Long-term Effects of Vegetation Management on the Biomass Stock of Four Coniferous Species in the PNW

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Background

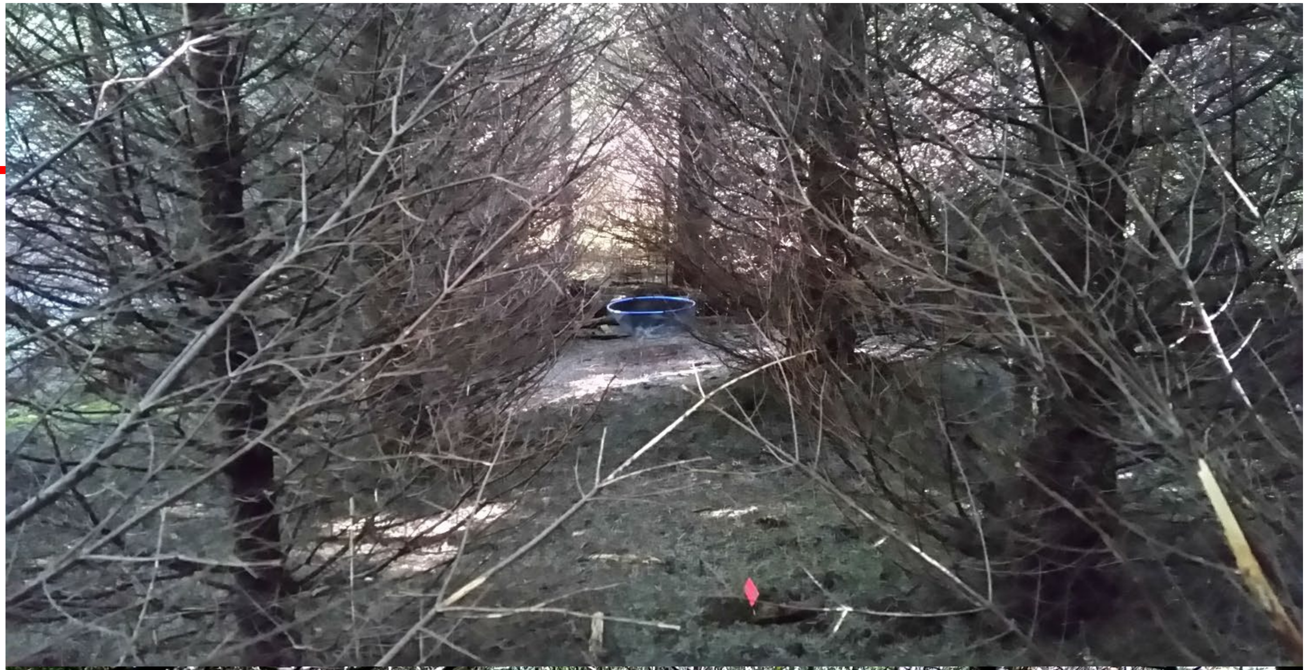
- The Vegetation Management Research Cooperative (VMRC) conducts applied reforestation research on conifer plantations in the Pacific Northwest (PNW).
- Membership includes 10 private forest management companies and 2 public land management agencies.
- The VMRC was established in 1993 and has several studies throughout the PNW.

Background

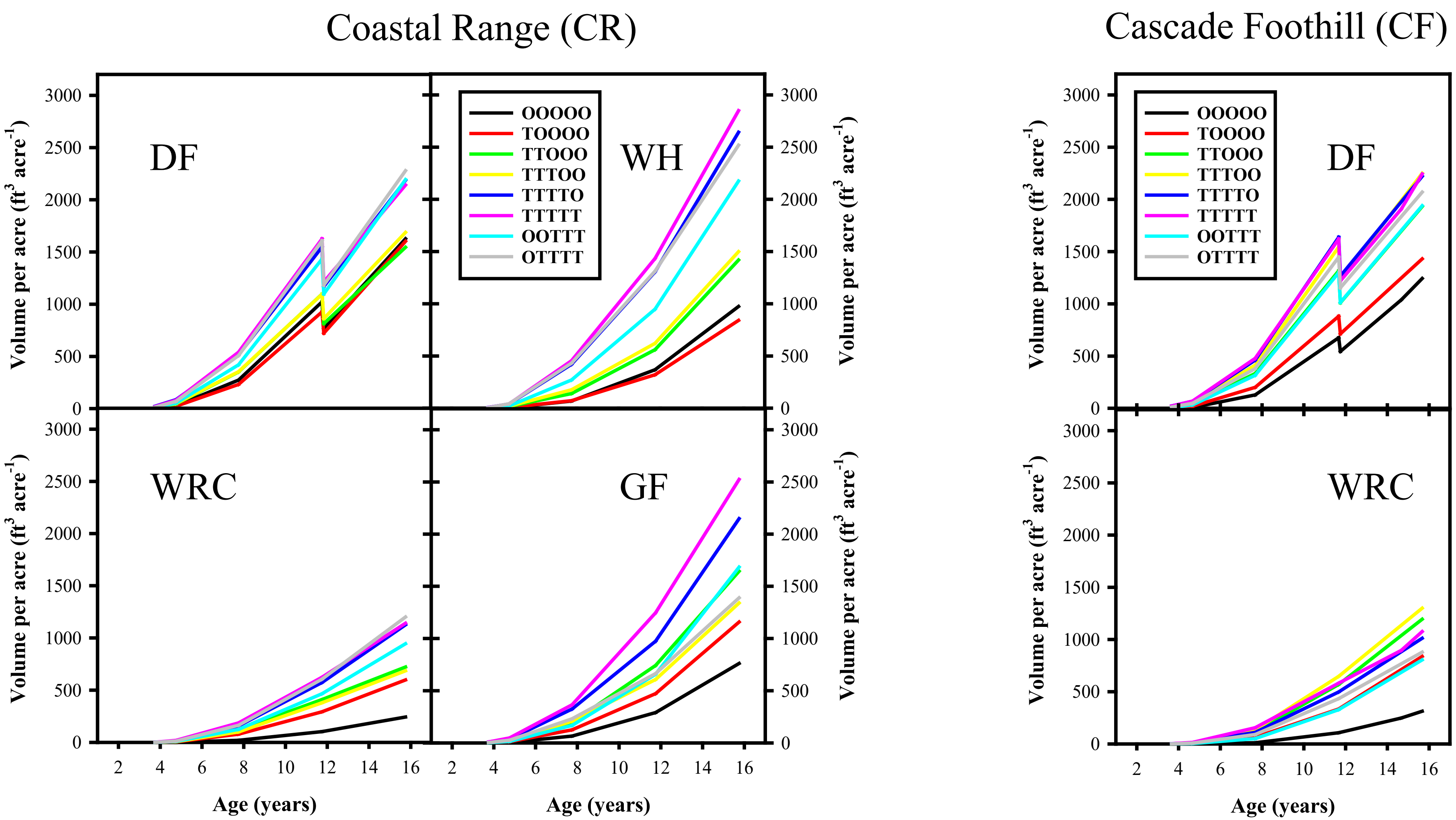
- Forest vegetation management (FVM) is an integral part of reforestation in the PNW
- Early control of competing vegetation reduces competition for light, water, and nutrients
- Most studies have focused on short-term responses of FVM

Background

- The VMRC has two contrasting study sites, one in the Coast Range (CR) and one in the Cascade Foothills (CF), with a wide range of vegetation management treatments that have created large differences in stand and ecosystem structure over the last 16 -17 years.



Background



Time series of stand volume for Douglas-fir (DF), western hemlock (WH), western red cedar (WRC) and grand fir (GF) stands growing under different treatments of vegetation control on a sites located in the Coastal Range (CR, left panel) and the Cascade Foothill (CF, right panel).

Background

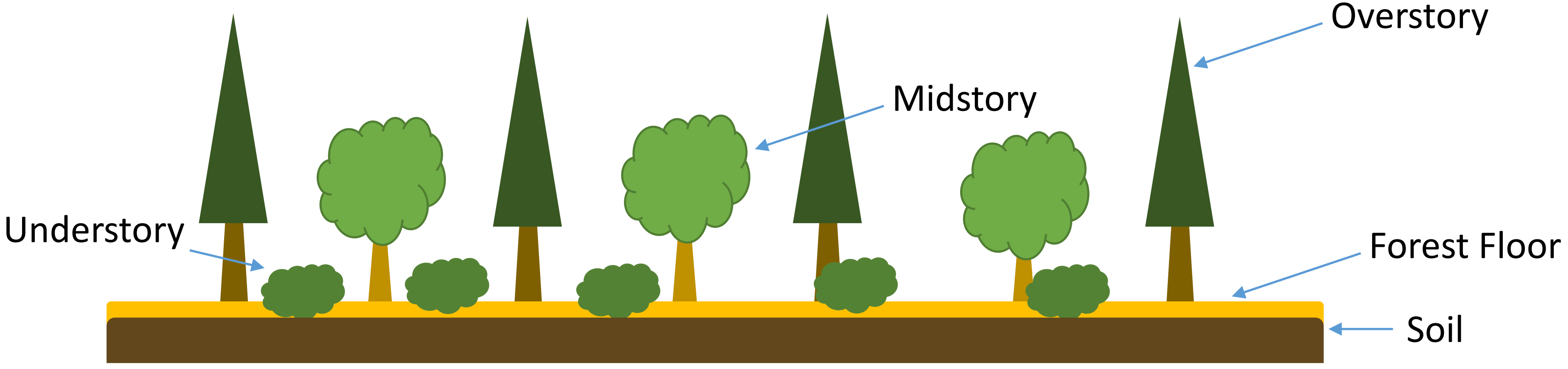
- FVM has been reported to increase growth rates and biomass accumulation in forests in other parts of the world.
- Net Primary Productivity (NPP) is an important variable of terrestrial ecosystems and a key component of the global carbon cycle.
- NPP improves our understanding of the impact that management practices can have on forest production and carbon sequestration.

Research Objectives

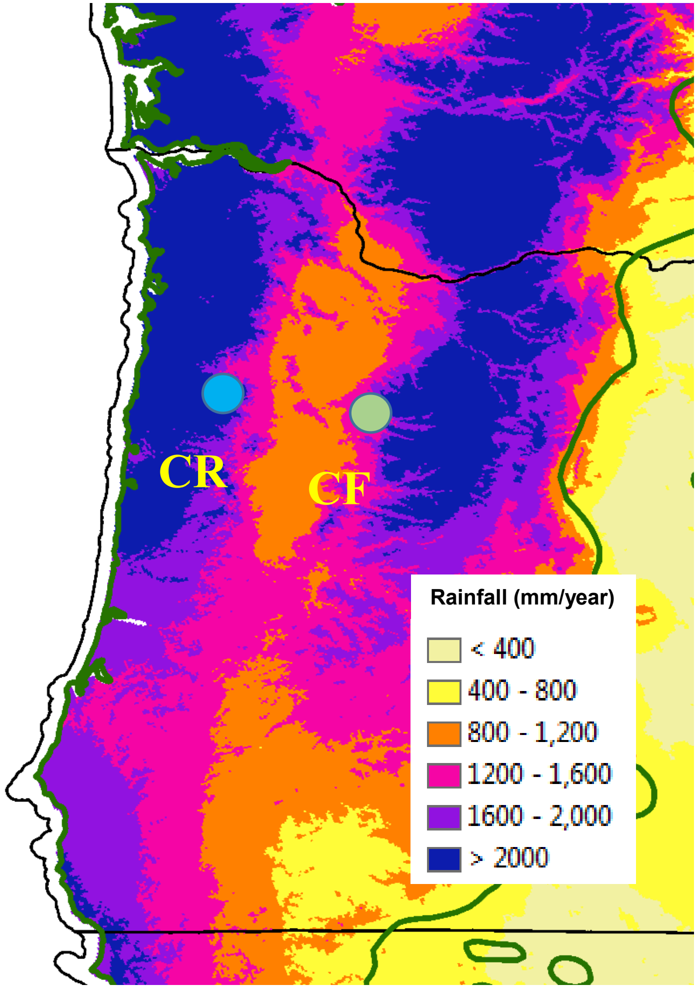
Determine the effect of crop species, FVM treatment, and site on:

1) Total tree biomass, competing vegetation (midstory and understory), forest floor, coarse woody debris, and top soil

2) Aboveground Net Primary Production (crop trees and vegetation)



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
WHC: 25%

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
WHC: 15%

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

Species:
- Douglas-fir
- Western redcedar

Container seedling: Styro 15

Treatments Description

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
- Douglas-fir plots thinned at age 12

Methods: Biomass Stock

- **Crop Trees:** Developed species specific allometric equations to predict tree foliage, live branch, dead branch, bark and stemwood biomass from DBH and height (44 trees). Applied equations to inventory data.
- **Mid-story**: 6 subplots of 2 x 2 m area per plot (7% plot area)
  - Measure DBH of all vegetation (use reported functions)
- **Understory**: 6 clip plots of 0.6 x 0.6 m per plot (for vegetation <1.5 m)
  - Dry weight of clip plots
- **Forest floor**: collected OM layer (Oa and Oi) in six 0.6 x 0.6 m 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 organic matter: Use same 6 samples used for fine roots

Methods: Biomass

Vegetation Management Research Cooperative

VMRC

Methods: 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

Methods: NPP

ANPP ($Mg\ ha^{-1}\ yr^{-1}$) (2016 –2018)

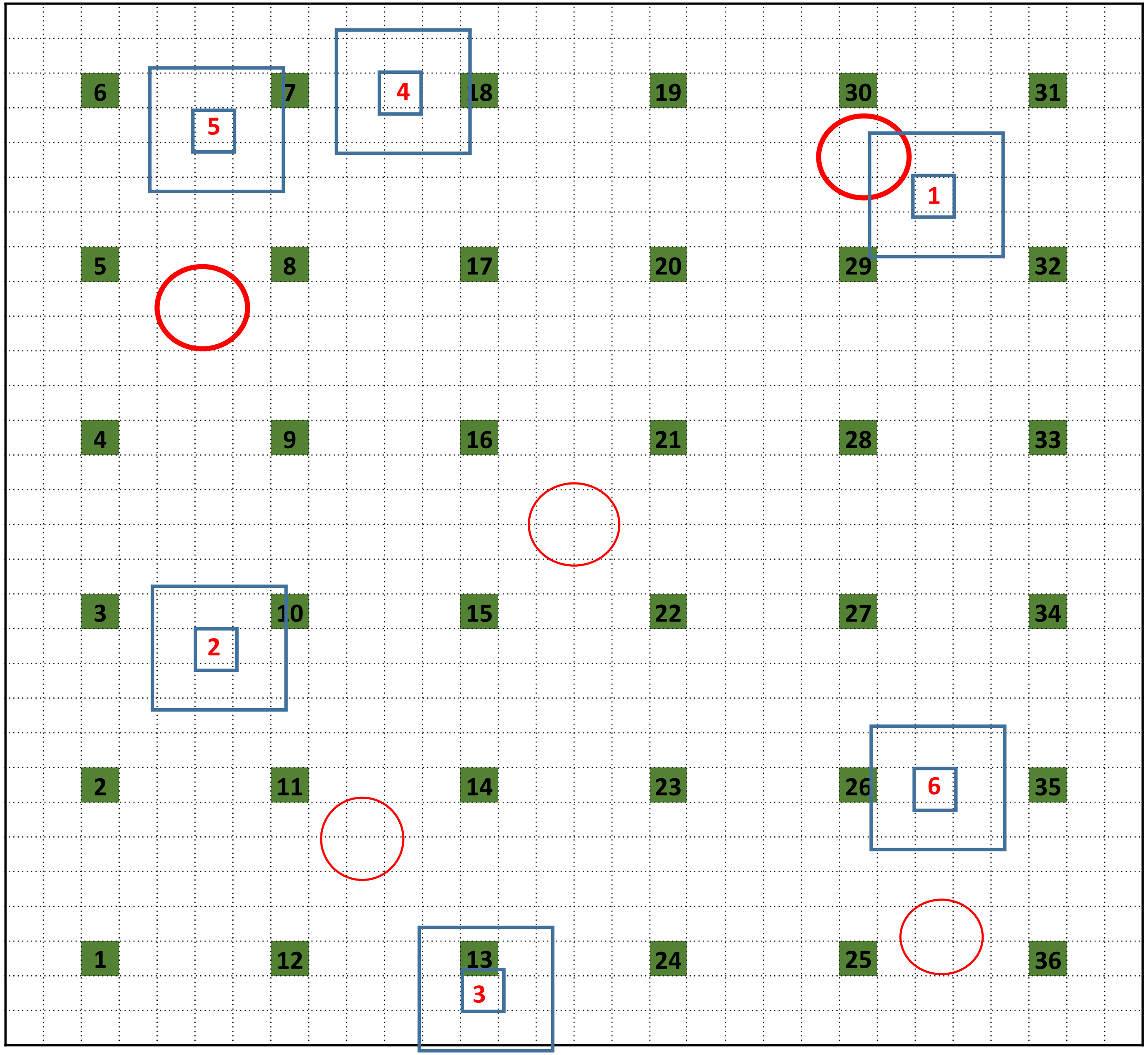
Δ AG Biomass (crop trees + midstory + understory) + Litterfall

Methods: Litterfall

- Start: February/ March 2016
- 5 traps in each plot
- Collected monthly
- Trap size: 0.5 m^2

(80 cm diameter)

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

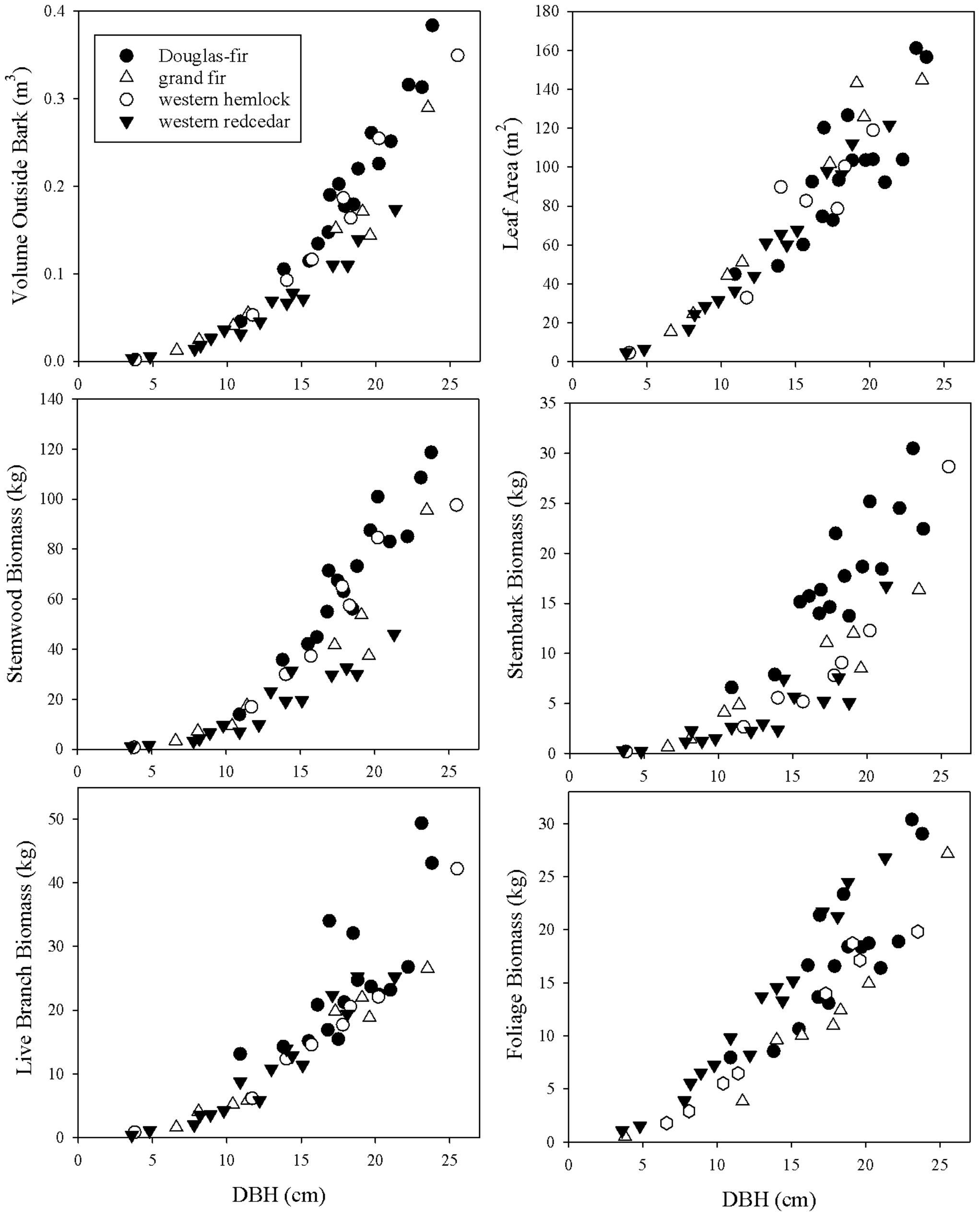
- Flagged Center and Corners of 2x2 m plot

Measurement Tree

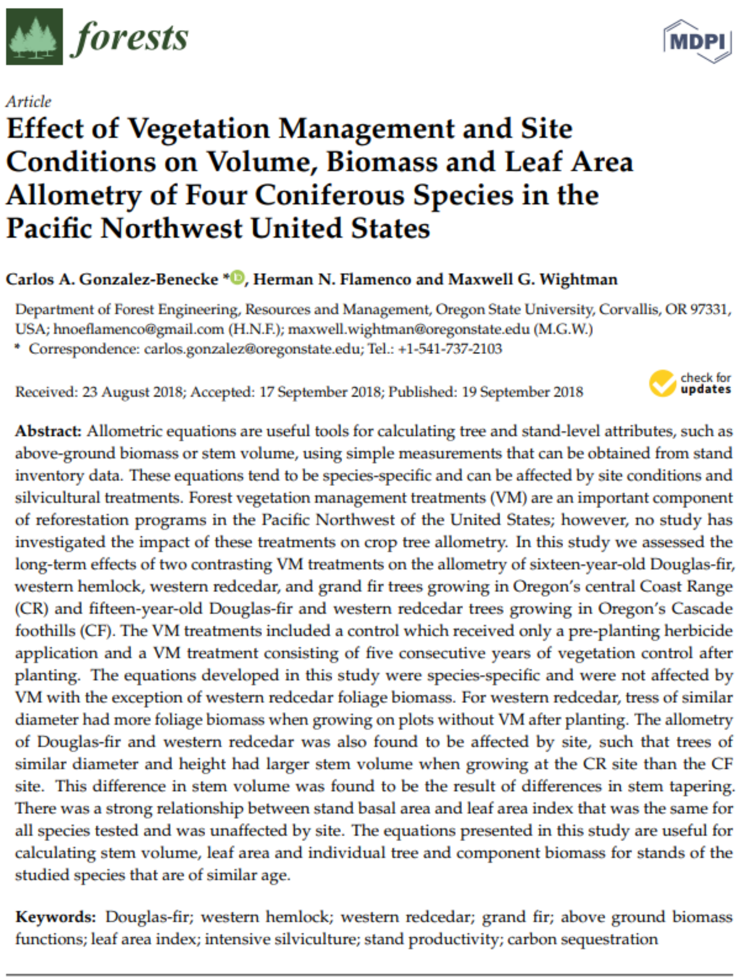
Results: Tree Inventory at age 16 years

Site	Species	Treatment	TPHA (ha^{-1})	Height (m)	QMD (cm)	BA (m^2 ha^{-1})
CR	Douglas-fir	C	688	14.0	18.5	18.4
		VM	703	15.1	20.7	23.6
	Western hemlock	C	860	10.8	14.2	13.7
		VM	1025	14.1	20.2	33.0
	Western redcedar	C	778	4.7	8.6	4.7
		VM	967	8.3	15.4	17.9
	Grand fir	C	927	8.7	12.3	11.1
		VM	997	12.1	20.1	31.8
CF	Douglas-fir	C	696	12.8	16.5	14.8
		VM	710	15.2	20.8	24.2
	Western redcedar	C	351	7.4	13.8	5.2
		VM	935	8.6	15.1	16.8

Results: Allometric Functions



Branch and Tree level functions



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Article

Effect of Vegetation Management and Site Conditions on Volume, Biomass and Leaf Area Allometry of Four Coniferous Species in the Pacific Northwest United States

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Abstract: Allometric equations are useful tools for calculating tree and stand-level attributes, such as above-ground biomass or stem volume, using simple measurements that can be obtained from stand inventory data. These equations tend to be species-specific and can be affected by site conditions and silvicultural treatments. Forest vegetation management treatments (VM) are an important component of reforestation programs in the Pacific Northwest of the United States; however, no study has investigated the impact of these treatments on crop tree allometry. In this study we assessed the long-term effects of two contrasting VM treatments on the allometry of sixteen-year-old Douglas-fir, western hemlock, western redcedar, and grand fir trees growing in Oregon's central Coast Range (CR) and fifteen-year-old Douglas-fir and western redcedar trees growing in Oregon's Cascade foothills (CF). The VM treatments included a control which received only a pre-planting herbicide application and a VM treatment consisting of five consecutive years of vegetation control after planting. The equations developed in this study were species-specific and were not affected by VM with the exception of western redcedar foliage biomass. For western redcedar, tress of similar diameter had more foliage biomass when growing on plots without VM after planting. The allometry of Douglas-fir and western redcedar was also found to be affected by site, such that trees of similar diameter and height had larger stem volume when growing at the CR site than the CF site. This difference in stem volume was found to be the result of differences in stem tapering. There was a strong relationship between stand basal area and leaf area index that was the same for all species tested and was unaffected by site. The equations presented in this study are useful for calculating stem volume, leaf area and individual tree and component biomass for stands of the studied species that are of similar age.

Keywords: Douglas-fir; western hemlock; western redcedar; grand fir; above ground biomass functions; leaf area index; intensive silviculture; stand productivity; carbon sequestration

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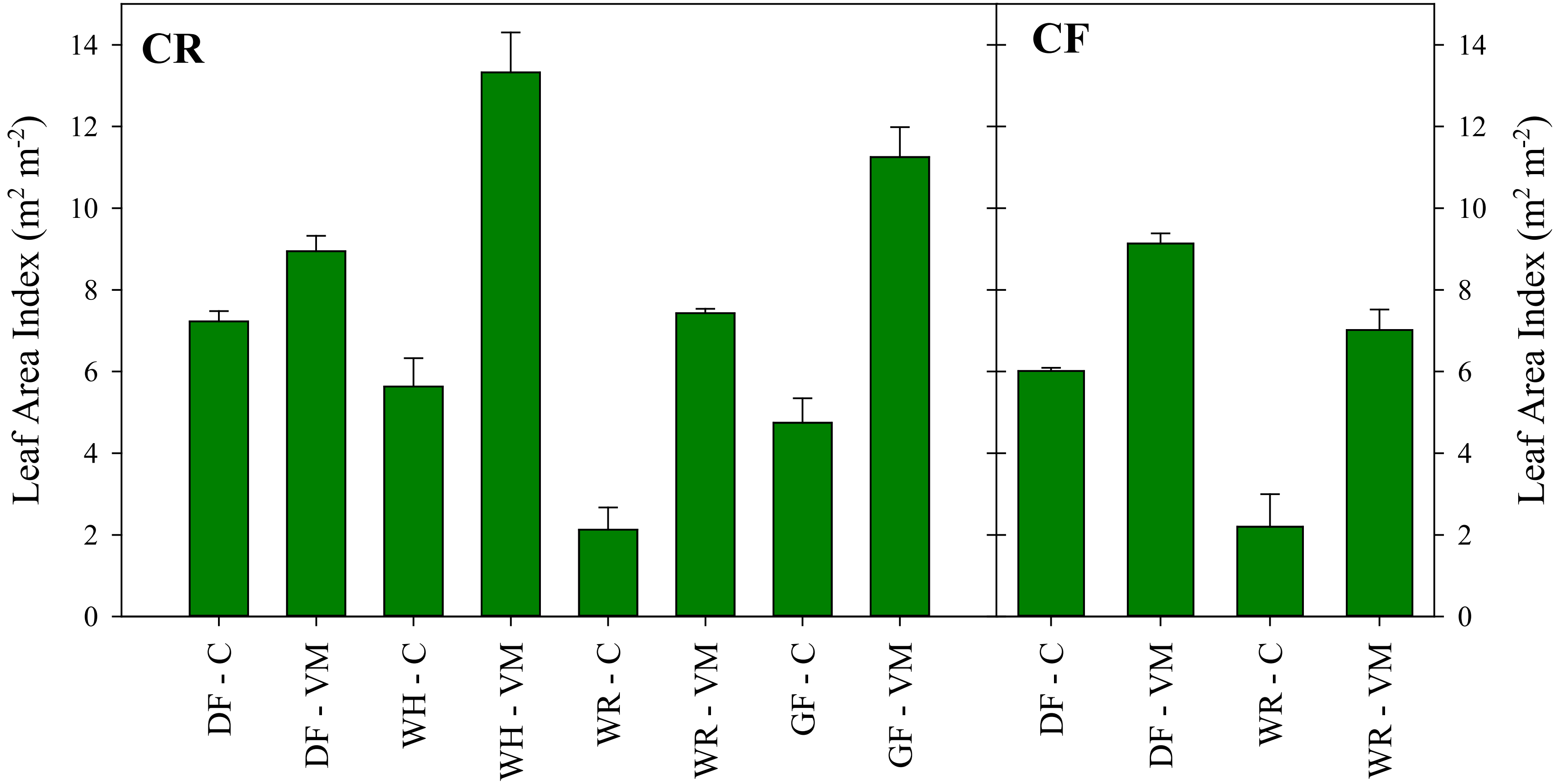
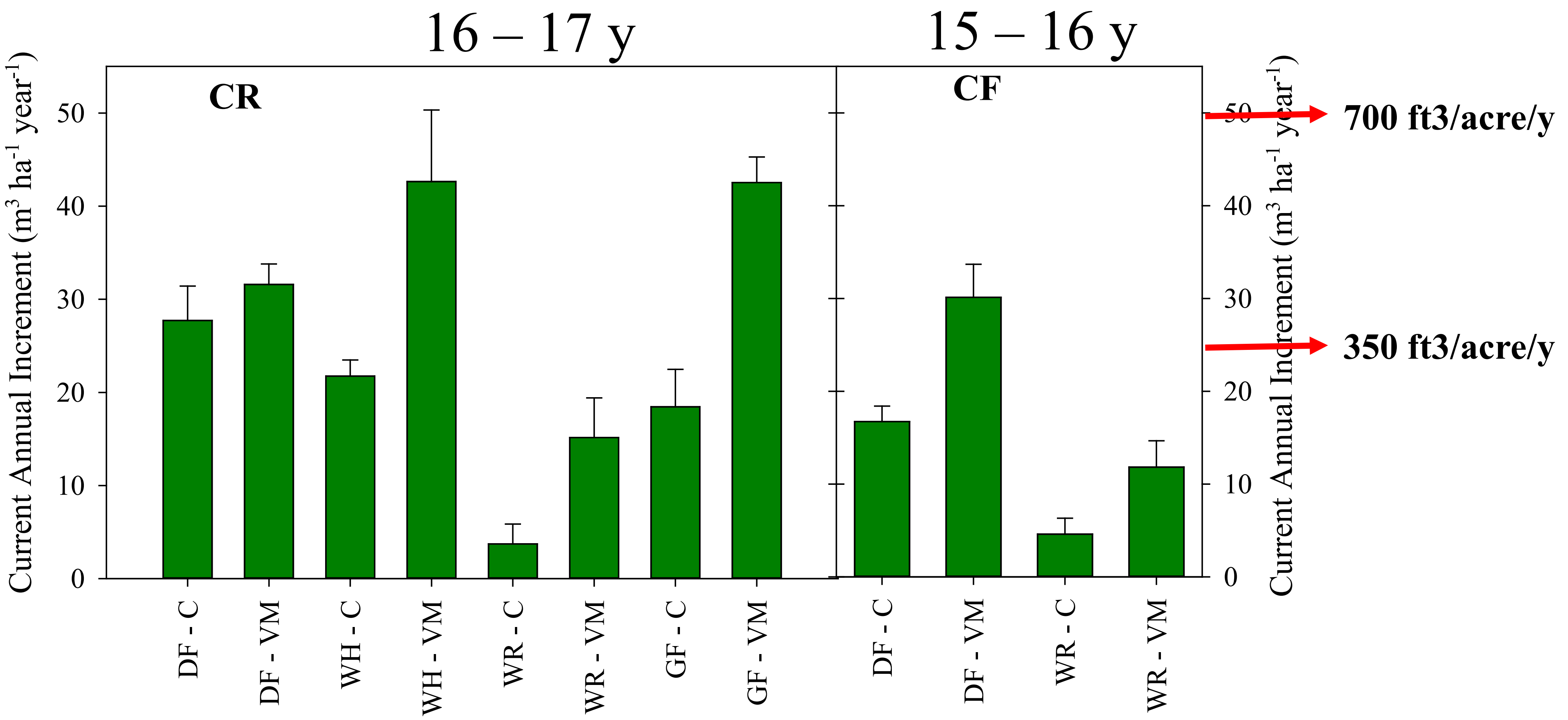
Results: Projected LAI (m^2 m^{-2})

Age 16 years



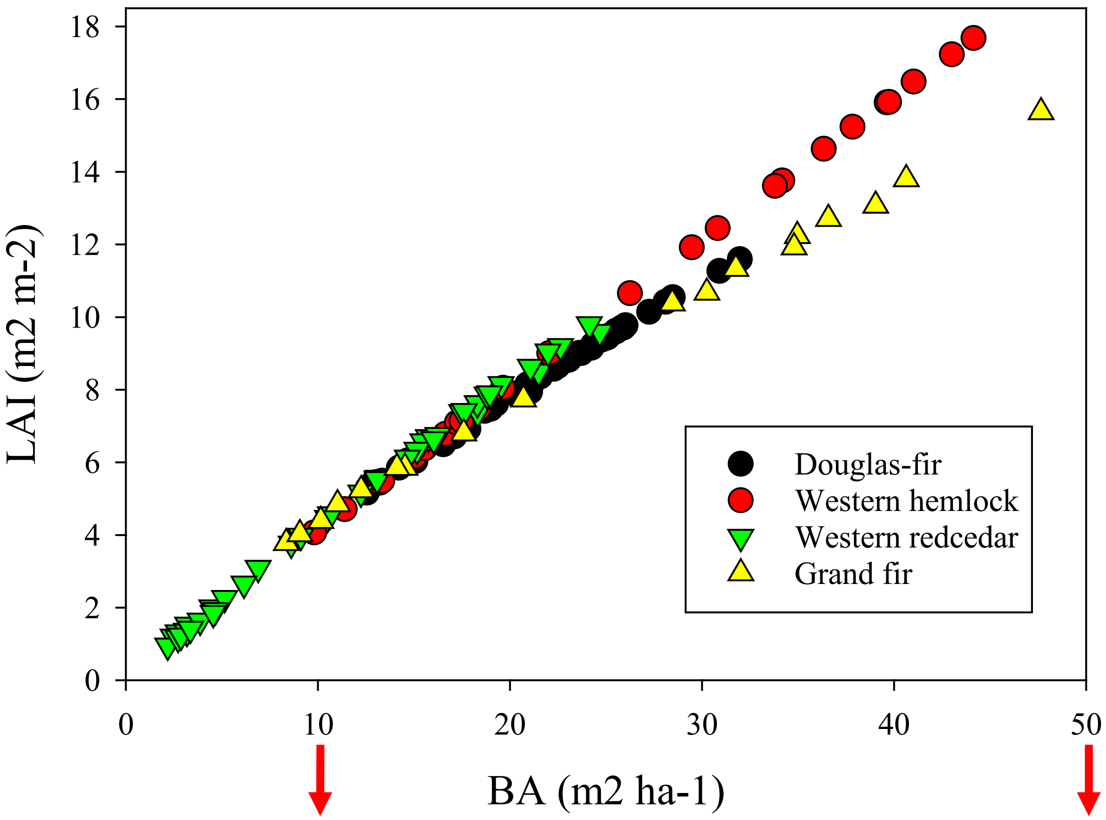
Site	**CR**				**CF**	
Species	**DF**	**WH**	**WR**	**GF**	**DF**	**WR**
P > F*	**0.009**	**0.001**	**0.001**	**0.002**	**<0.0001**	**0.002**

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



Site	CR				CF	
Species	DF	WH	WR	GF	DF	WR
P > F*	0.403	**0.038**	**0.075**	**0.008**	**0.015**	**0.072**

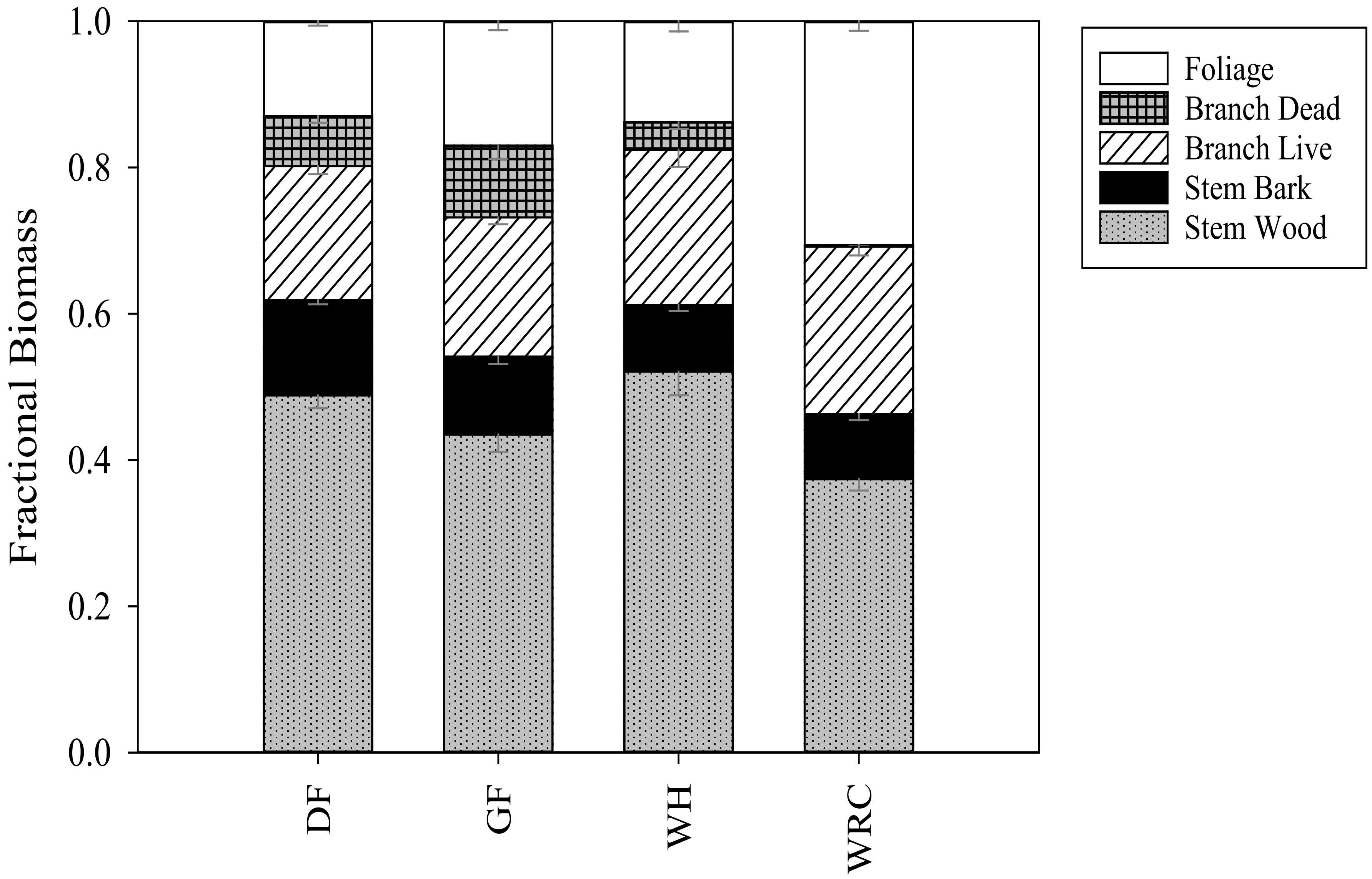
BA and LAI Relationship



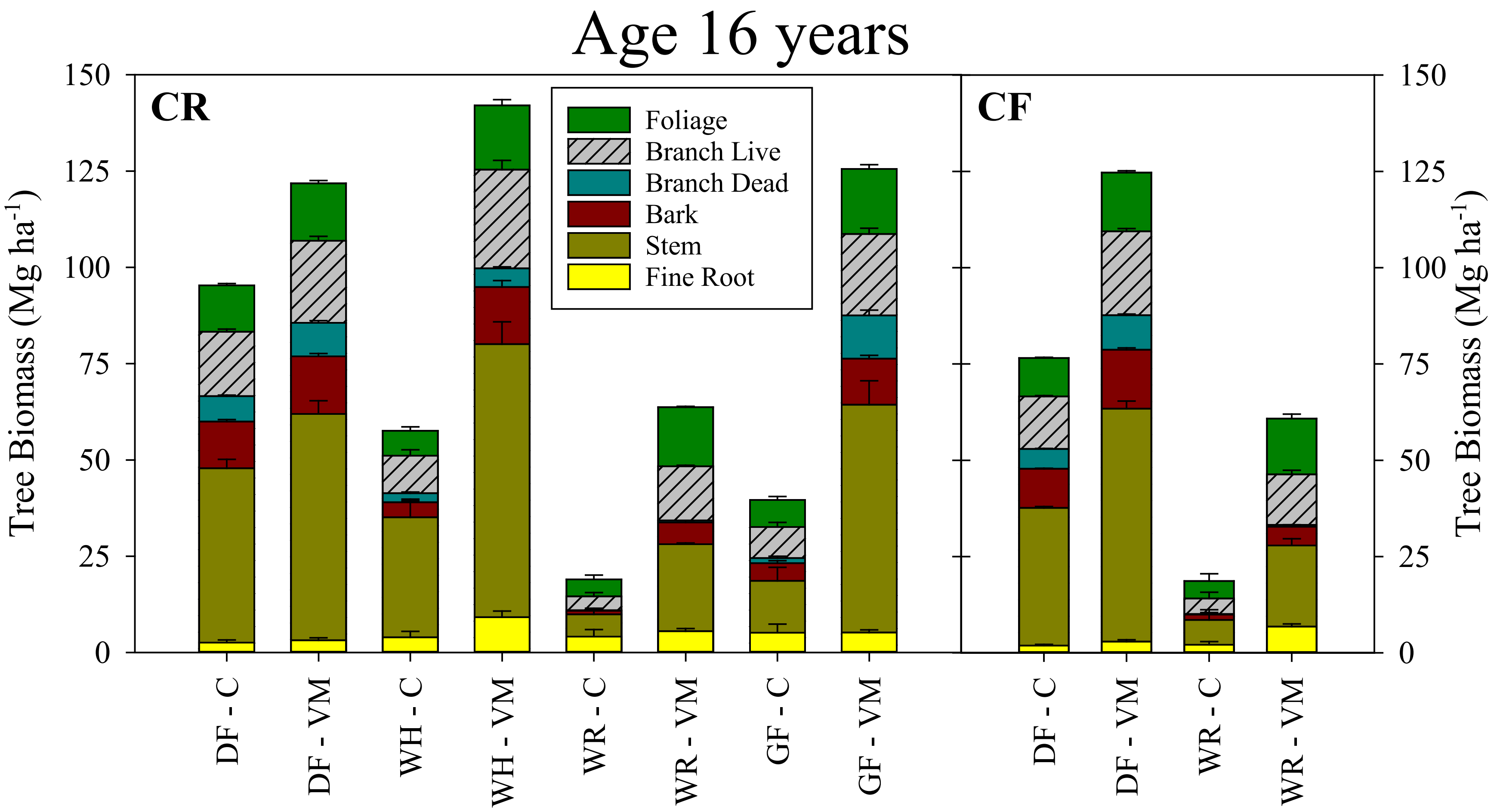
44 ft2/acre

220 ft2/acre

Results: Biomass Partitioning

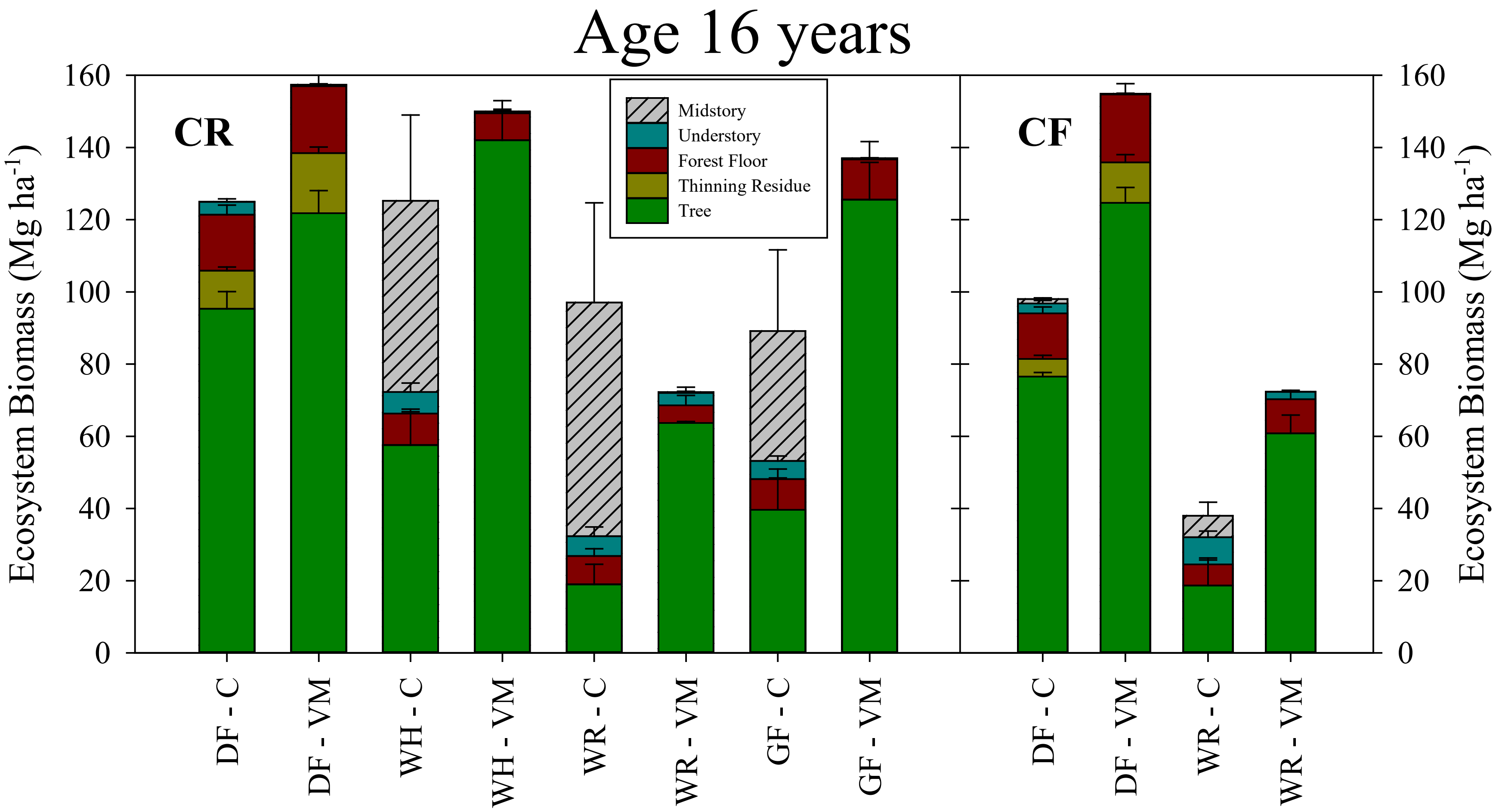


Results: Crop Tree Stand Biomass (Mg ha^{-1})



Site	CR				CF	
Species	**DF**	**WH**	**WR**	**GF**	**DF**	**WR**
P > F*	**0.009**	**0.001**	**0.001**	**0.003**	**<0.0001**	**0.002**

Results: Ecosystem Biomass (Mg ha^{-1})



Site	CR				CF	
Species	**DF**	**WH**	**WR**	**GF**	**DF**	**WR**
P > F*	**0.005**	0.281	0.282	0.133	**<0.0001**	**0.016**

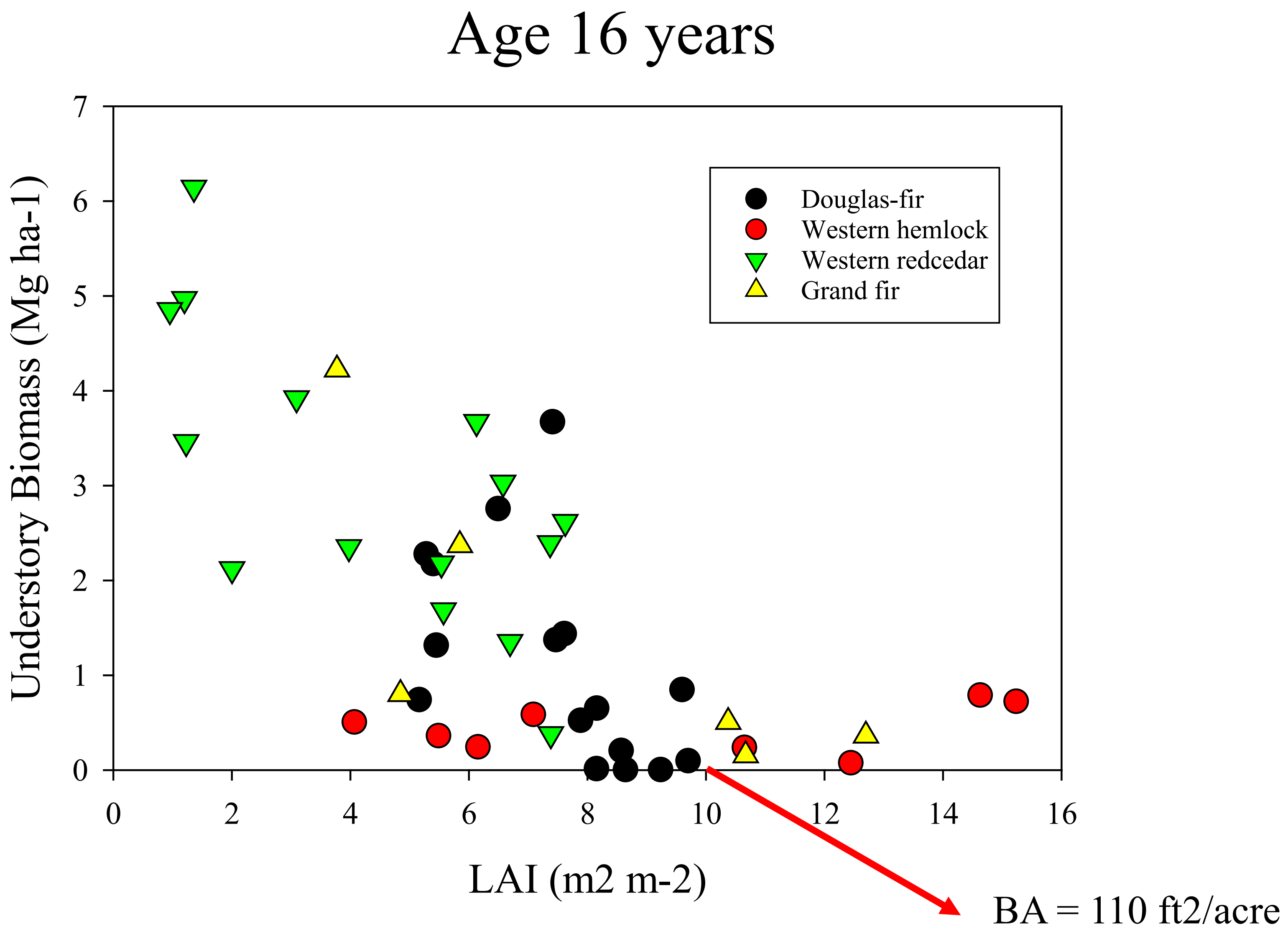
Results: Ecosystem Biomass (Mg ha^{-1})

Western hemlock at age 18 years

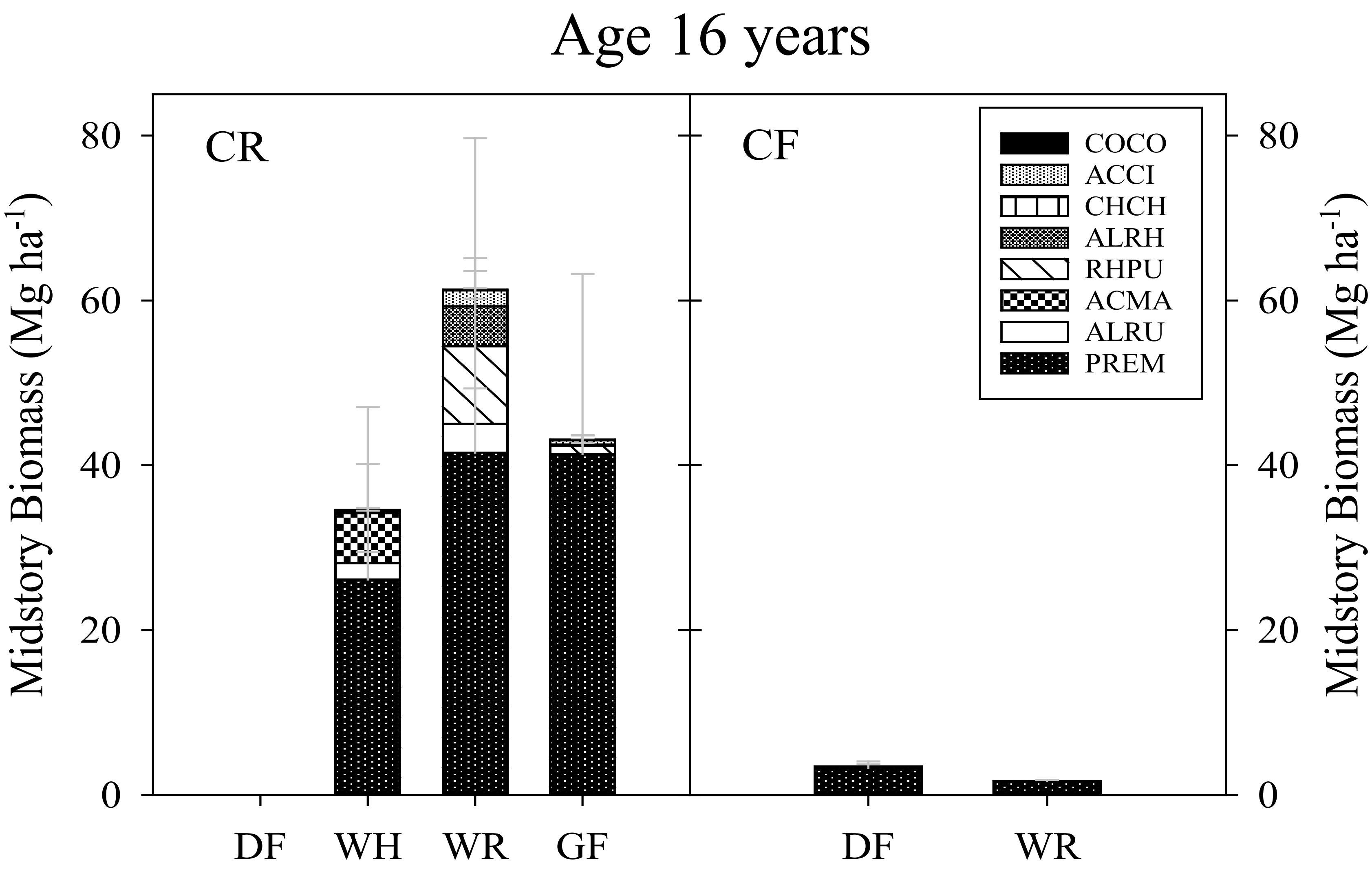
Sustained VM

No VM

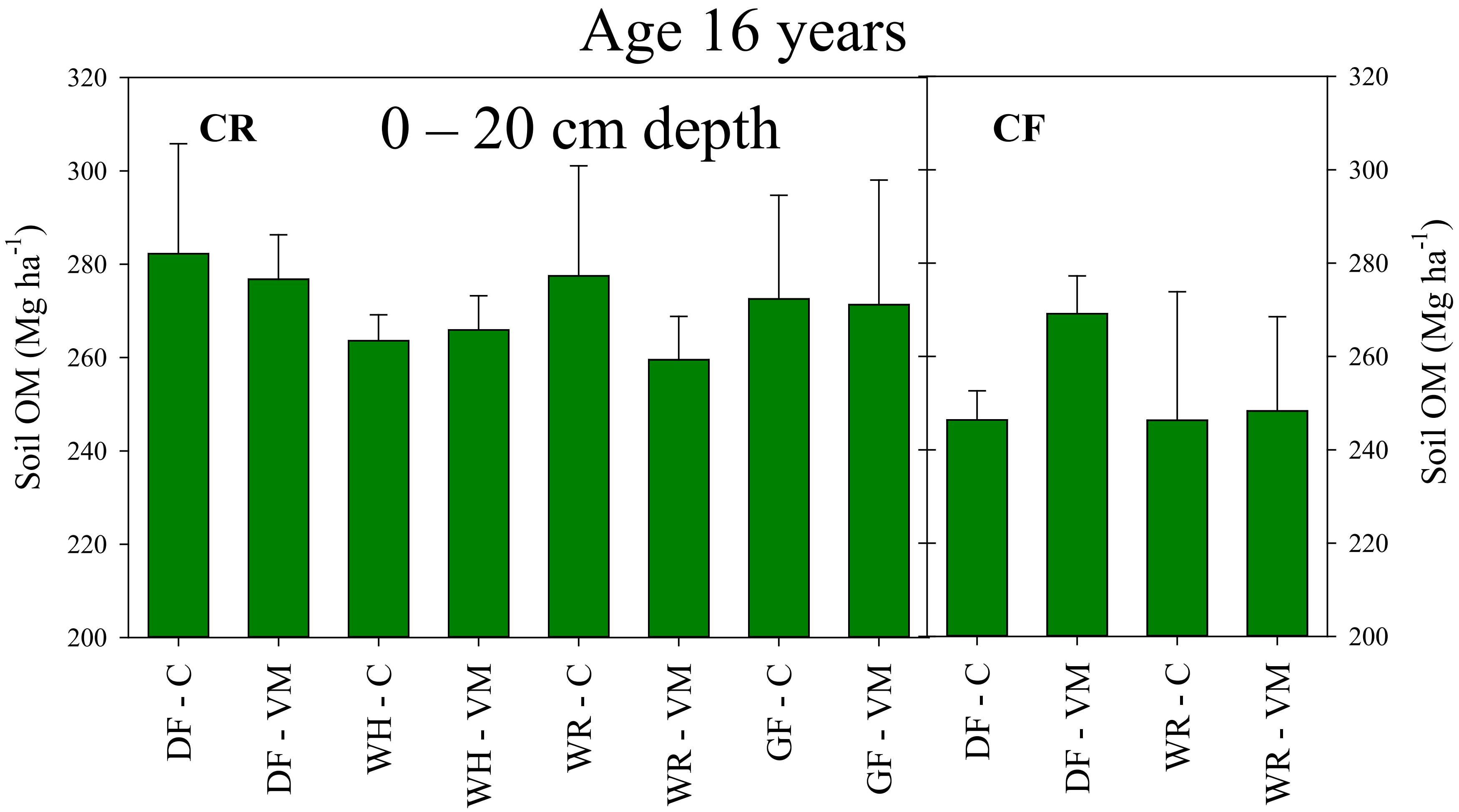
Results: Ecosystem Biomass (Mg ha^{-1})



Results: Midstory Biomass (Mg ha^{-1})

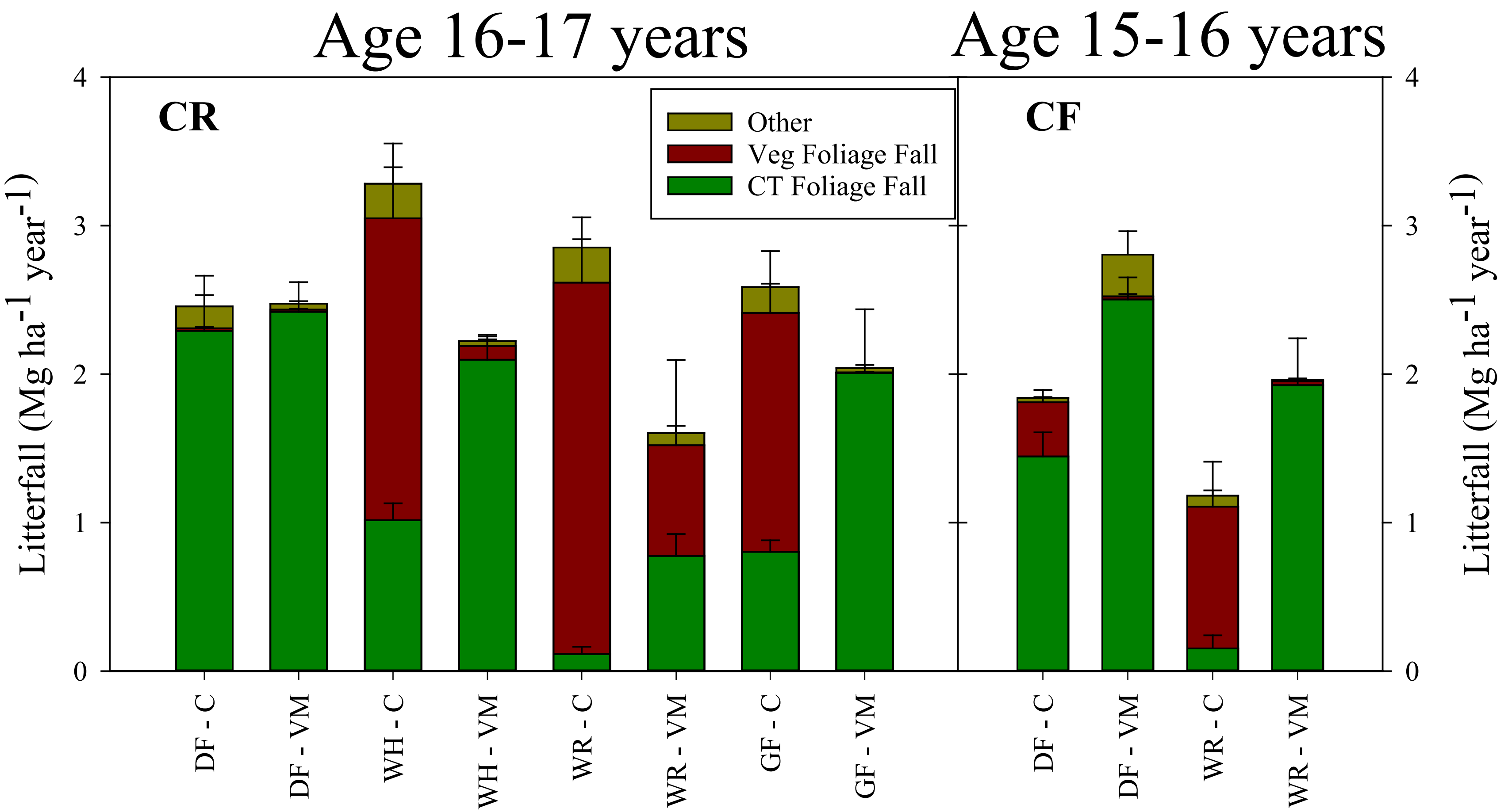


Results: Soil Organic Matter (Mg ha^{-1})



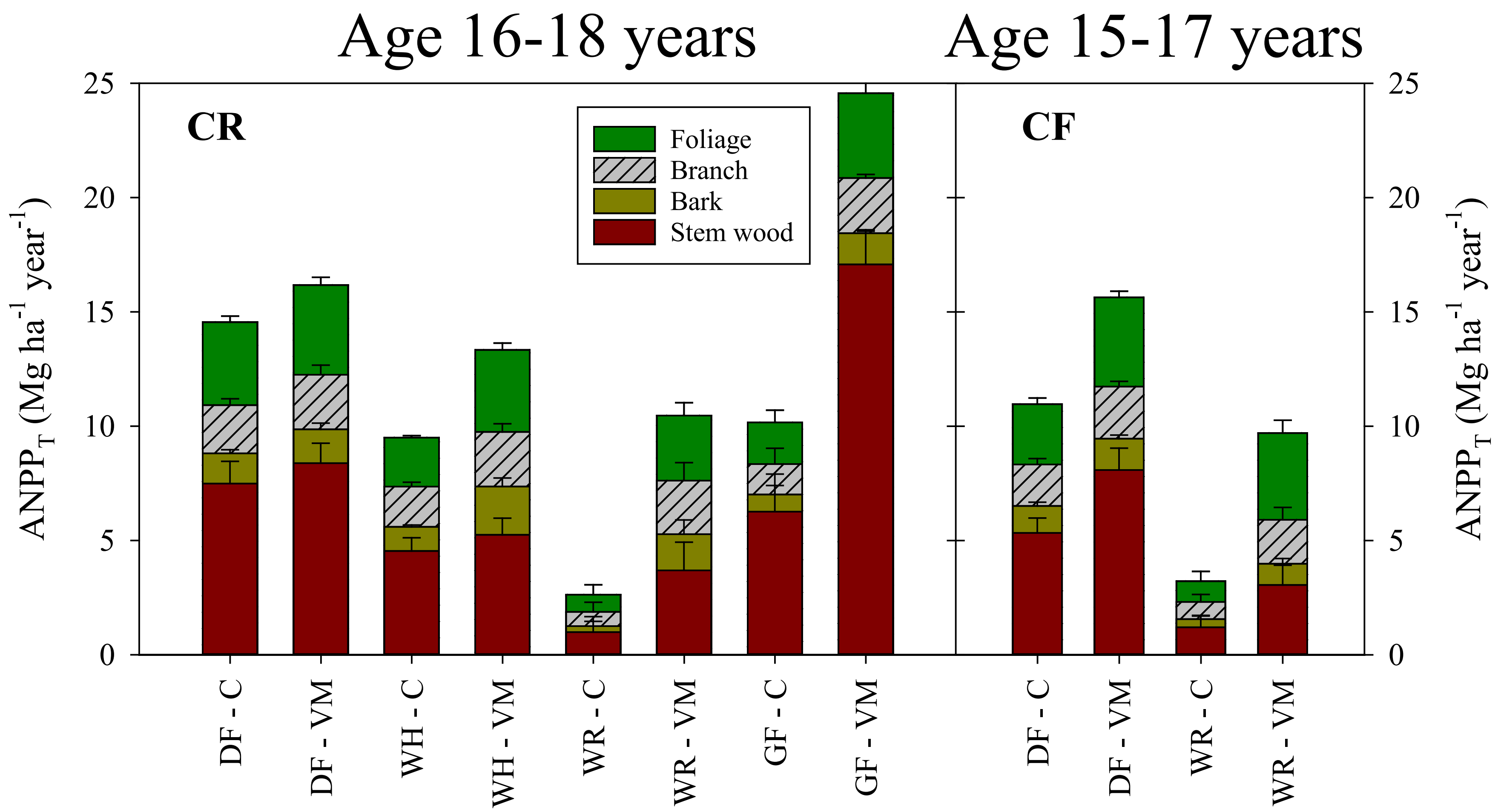
Site	**CR**				**CF**	
Species	**DF**	**WH**	**WR**	**GF**	**DF**	**WR**
P > F*	0.836	0.81	0.518	0.974	0.067	0.955

Results: Needlefall (Mg ha^{-1} year^{-1})



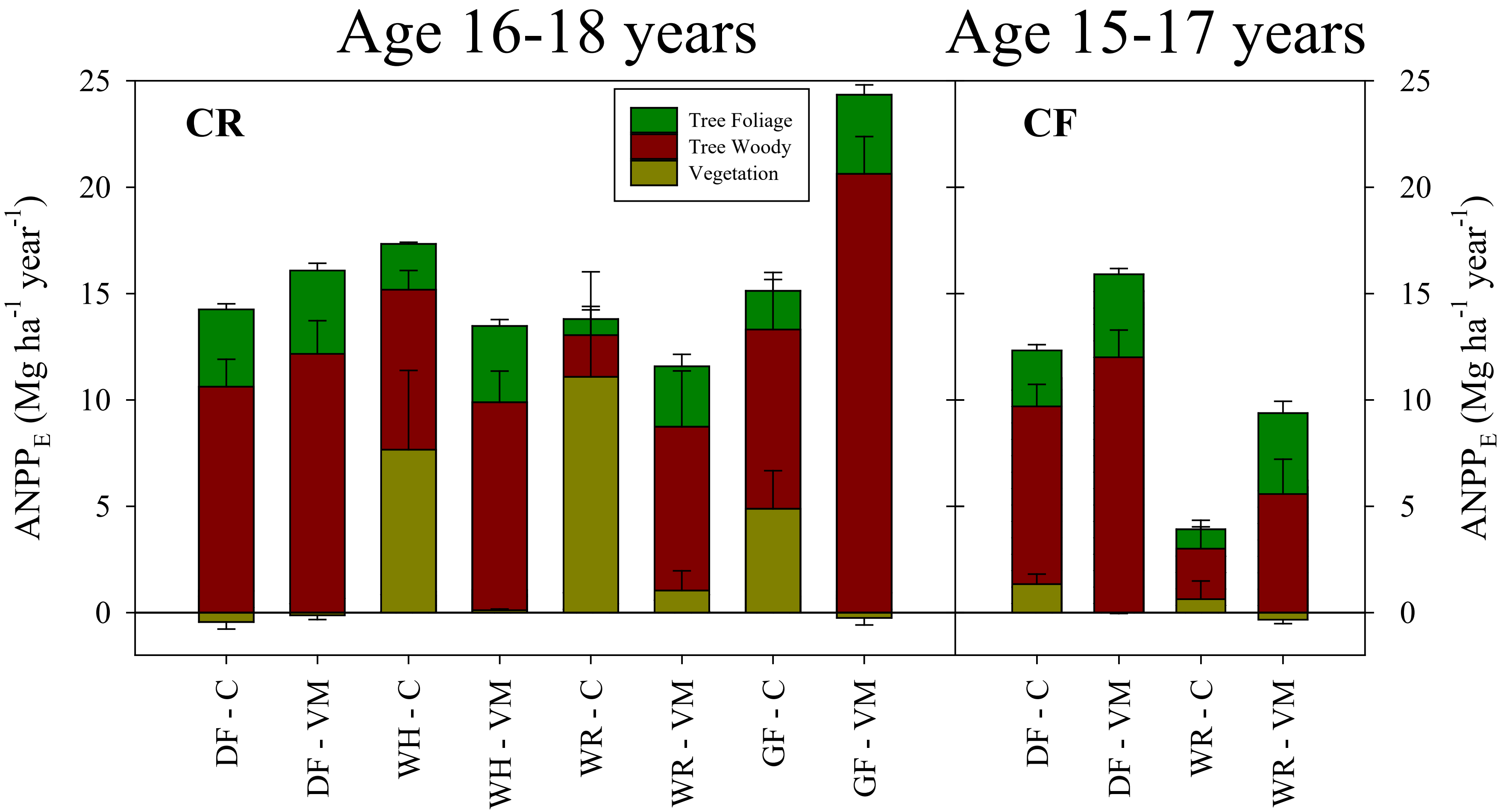
	CR				CF	
Trait	DF	WH	WR	GF	DF	WR
Crop Tree Foliage Fall	0.766	**0.001**	**0.008**	**0.026**	**0.002**	**0.001**
Total LF	0.996	**0.034**	0.114	0.329	**0.012**	0.178

Results: Crop Tree NPP (Mg ha^{-1} year^{-1})



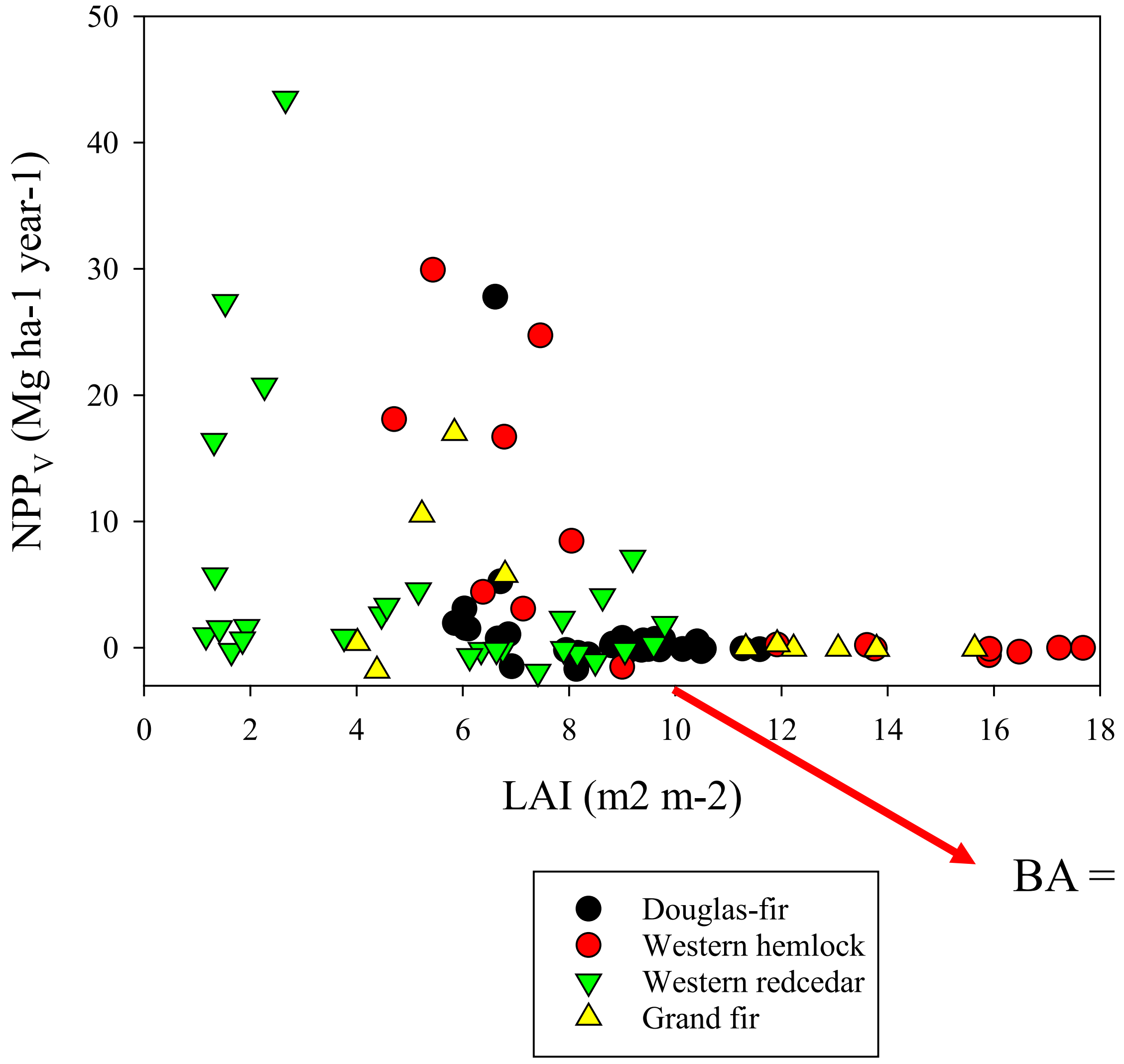
Site	**CR**				**CF**	
Species	**DF**	**WH**	**WR**	**GF**	**DF**	**WR**
P > F*	0.279	**0.031**	**0.028**	**0.036**	**0.022**	**0.008**

Results: Ecosystem NPP (Mg ha^{-1} year^{-1})



Site	**CR**				**CF**	
Species	**DF**	**WH**	**WR**	**GF**	**DF**	**WR**
P > F*	0.252	0.966	0.369	0.263	**0.061**	**0.024**

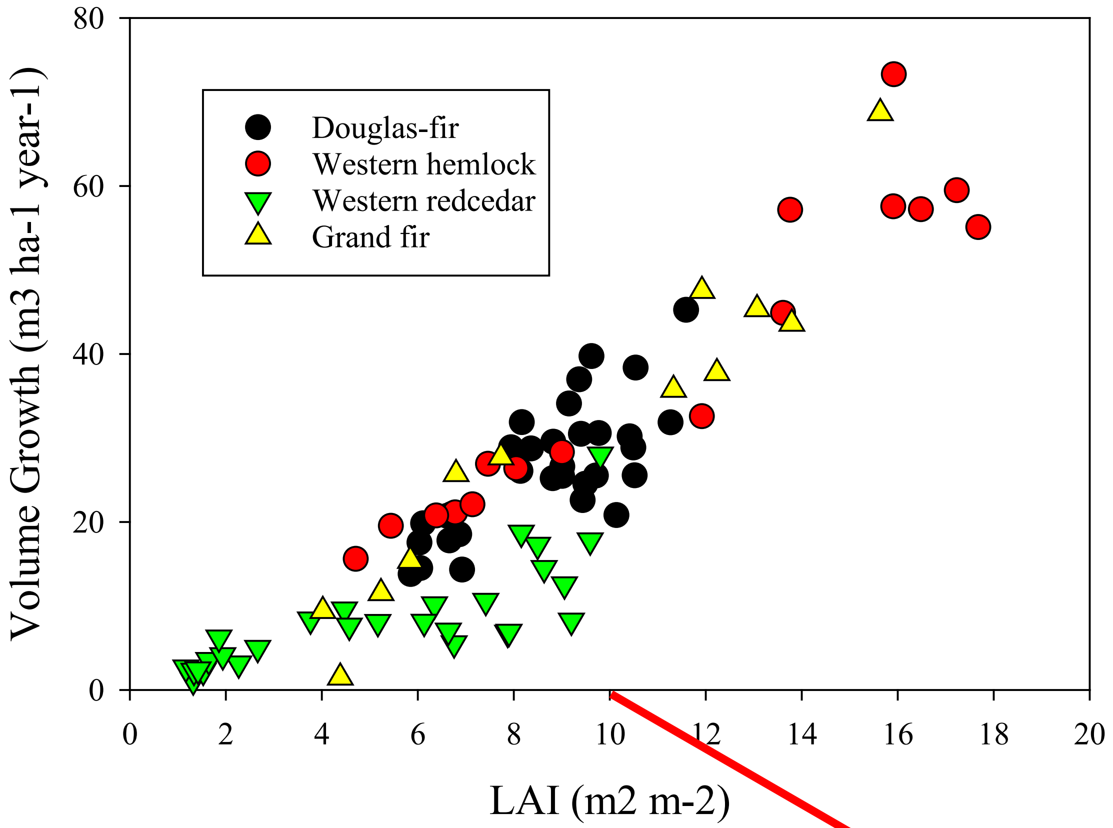
Results: Ecosystem NPP (Mg ha^{-1} year^{-1})



BA = 110 ft2/acre

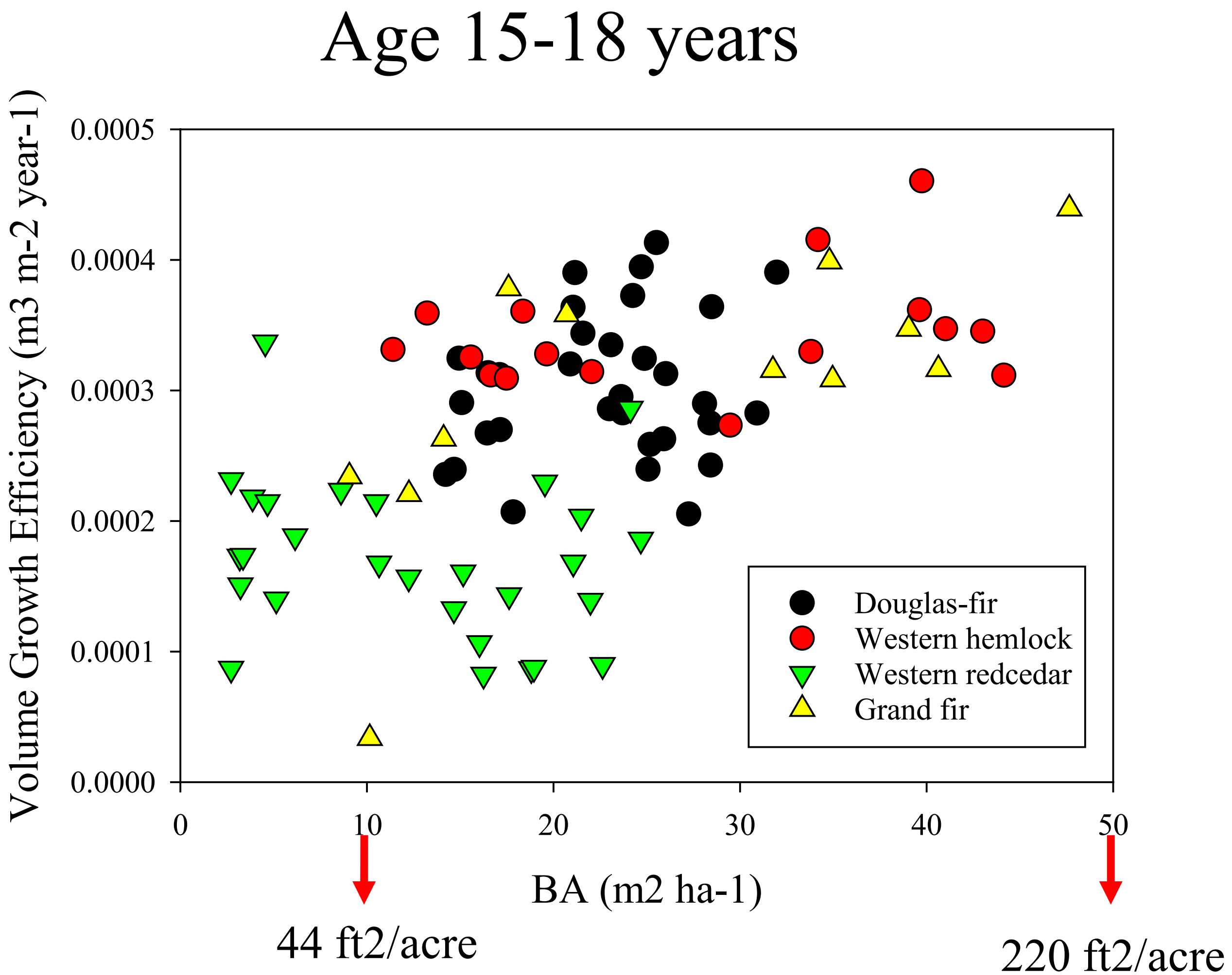
Results: Growth Efficiency

Age 15-18 years

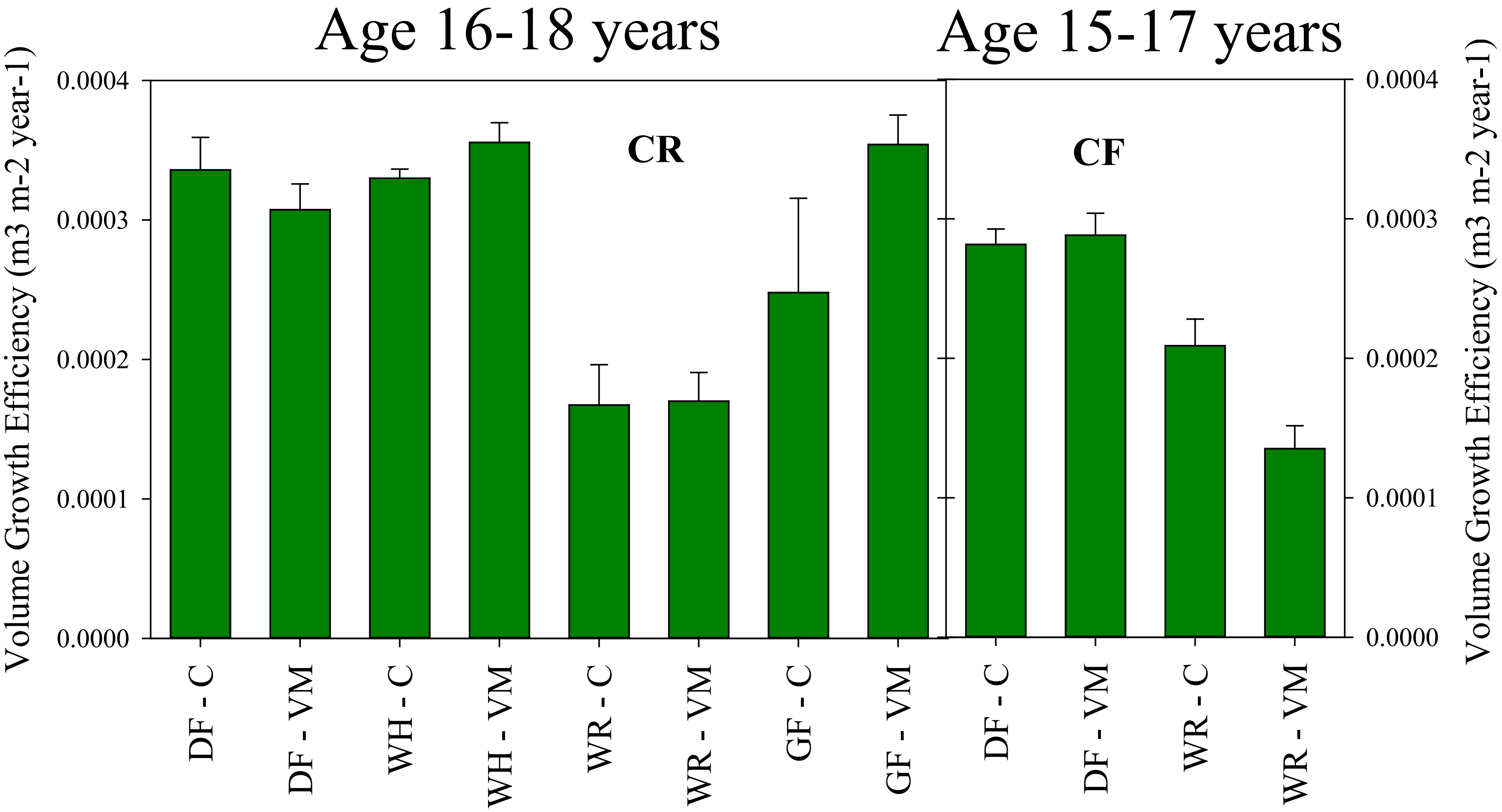


BA = 110 ft2/acre

Results: Growth Efficiency



Results: Growth Efficiency: Volume



Site	CR				CF	
Species	**DF**	**WH**	**WR**	**GF**	**DF**	**WR**
P > F*	0.375	0.149	0.943	0.209	0.743	**0.027**

Conclusions: Biomass Stock

- For all species at both sites, FVM treatments applied during the first five years of stand establishment increased LAI and biomass of crop trees at age 16 (11 years after treatment ended).

- At the CR site there was no difference in total ecosystem biomass between C and VM plots due to a robust hardwood midstory developing in C plots.
- At the CF site there was a large gain in total ecosystem biomass in response to VM treatments. The midstory was a small component of ecosystem biomass at this site.

- Soil organic mater content was not affected by VM treatments.

Conclusions: NPP (Productivity)

- Sustained FVM produced long-term increment in crop tree 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.

Conclusions: NPP (Productivity)

- Single-species planted stands were highly efficient in capturing site resources (light, nutrients and water).

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

Conclusions: GE (Growth Efficiency)

- Western red cedar showed lower volume growth efficiency (VGE), as allocates proportionally more growth to foliage than other conifers being compared.

- FVM treatments did not affect VGE at the CR site, but reduced it for WRC at the CF site.

Incoming Research

- Spp x FVM x Site Effects on:
  - Nutrient Stock (Ongoing….)
  - Water Use and Water Use Efficiency (Near future….$$)

Further Reading

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Keywords: Douglas-fir; western hemlock; western redcedar; grand fir; above ground biomass functions; leaf area index; intensive silviculture; stand productivity; carbon sequestration

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ABSTRACT

Silvicultural treatments applied during the early stages of stand development can have long-lasting impacts on forest ecosystem structure. Forest vegetation management (VM) is an important component of many reforestation programs and although several studies have demonstrated the benefits of VM on planted conifer growth and survival, few reports have been published on the long-term effects of VM treatments on total ecosystem biomass accumulation. In this study we assessed the effects of two contrasting VM treatments on total tree and ecosystem biomass stock for Douglas-fir, western hemlock, western redcedar, and grand fir growing in Oregon's central Coast Range (CR) and Douglas-fir and western redcedar growing in Oregon's Cascade foothills (CF). The assessments were made at age 16 years, 11 years after treatment application ended. The study contained two vegetation management treatments: control (C) and vegetation management (VM). Both the C and VM plots received a pre-planting herbicide site preparation treatment. The VM plots had, additionally, sustained vegetation control using herbicides during the first 5 years after planting. At age 16 years, at the CR site, the VM treatment increased the biomass stock of crop trees by 26.5, 91.2, 44.7, and 96.1 Mg ha^{-1} for Douglas-fir, western hemlock, western redcedar, and grand fir, respectively. At the same age, at the CF site, the VM treatment increased crop tree biomass stock by 48.1 Mg ha^{-1} for Douglas-fir and 42.2 Mg ha^{-1} for western redcedar. When other ecosystem components were considered, however, total ecosystem biomass did not differ between C and VM treated plots for western hemlock, western redcedar and grand fir at the CR site largely due to the development of an abundant hardwood midstory. On the other hand, VM treatments increased the ecosystem biomass stock of Douglas-fir and western redcedar at the site with a low abundance of hardwood midstory (CF site). Midstory biomass of C plots at the CR site averaged 52.9, 64.7, and 36.0 Mg ha^{-1}, for western hemlock, western redcedar, and grand fir, respectively. At the CF site, midstory biomass of C plots averaged 1.2 and 5.9 Mg ha^{-1}, for Douglas-fir and western redcedar, respectively. The results of this study demonstrate that sustained VM treatments during the first 5 years of stand establishment increases the biomass stock of crop trees, directing site resources towards planted crop trees.

1. Introduction

Silviculturists can influence the trajectory and rate of forest development using several different management techniques. The use of artificial regeneration (planted seedlings) and forest vegetation management treatments are two important management strategies used in the United States Pacific Northwest (PNW) to successfully establish healthy and highly productive conifer plantations. When establishing a new stand, forest managers must select a crop tree species and make vegetation management decisions that may have long-term impacts on stand condition and growth. Understanding how these decisions impact forest ecosystems can help silviculturists to develop management strategies for diverse objectives such as timber production, forest restoration, or carbon sequestration.

Forest vegetation management (VM) is an integral part of reforestation in the PNW. After a harvest, site resources become readily available and early seral species quickly use these resources to occupy the site. This can create intense competition with crop trees, especially during the dry summers typical to the region (Dinger and Rose, 2009). Research has shown that controlling competing vegetation increases the growth of planted conifer species in the PNW (Newton and Preest, 1988, Rose et al., 2006; Maguire et al., 2009). The most effective VM method in the PNW, and in other parts of the world, has been herbicide use due to its low cost, high efficacy, and associated improvements in seedling growth and survival (Ketchum et al., 1999, Rose et al., 2006, Maguire et al., 2009).

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Effects of Vegetation Management on Wood Properties and Plant Water Relations of Four Conifer Species in the Pacific Northwest of the USA

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Abstract: In plantation forests, competition from unwanted vegetation may reduce survival and negatively impact tree growth. The goal of this study was to examine the influence of vegetation management treatments on plant water relations and wood properties. Control trees (no treatment) were compared to trees subjected to post-planting competing vegetation control for five consecutive years after planting. Four conifer species (Douglas-fir, western hemlock, western redcedar, and grand fir) were studied on two different sites in western Oregon, USA. Carbon isotope (^{13}C) analysis was used to study intrinsic water use efficiency (iWUE) and X-ray densitometry was used to measure specific gravity, ring width, and latewood percent. We found a significant interaction between vegetation management treatment and wood ring (growing season) in iWUE for Douglas-fir. There was little effect of vegetation management treatment on ring specific gravity for all species. Only western redcedar growing at a central Coast Range site showed increased ring specific gravity under sustained competing vegetation control. When growing under conditions of sustained control of competing vegetation, western redcedar at a central Coast Range site had a significant increase in earlywood specific gravity, while Douglas-fir at a Cascade Foothills site had a significant decrease in latewood specific gravity. Western redcedar and grand fir had a significant interaction-effect on its latewood percentage, with treatment trees having a higher latewood percentage than control trees after ring 8. Further, Douglas-fir and western hemlock had a significant increase in ring, earlywood, and latewood area with treatment, and grand fir had a significant interaction-effect of treatment × ring for ring, earlywood, and latewood area. This study indicates that, for conifer trees growing under sustained vegetation control, growth gains could be achieved without compromising wood properties. However, if harvested at a target diameter, these trees will have a larger proportion of low quality corewood compared to trees from conventionally managed stands.

Keywords: competing vegetation control; intensive silviculture; wood specific gravity; carbon isotope discrimination: water use efficiency; Douglas-fir; grand fir; western hemlock; western redcedar

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