$ differed between species, not sites

Summary

At age 16 years:

- H5: Top soil biomass does not differ between FVM treatments.
    - Accepted: No difference in SOM

Conclusions

- Sustained FVM produced long-term increment in crop tree biomass stock and net primary productivity (11 years after treatment ended).

- High tree productivity can be attained independent of site, however, one site can have more to gain from FVM than another

- Sustained FVM had no effect on ecosystem productivity, as site resources were shifted towards crop trees

Conclusions

Two viable management options depending on objectives:

Future Directions

- Nutrient Content
- Soil Organic Matter at deeper soil layers
- Extend Litterfall and NPP to 4-5 years (account for weather variability)
- Crown Architecture Analysis
- Uncertainty Analysis

Acknowledgements

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Questions?

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