Ecophysiology and Vegetation Management: Understanding Treatment Responses

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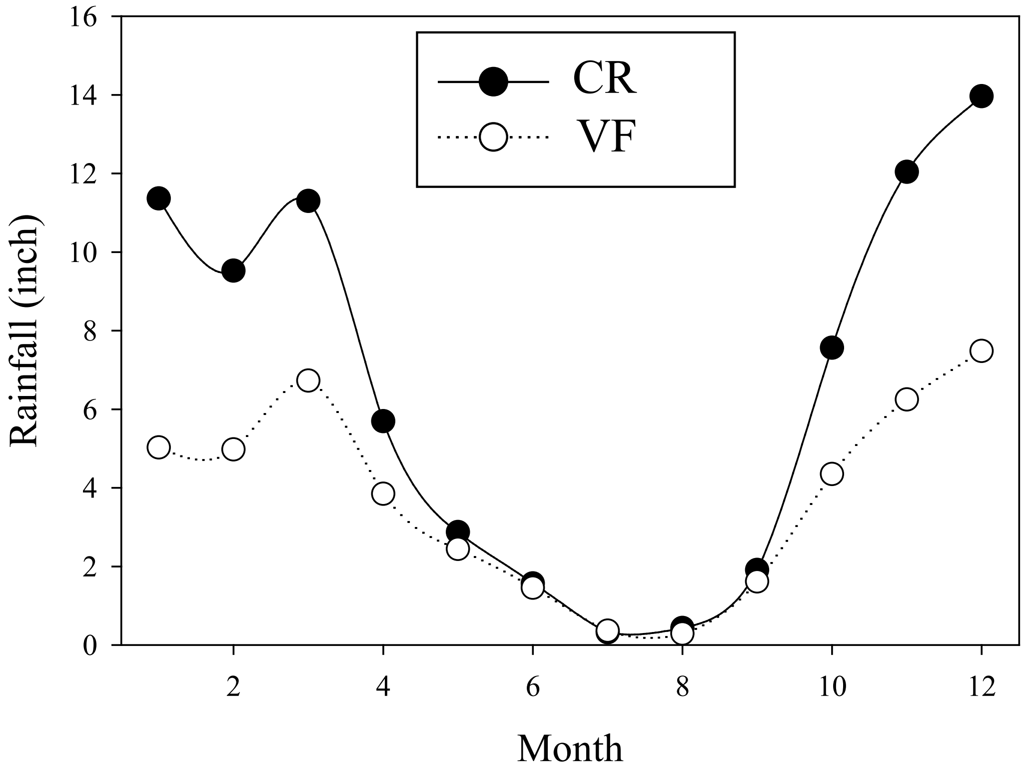
Background

Ecophysiology: "The study of the physiological mechanisms by which organisms cope with their environments" – Lambers et al. 2008

- How do plants respond to changing environmental conditions? (soil moisture, temperature, vapor pressure deficit, etc.)

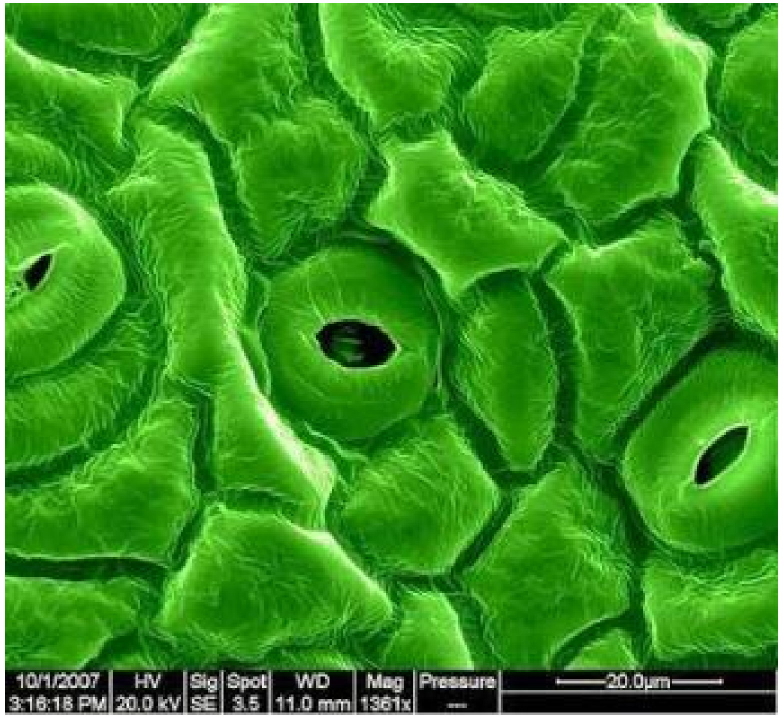


In the context of reforestation in the PNW we often focus on tree seedling water relations

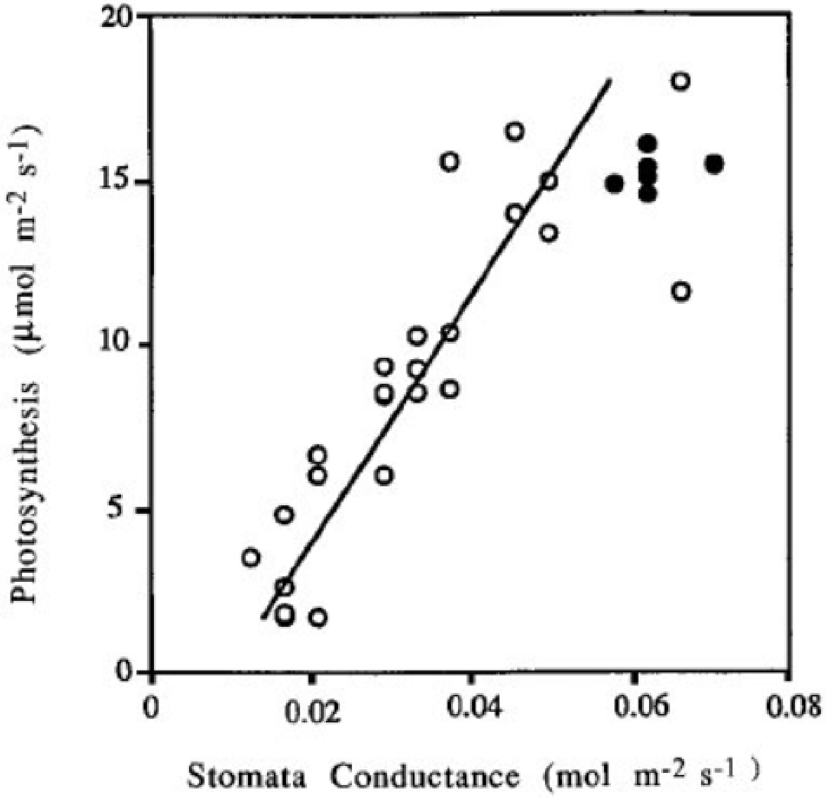
Carbon Gain vs Water Loss

Plants are constantly facing a **trade off** between **carbon gain** and **water loss**:

- Gas exchange between the atmosphere and plant leaves is facilitated through **stomatal regulation**
- When stomata are open CO_2 diffuses into the leaf → photosynthesis → plant growth
- At the same time H_2O diffuses out of the leaf → reduces water availability
- The rate at which CO_2 diffuses into the leaf can limit photosynthetic rate → growth

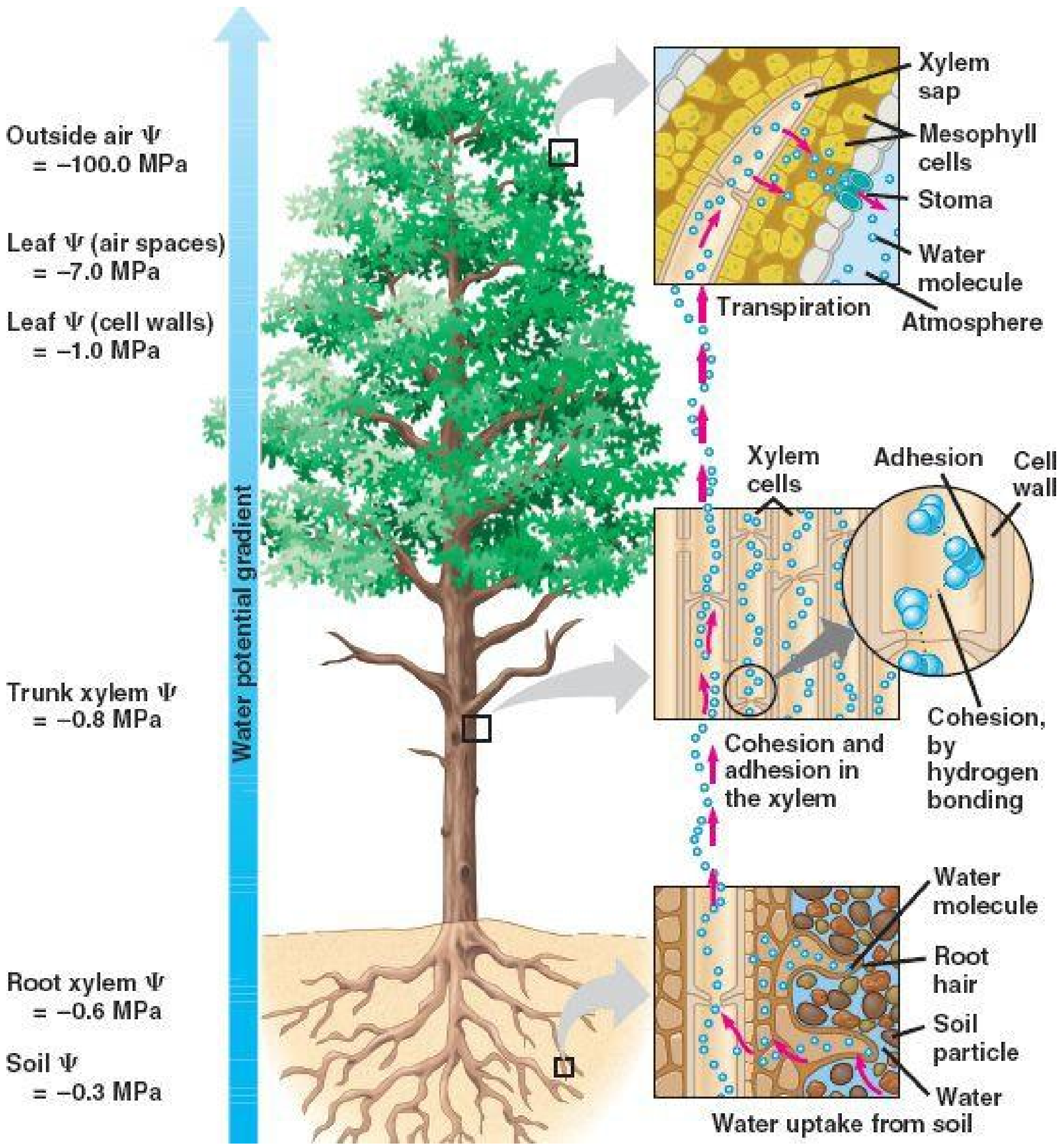


www.quora.com/Are-stomata-cellular-structures-If-yes-then-why-and-if-no-then-also-why



Waring and Silvester 1994

The Cohesion Tension Theory



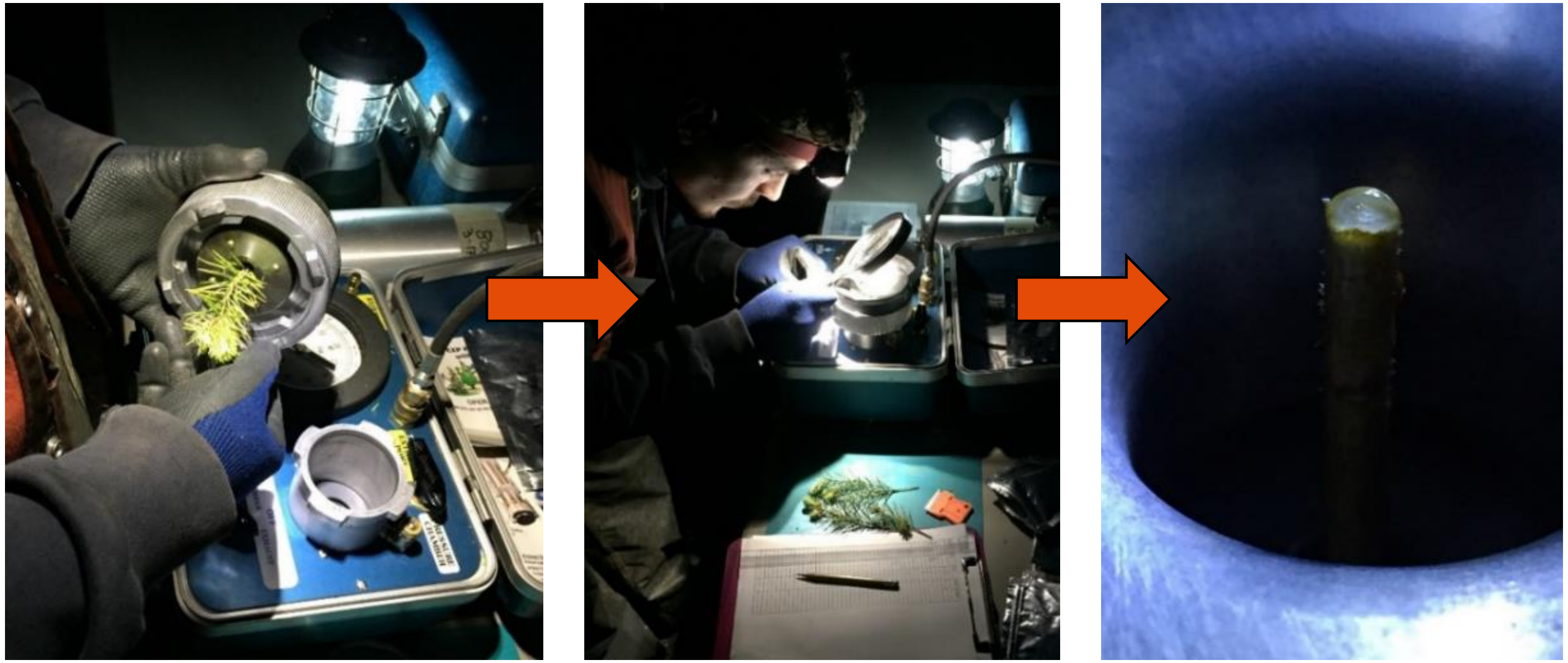
Water transport in plants is a passive process facilitated by large differences between soil and atmospheric water potential.

- Hydrogen bonding among water molecules creates an unbroken "chain" from plant roots to plant leaves
- As water evaporates from the leaves the "chain" is pulled up moving water through the plant
- If the difference between soil and leaf water potential becomes too great the "chain" of water can become broken (cavitation) → reduced hydraulic conductivity → Mortality
- Plants can regulate leaf water potential through stomatal regulation in order to avoid cavitation
- The rate of water loss (transpiration) depends on the difference between soil and atmospheric water potential (driving force), stomatal conductance, tree hydraulic conductivity and tree leaf area

Plant Water Stress: Predawn Water Potential

During the night, when stomata are closed, the tension in the “chain” of water within a plant comes into equilibrium with the soil water potential

Therefore measuring leaf water potential before dawn provides an index of soil moisture and seedling water stress.



Effects of Water Stress on Tree Seedlings

Reduced Growth

- Water stress limits tree growth by reducing stomatal conductance → reduces photosynthetic rate → reduces water and CO_2 available to the tree.

Mortality

- **Carbon starvation:** tree morality caused by a depletion of tree carbon reserves due to stomatal closure in response to drought.
- **Hydraulic failure:** tree morality caused by a failure of the water transportation system (extensive cavitation).

Ecophysiology and VM Research

The growth and survival of conifer seedlings in the PNW is significantly impacted by water stress:

- Prolonged summer drought
- Competition with vegetation

Understanding how VM treatments affect seedling water relations can help us to better understand observed crop tree responses to VM treatments:

- Why do VM treatment responses vary by site?
- How we can extrapolate observed responses to other sites?

CoSInE

Competition & Site Interactions Experiment

Study Rational

Vegetation management increases seedling survival and growth; however, the magnitude of this response is site specific and depends on:

- Crop tree species
- Understory community composition and abundance
- Type of vegetation management treatment applied
- Site climate conditions
- Site soil conditions
- Stock type planted

CoSInE Study Objectives

- Use **ecophysiology** to develop a **mechanistic** understanding of VM treatment responses in order to create a decision support tool to assist forest mangers.

- Develop a data network to develop a G&Y model for responses to FVM (CIPS)

The specific objectives are to determine the effect of FVM regime and site conditions on:

- understory vegetation biomass development
- seedling survival, productivity, and biomass development
- seasonal and long-term soil moisture and plant water use dynamics

CoSInE Study Methods

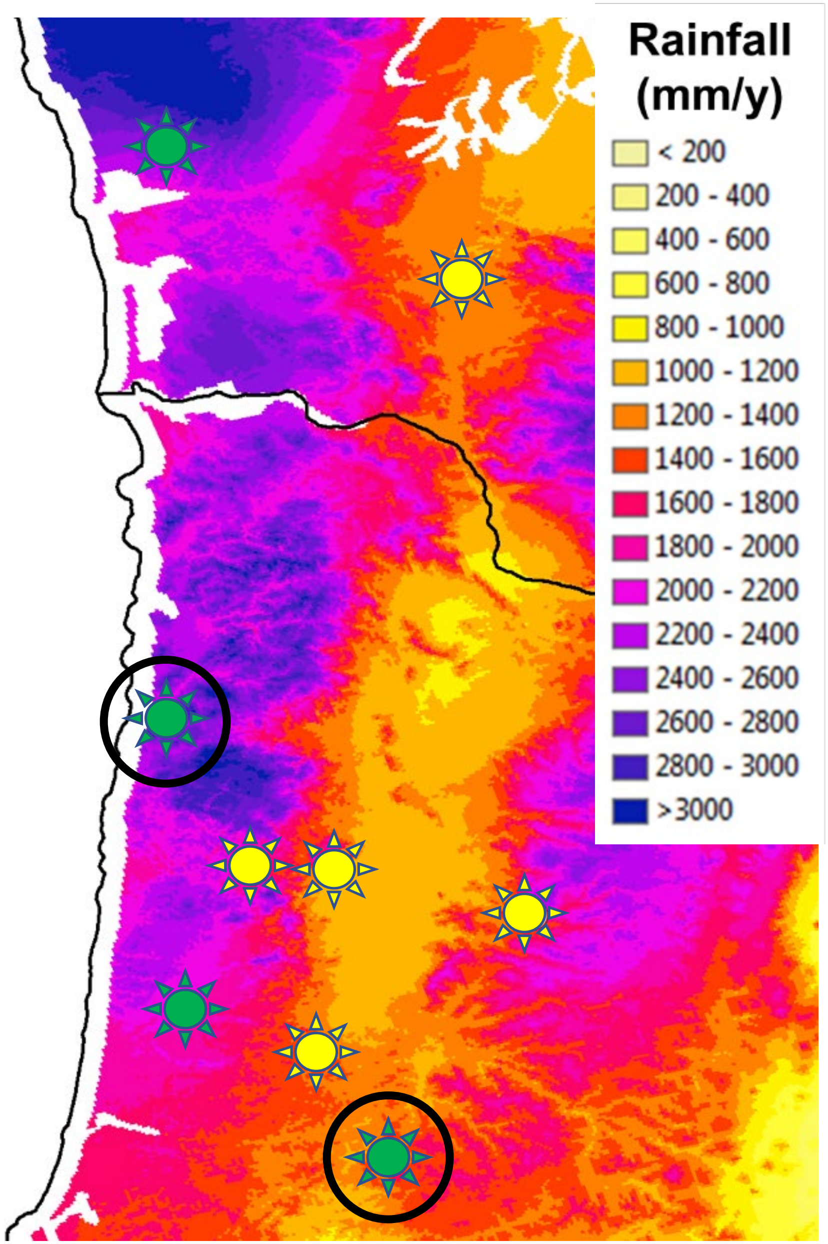
Evaluate the influence of a **common set of VM** treatments on conifer seedling survival, growth and ecophysiological responses **across a wide range of site** conditions. The treatment design is a 2 x 2 x 2 factorial.

Treatment Type	Fall site Preparation	Spring Release Growing Season 1	Spring Release Growing Season 2
1 (000)	0	0	0
2 (010)	0	1	0
3 (001)	0	0	1
4 (011)	0	1	1
5 (100)	1	0	0
6 (110)	1	1	0
7 (101)	1	0	1
8 (111)	1	1	1

Planting desnisty:10’ x 10’ (436 tree acre^{-1})
Treatment plots size: 120’ x 120’
Measurement plot size: 80’ x 80’ (64 measurement trees)

CoSInE Study Network

Study ID	Site Name	Crop Species	Rainfall (inches)	Temperature (°F)	Soil Sereis	Soils Type	WHC (mm)
CO101	Bulgogi	WH	104.7	50.2	Tolovana-Templeton	Silty loam	282
CO102	Whipple Hill	DF	50.7	51.4	Windygap	Silty loam	171
CO103	"Rayonier Site"	WH/DF	104.3	49.8	Lytell	Silty loam	208
CO104	River Ranch	DF	79.7	52.3	Blackly	Silty clay loam	172
CO201	Mac-Dunn	DF	59.6	51.8	Dixonville-Gellaty Complex	Silty clay loam	172
CO202	Boss Hog	DF	60.6	51.3	Honeygrove	Silty clay loam	159
CO203	Burntwoods	DF	77.8	51.3	Apt-McDuff	Silty clay loam	179
CO204	Mountain Sun	DF	49.9	50.9	Prather	Silty clay loam	154
CO205	7B PIECES	DF	56.5	52.3	Peavine	Silty clay loam	164



Nine Sites

Annual Rainfall: 49.9-104.7 in

Mean Annual Temperature: 49.8-52.3 °F

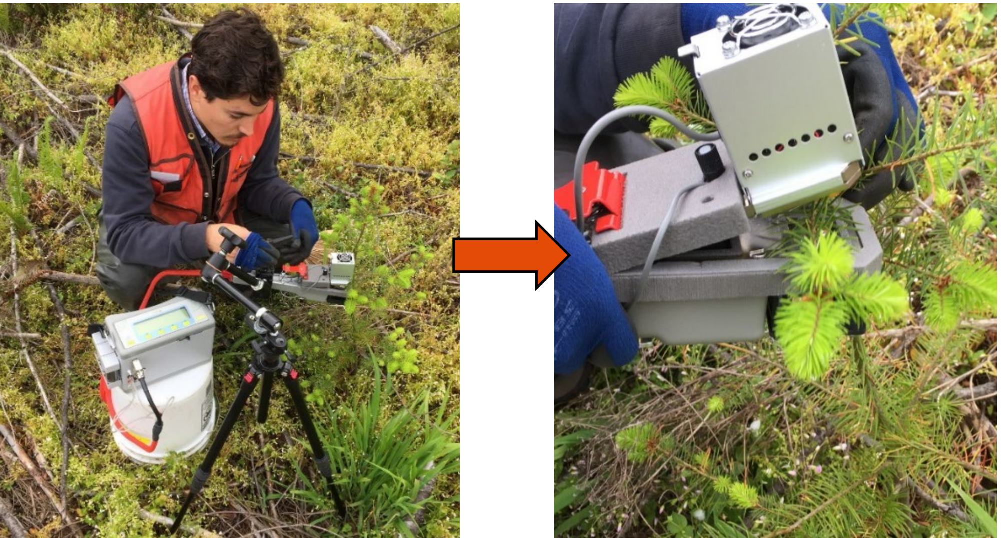
Soil Water Holding Capacity (top 1 m): 154-282 mm

Time Since Harvest: 3 – 13 months

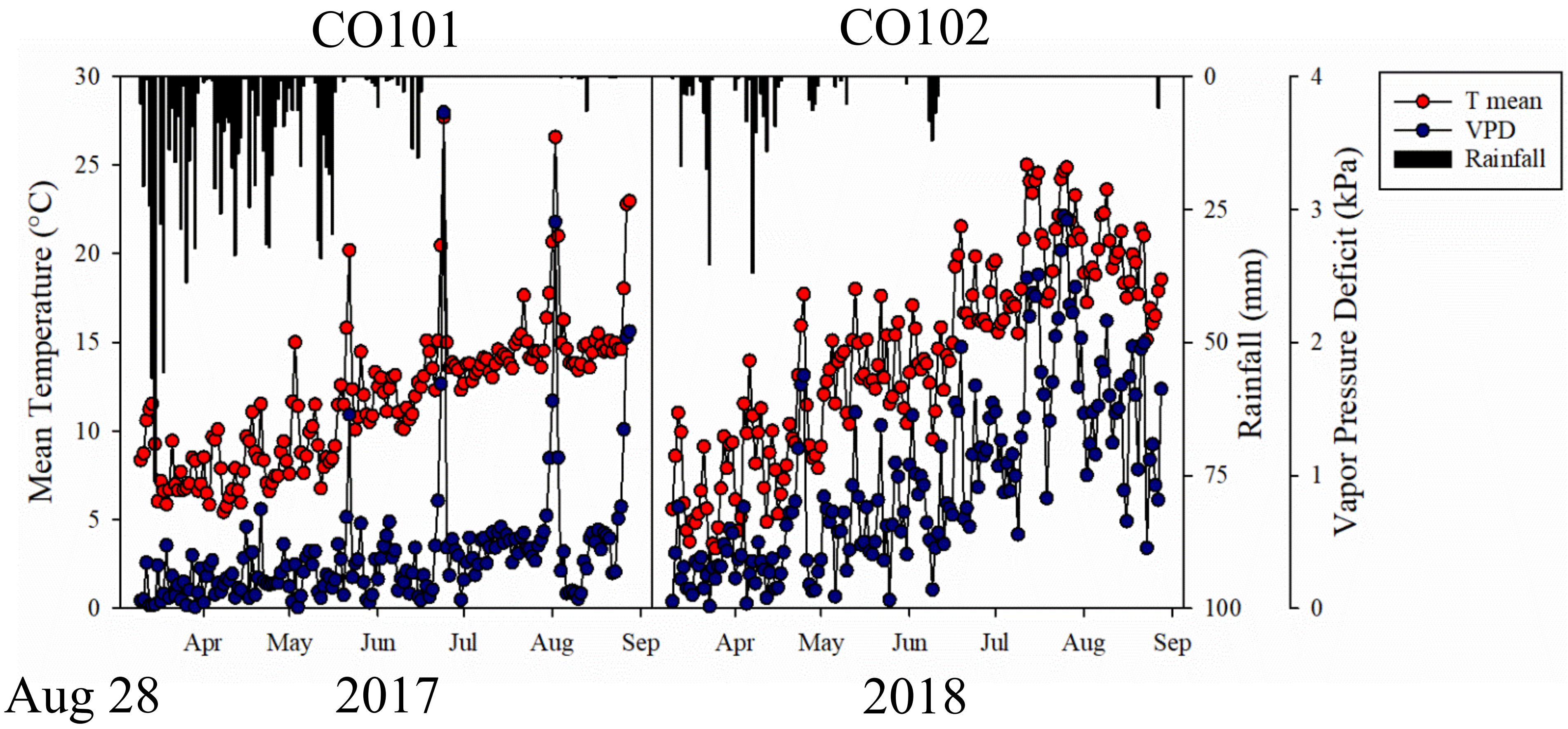
CoSInE Study Methods

<u>CoSInE Measurements</u>

- Weather
- Soil Moisture
- Vegetation cover/biomass
- Tree growth
- Tree predawn water potential
- Soil properties
- Additional Measurements: Stomatal conductance, chlorophyll fluorescence, xylem hydraulic conductivity.



Results: Weather conditions (Growing Season 1)

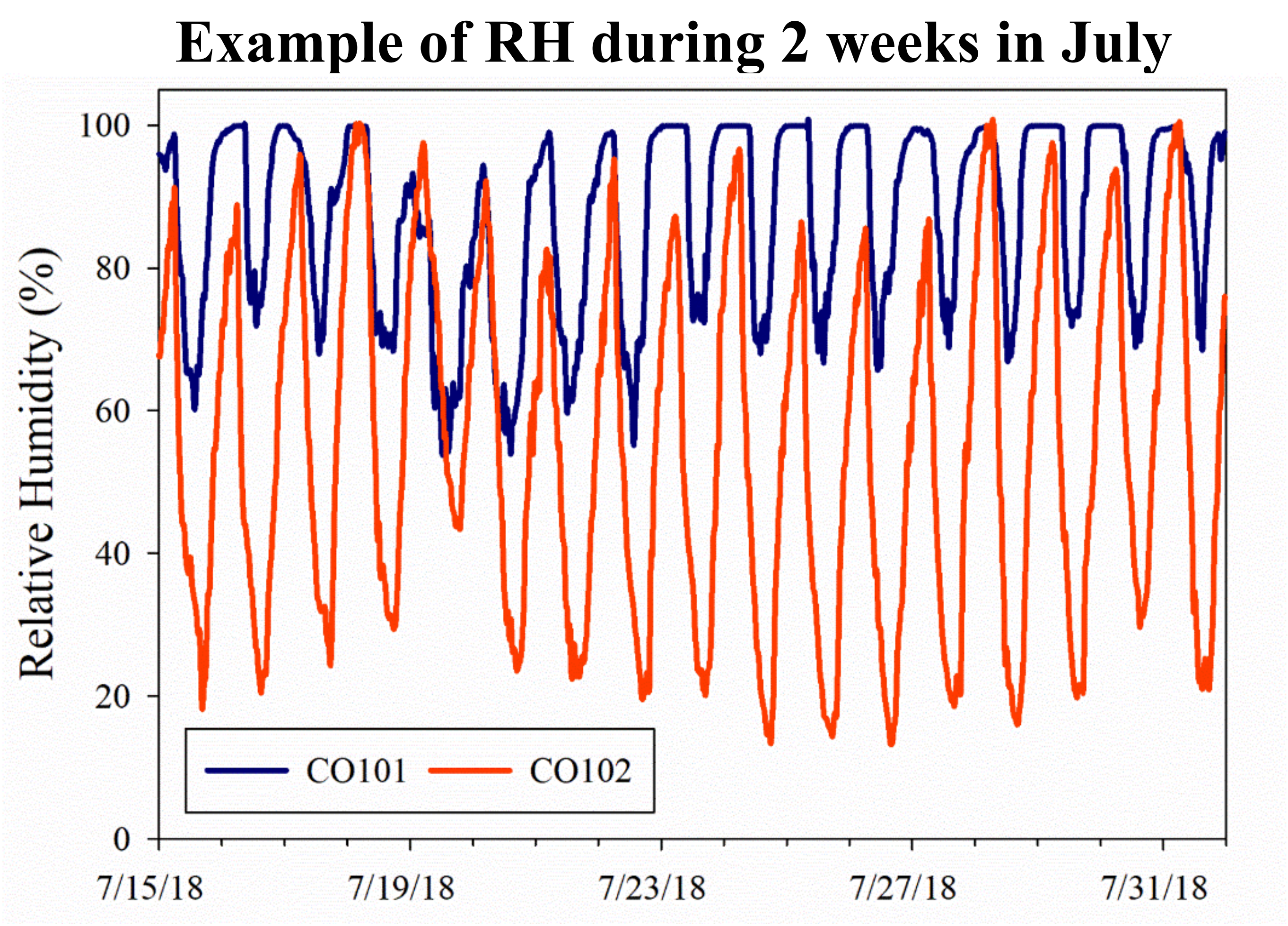


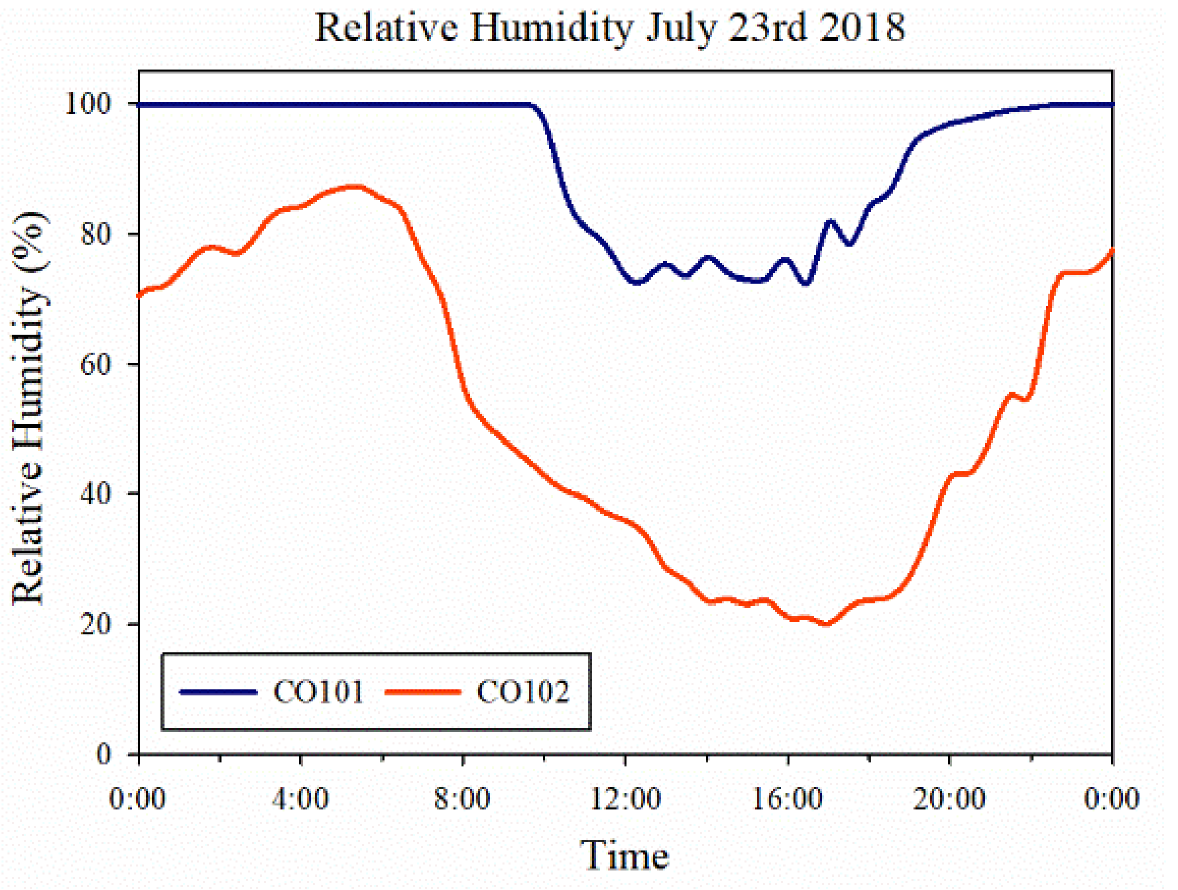
March 10 – Aug 28

Total rainfall: 1020 mm
Mean Temp: 14.6 ˚C
Mean VPD: 0.55 kPa

Total rainfall: 251 mm
Mean Temp: 18.4 ˚C
Mean VPD: 1.4 kPa

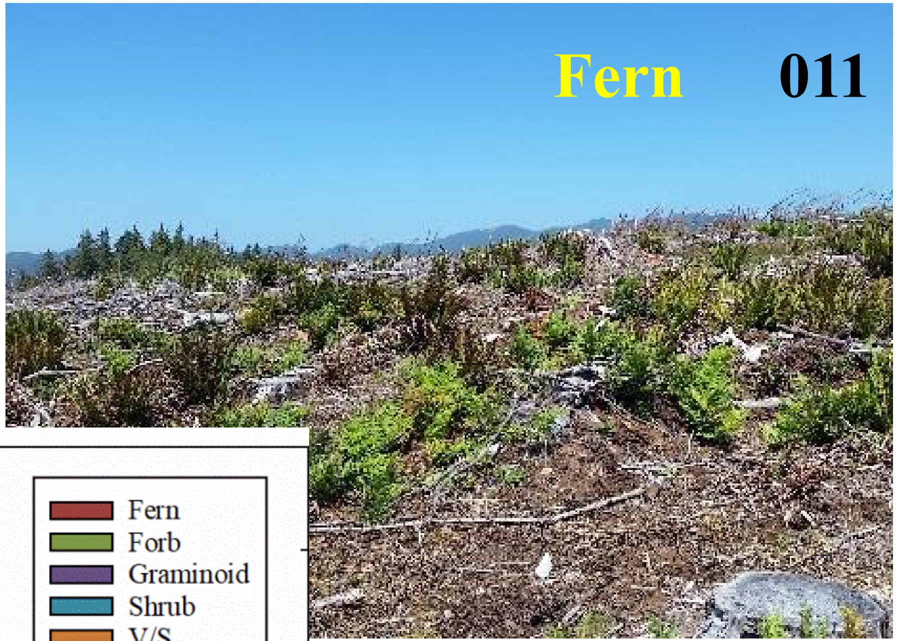
Results: Relative Humidity

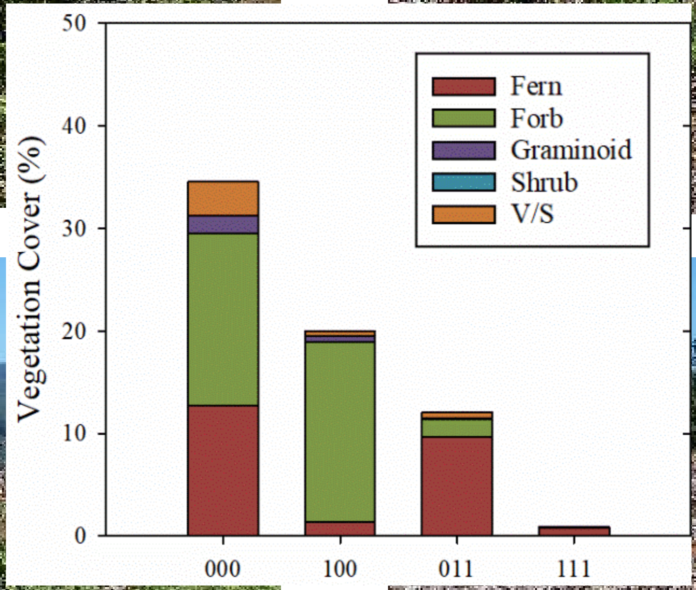


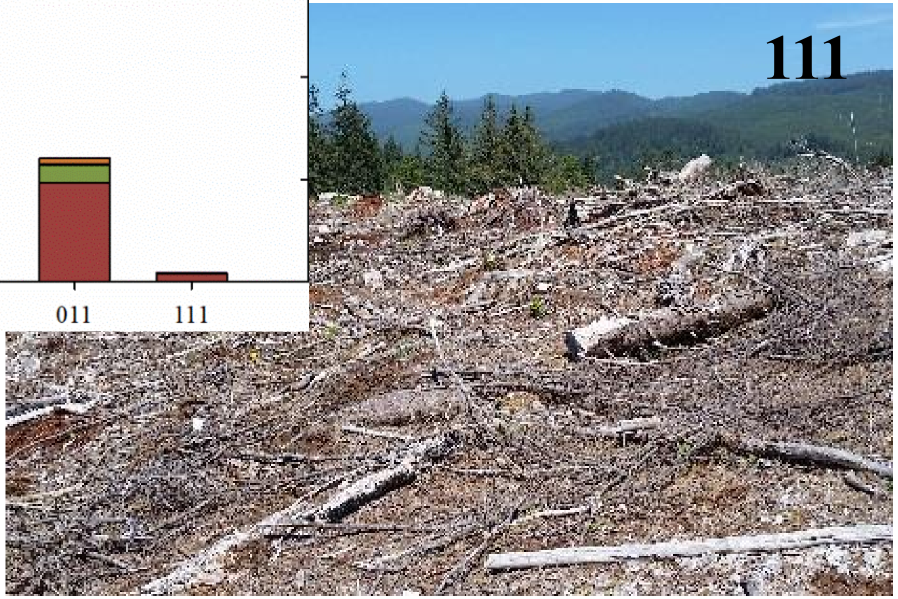


- CO101 Influence of the ocean
- CO102 higher evaporative demand

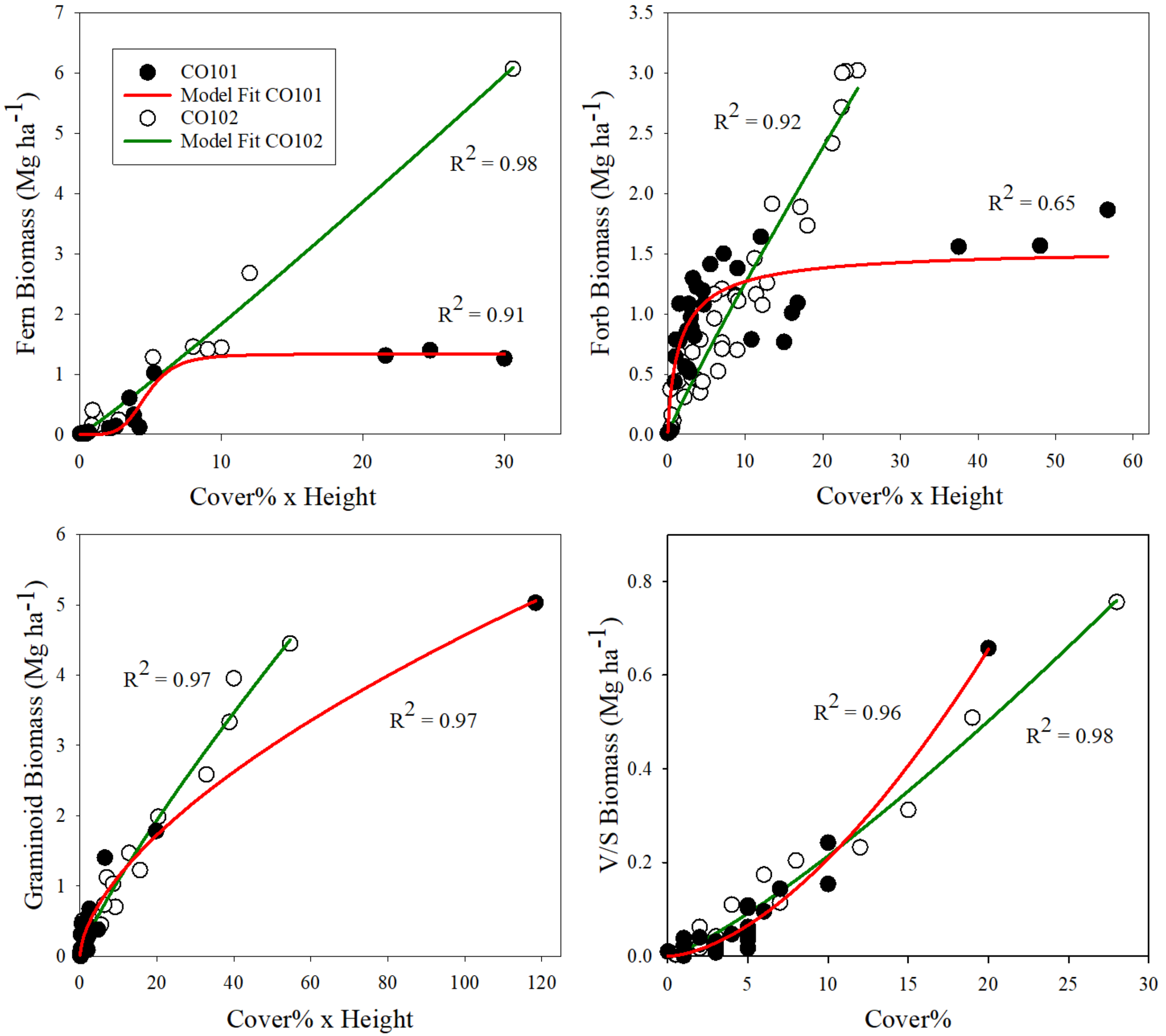
Results: Competing vegetation (Growing Season 1)



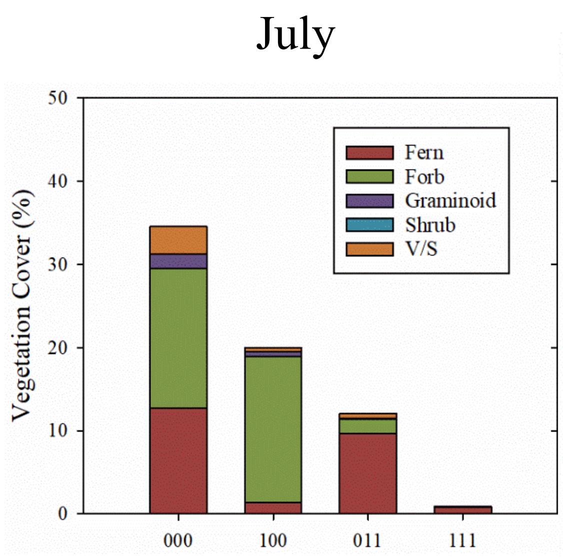


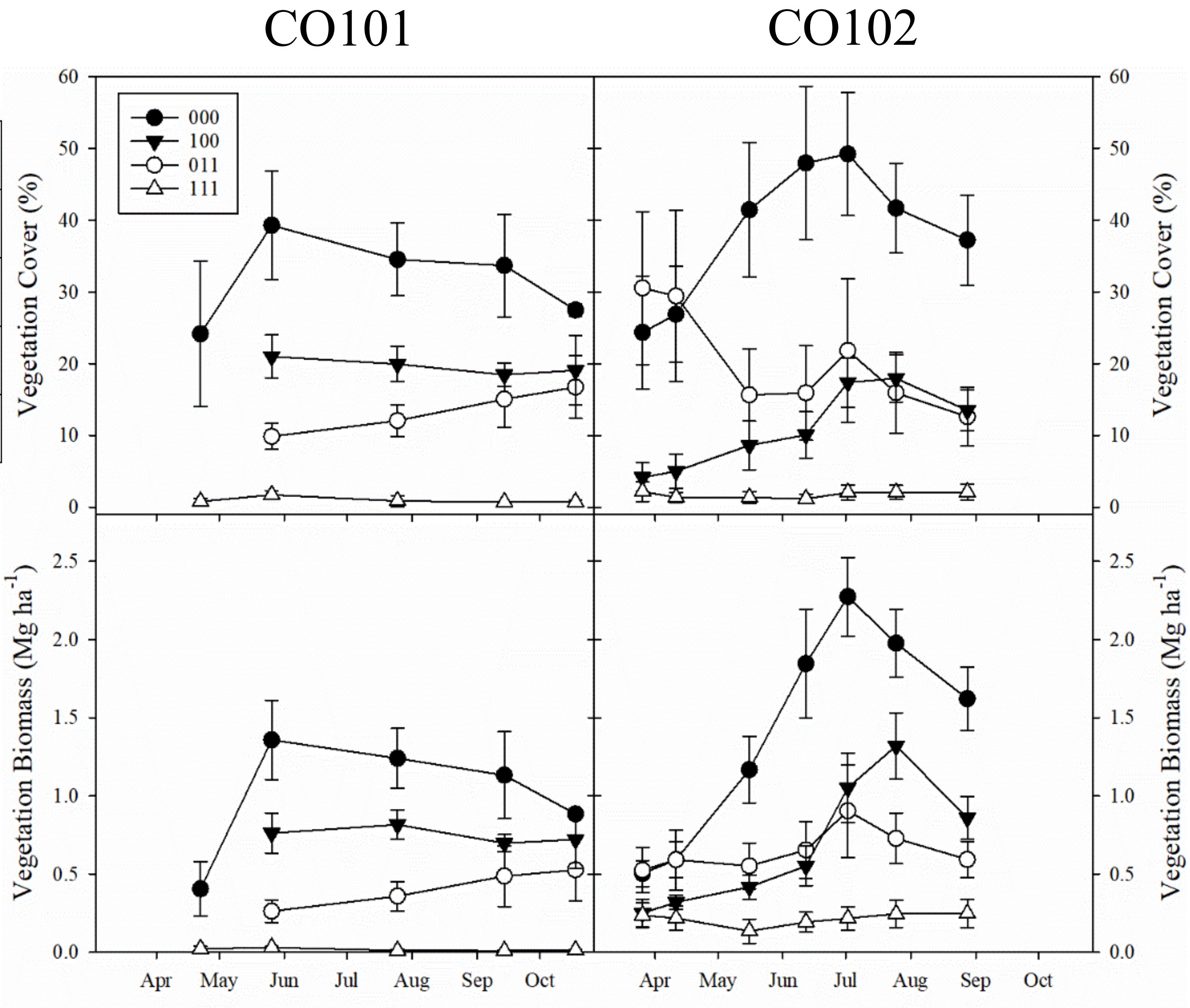


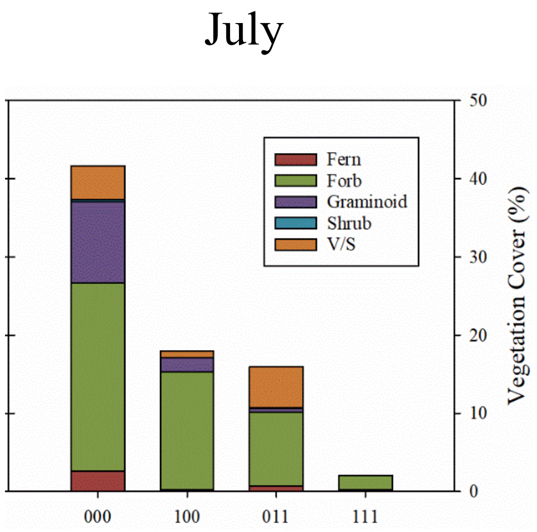
Results: Vegetation Biomass



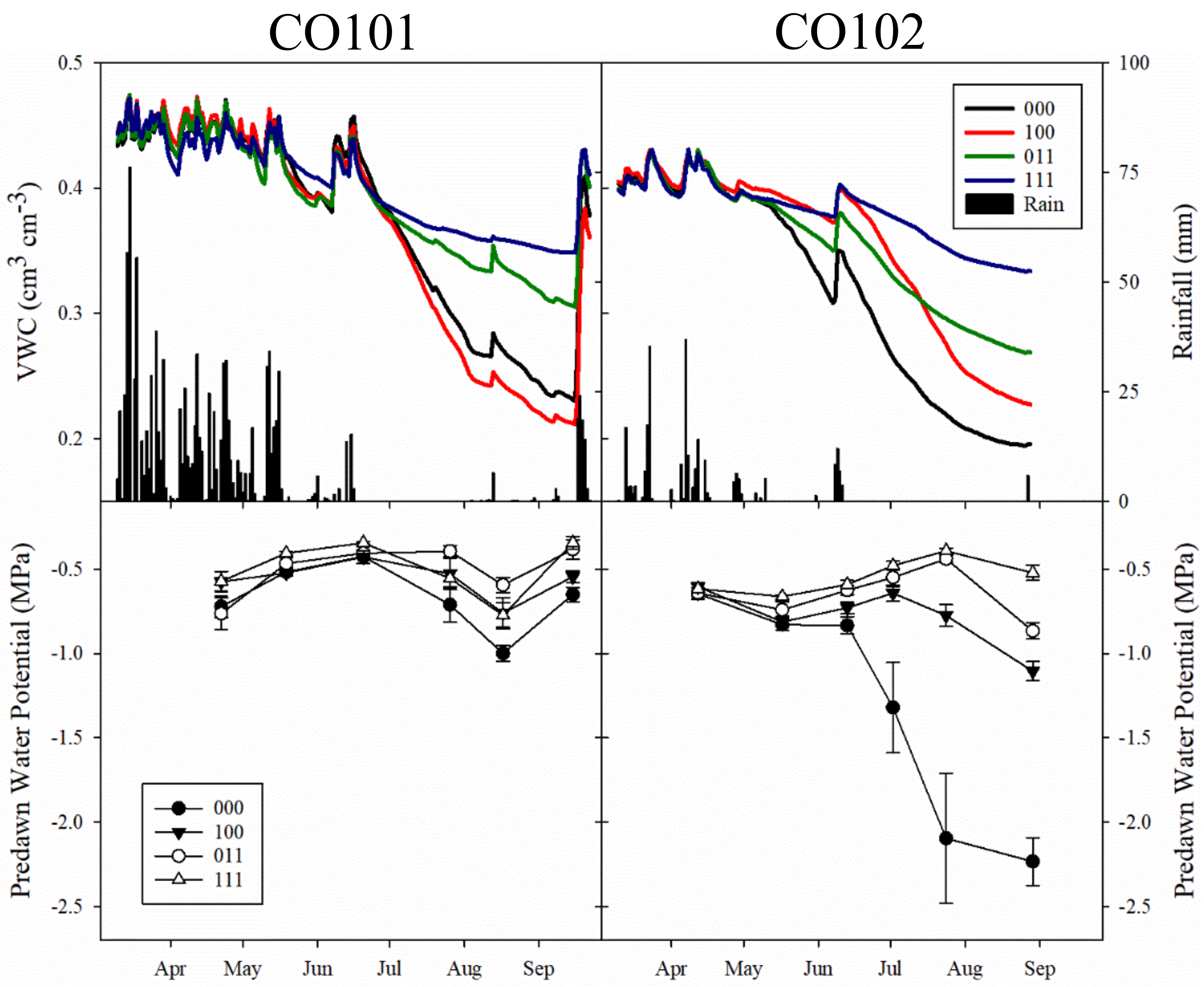
Results: Competing vegetation (Growing Season 1)



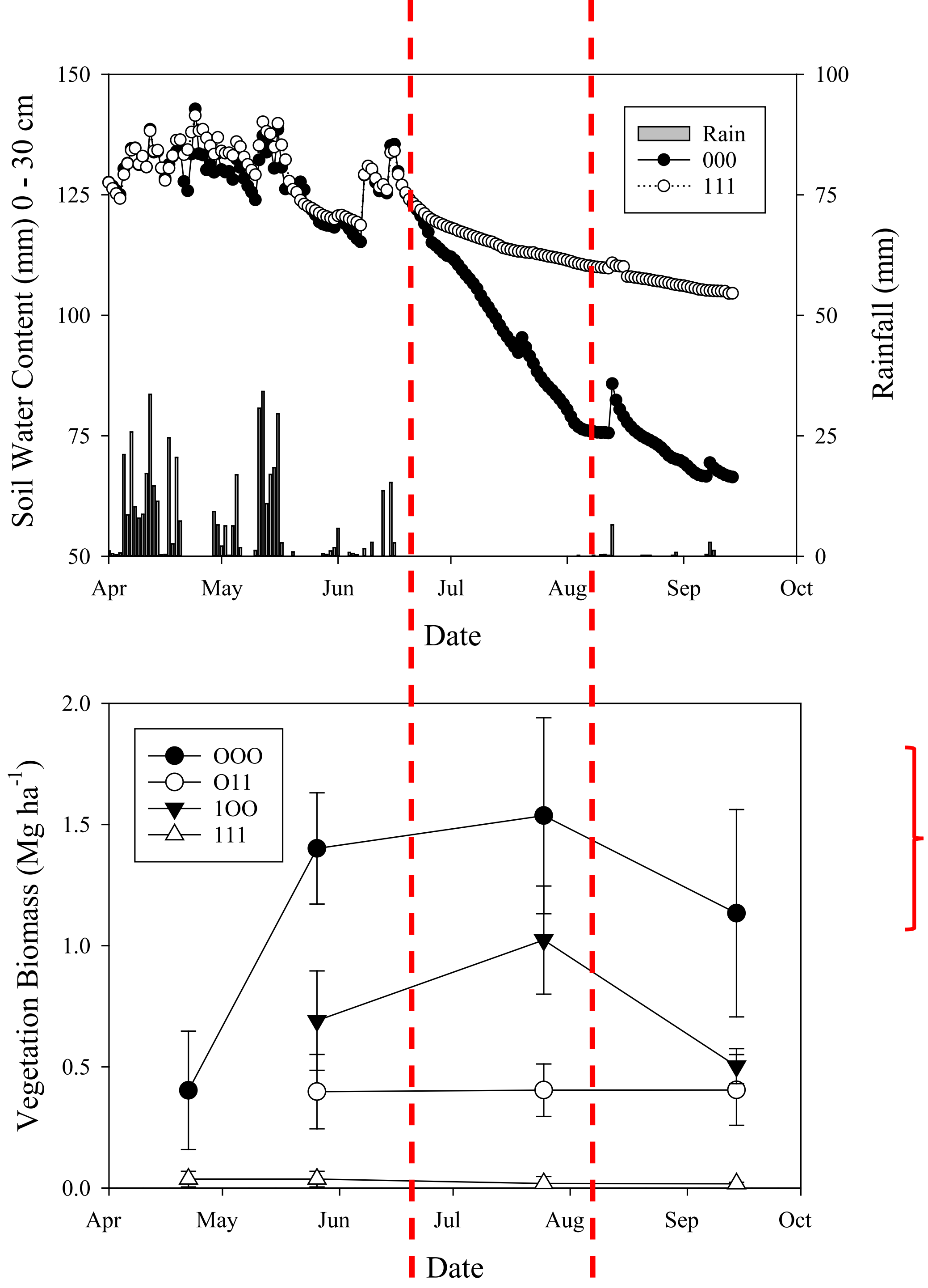




Results: VWC and Pre-dawn Water Potential (Growing Season 1)



Water Use by Vegetation



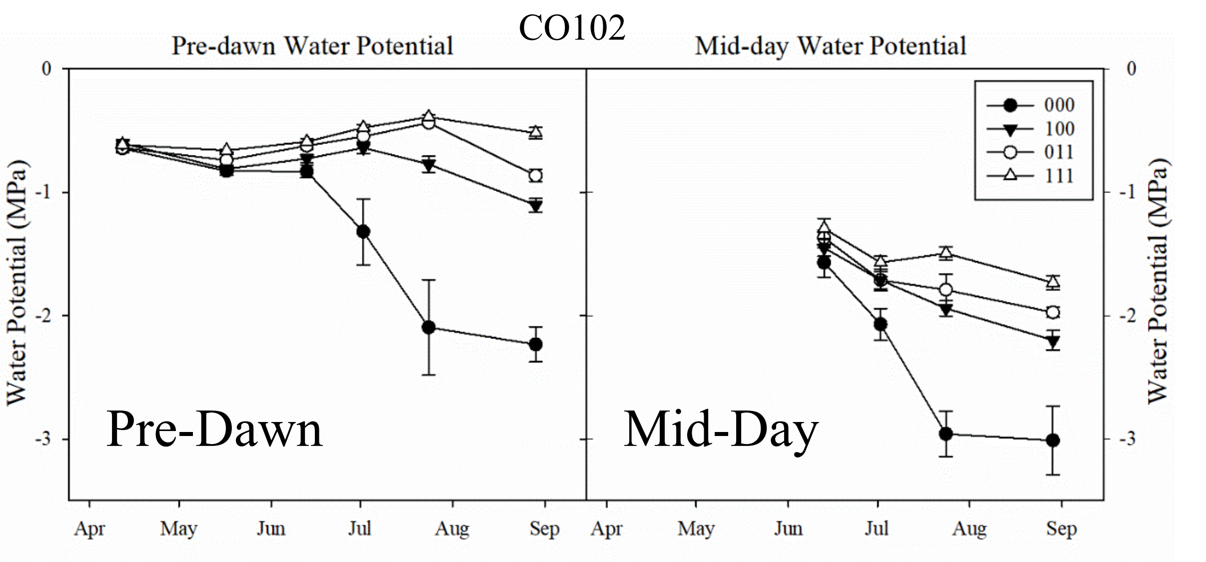
Δsw (mm in 46 days)
000 = 55

Biomass
000 = 1.48 Mg ha^{-1}

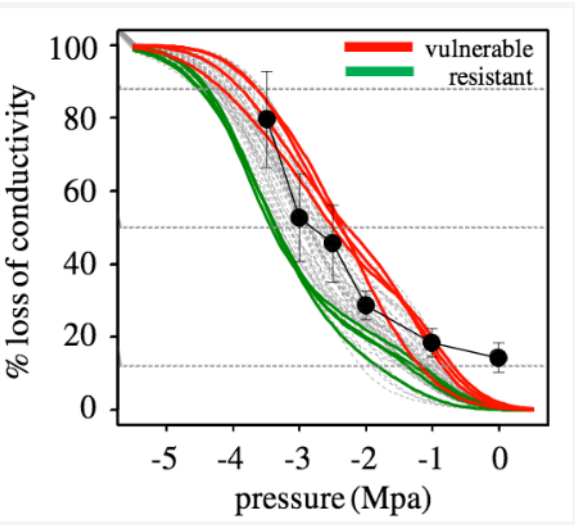
Water Use
000 = 24.7 mm / Mg / month

New Measurements

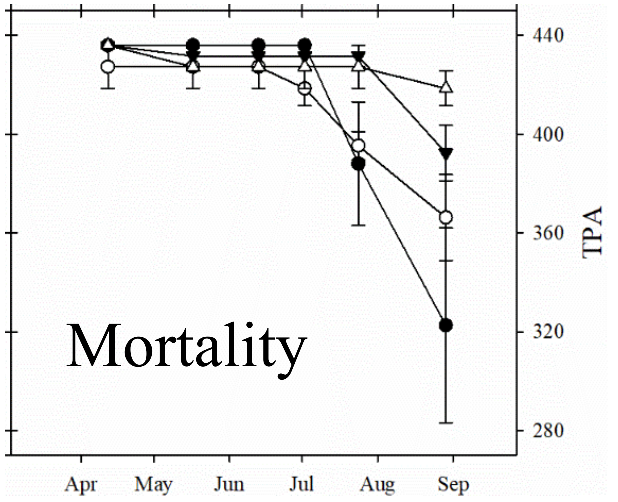
We will continue with continuous (weather and soil moisture) and monthly (vegetation cover and biomass; seedling growth; seedling xylem water potential) measurements



- New measurements: Hydraulic conductivity (stem and roots), chlorophyll fluorescence, photosynthesis, and stomatal conductance.



Dalla-Salda et al. 2014



Integration of Ecophysiological Data into Growth Models

- The data being collected at the CoSInE sites will be integrated into models.
  - Long-term responses: G&Y Model (CIPS)
  - Process-based model (modified version of model 3-PG until canopy closure)
    - Include effects of climate, soil and FVM

Acknowledgements

Vegetation Management Research Cooperative Members

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Green Diamond Resource Company

Greenwood Resources

Hancock Forest Management

Lone Rock Timber

Olympic Resource Management

Oregon Department of Forestry

Oregon State University

Rayonier Inc.

Roseburg Forests Resources

Silver Butte

Sierra Pacific Industries

Starker Forests, Inc.

Washington Department of Natural Resources

Weyerhaeuser

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Dow Chemical

Helena Chemical

Stuewe and Sons

Thanks !!!

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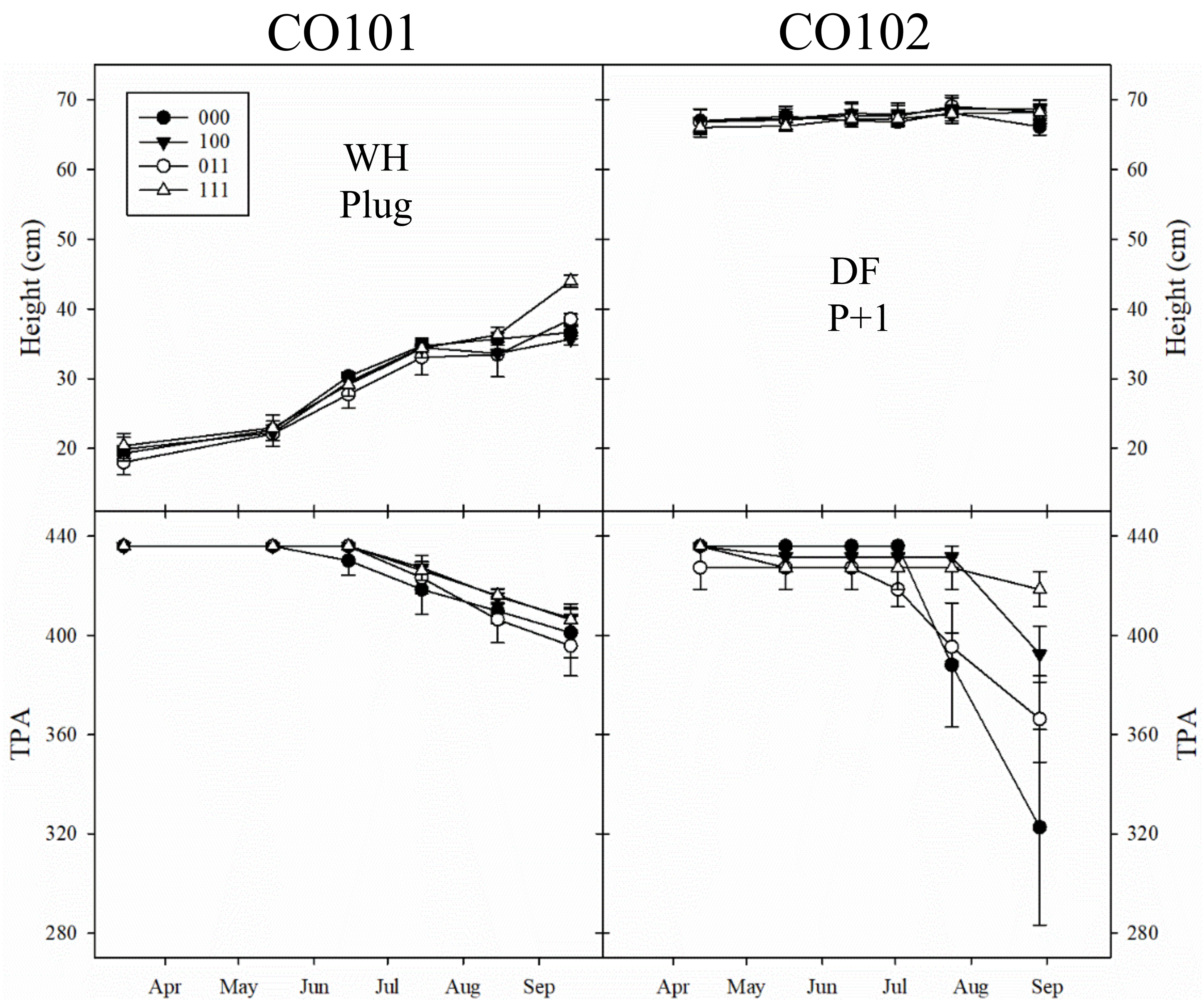
Results: Seedling Height and Mortality (Growing Season 1)



Use of Water Stress Integral in VM Studies

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https://doi.org/10.1007/s11056-018-9657-1

CrossMark

Use of water stress integral to evaluate relationships between soil moisture, plant water stress and stand productivity in young Douglas-fir trees

Carlos A. Gonzalez-Benecke[1] · Eric J. Dinger[2]

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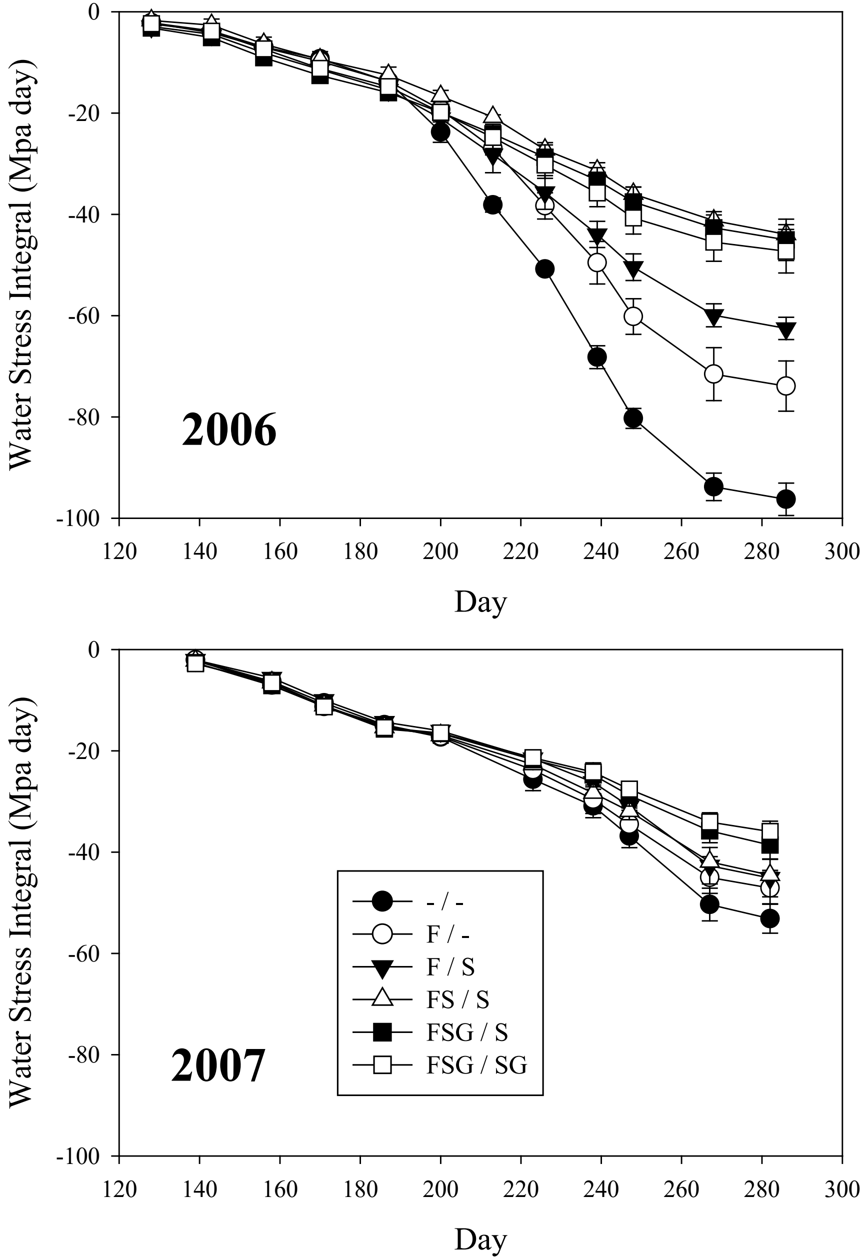
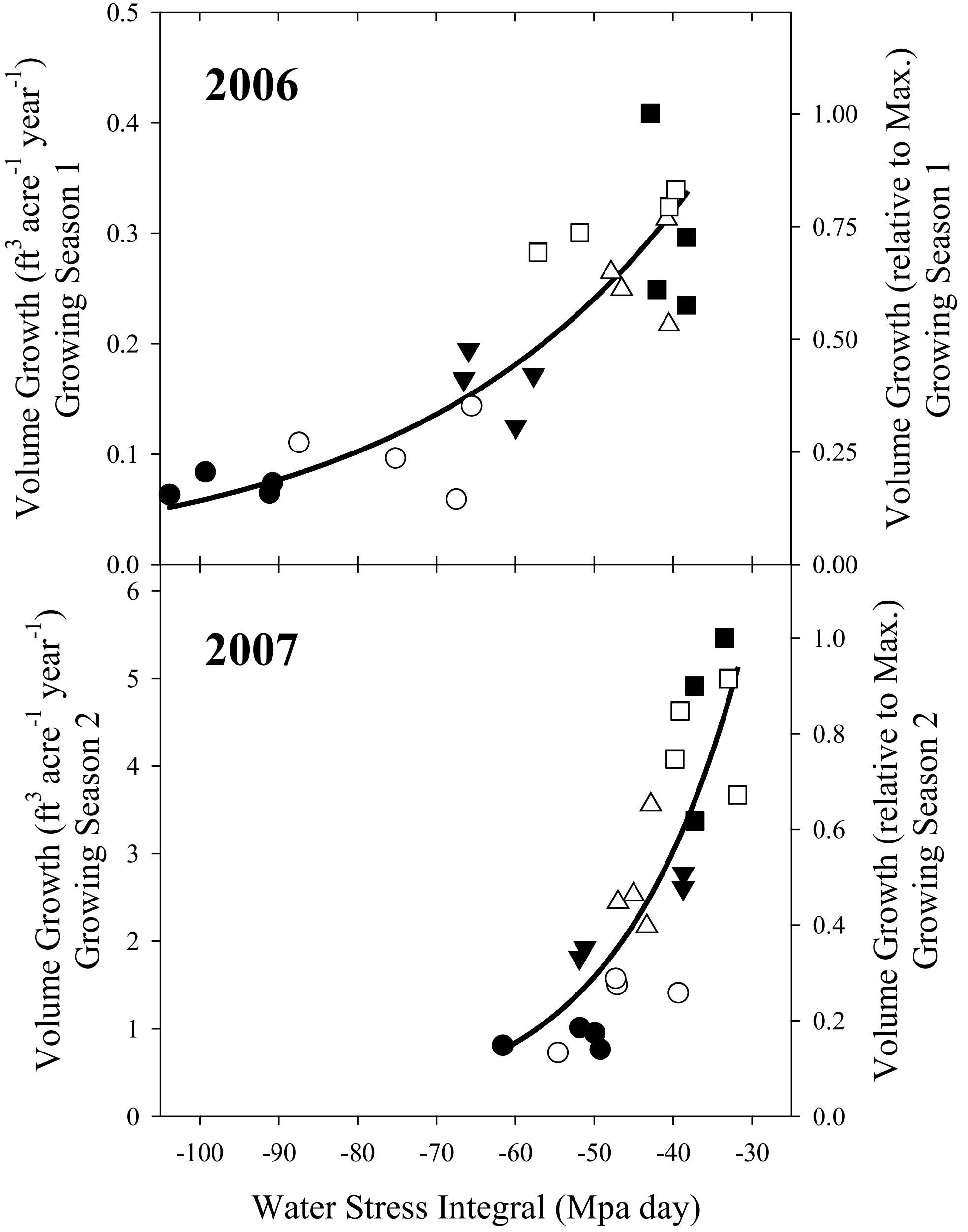
Study Objectives

- Analyze the effect of vegetation management treatments on soil moisture, plant water relations and seedling growth.

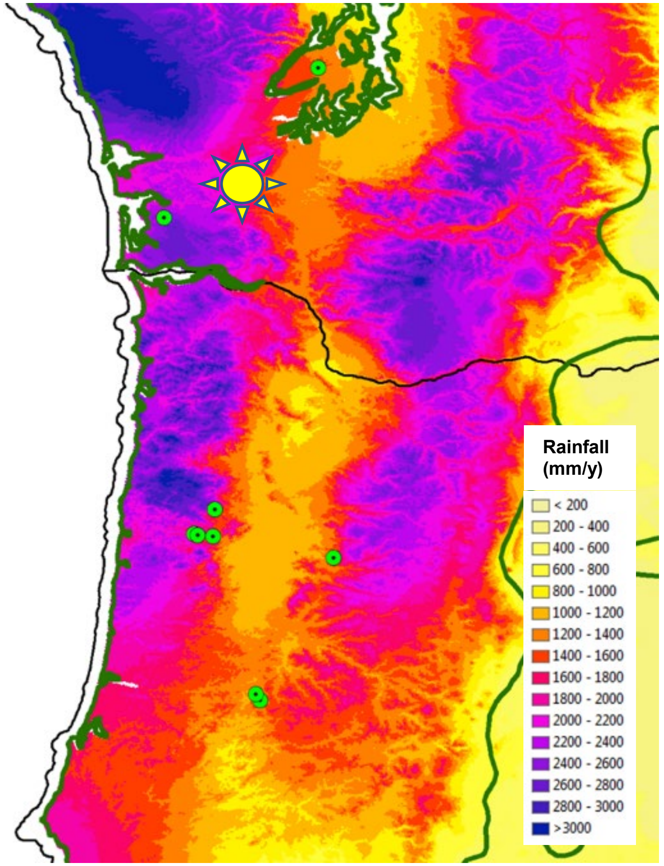
- Test the use of Water Stress Integral as a tool to link plant water stress and Douglas-fir growth under field conditions.

Use of Water Stress Integral in VM Studies





Study Description



Site: Oakville
Institution: WADNR
State: WA
County: Grays Harbor
Soil texture: fine loamy
Mean Annual Temp.: 10.7 C (51.3 F)
Mean Annual Rainfall: 1450 mm (57.4 in)

	2005	2006		2007	
Treatment	Fall SP	SR	E-S R	SR	E-S R
O/O	O	O	O	O	O
F/O	SP	O	O	O	O
F/S	SP	O	O	T	O
FS/S	SP	T	O	T	O
FSG/S	SP	T	T	T	O
FSG/SG	SP	T	T	T	T

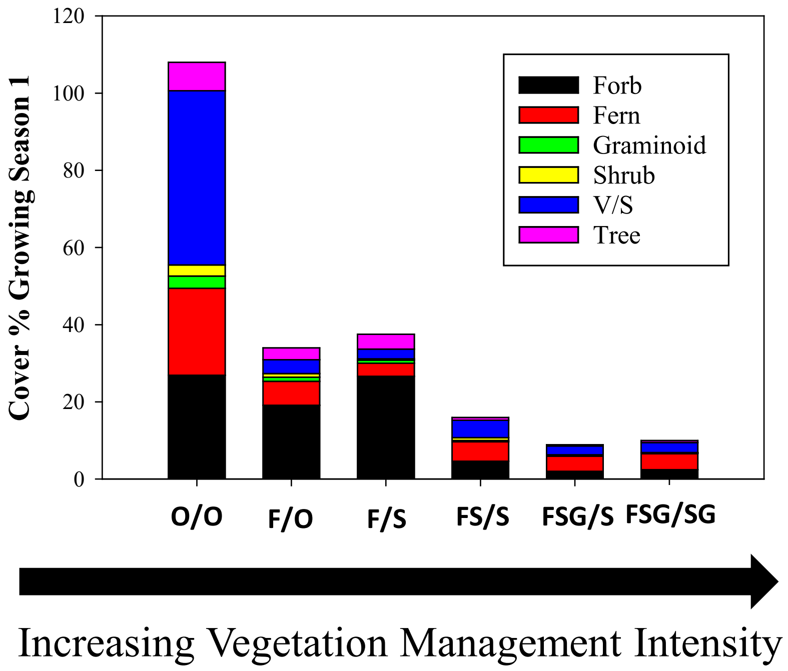
Planting date: February 25, 2006

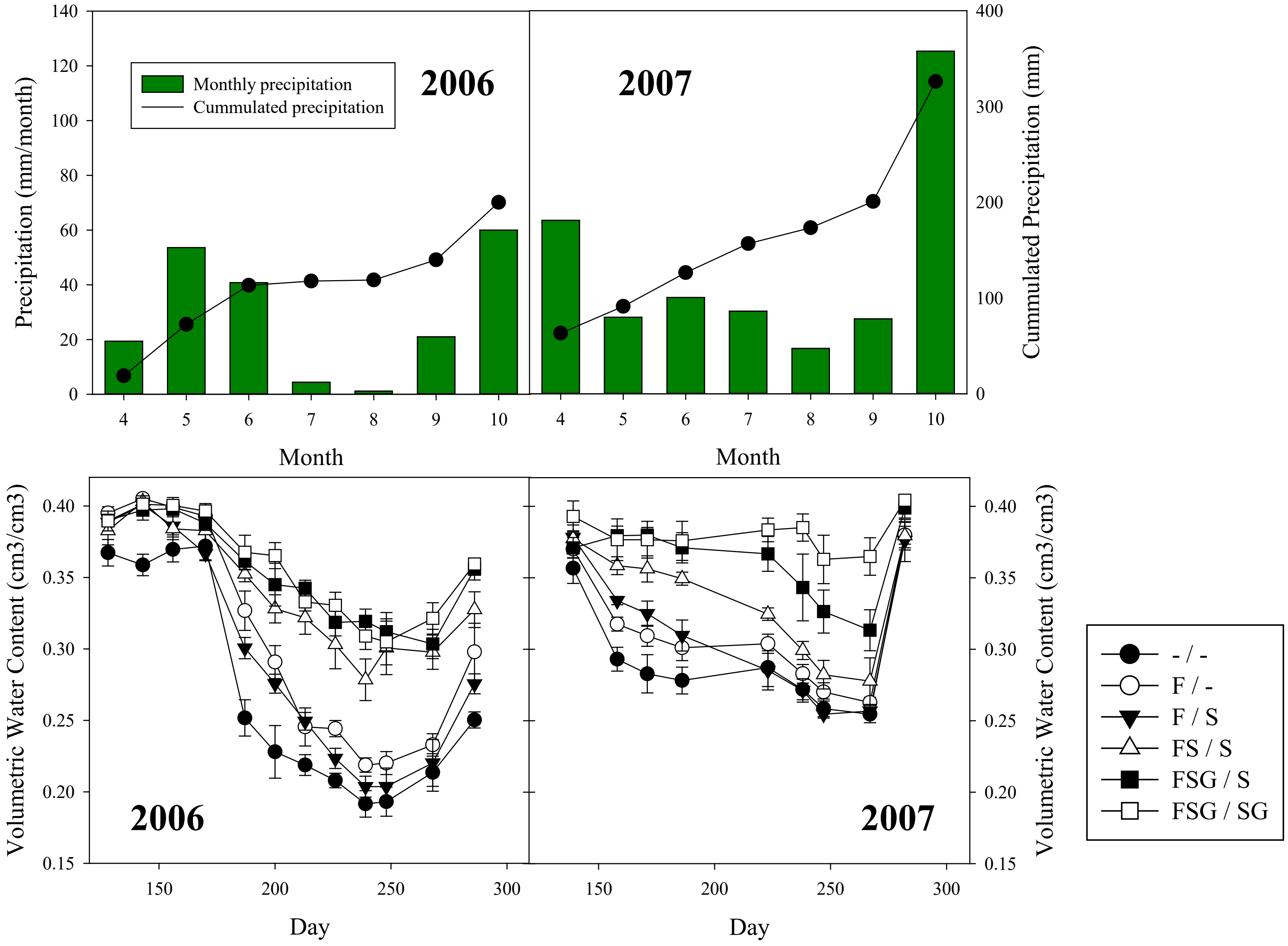
Planting density: 10’ x 10’

Plot size: 80’ x 80’
(36 measurement trees, one tree buffer)

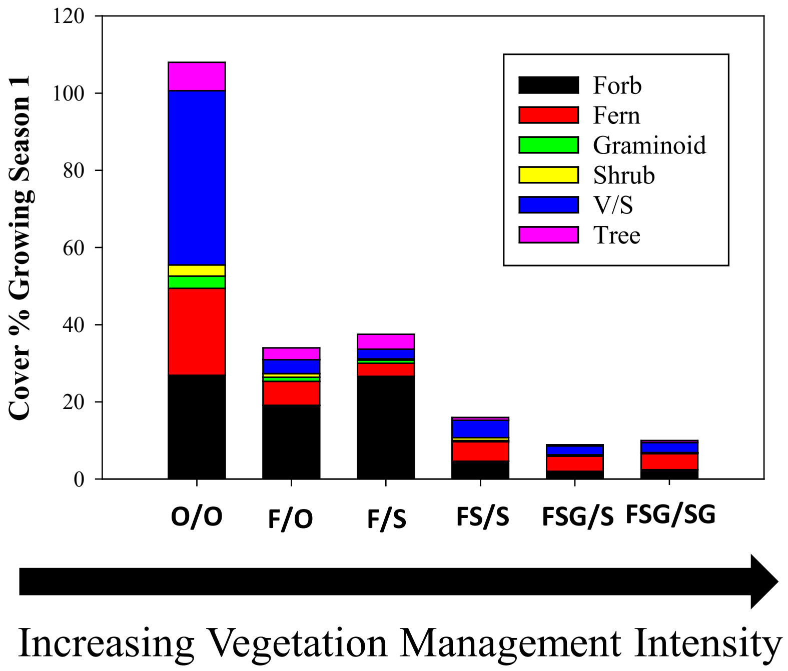
Stock type: Douglas-fir bareroot 1+1

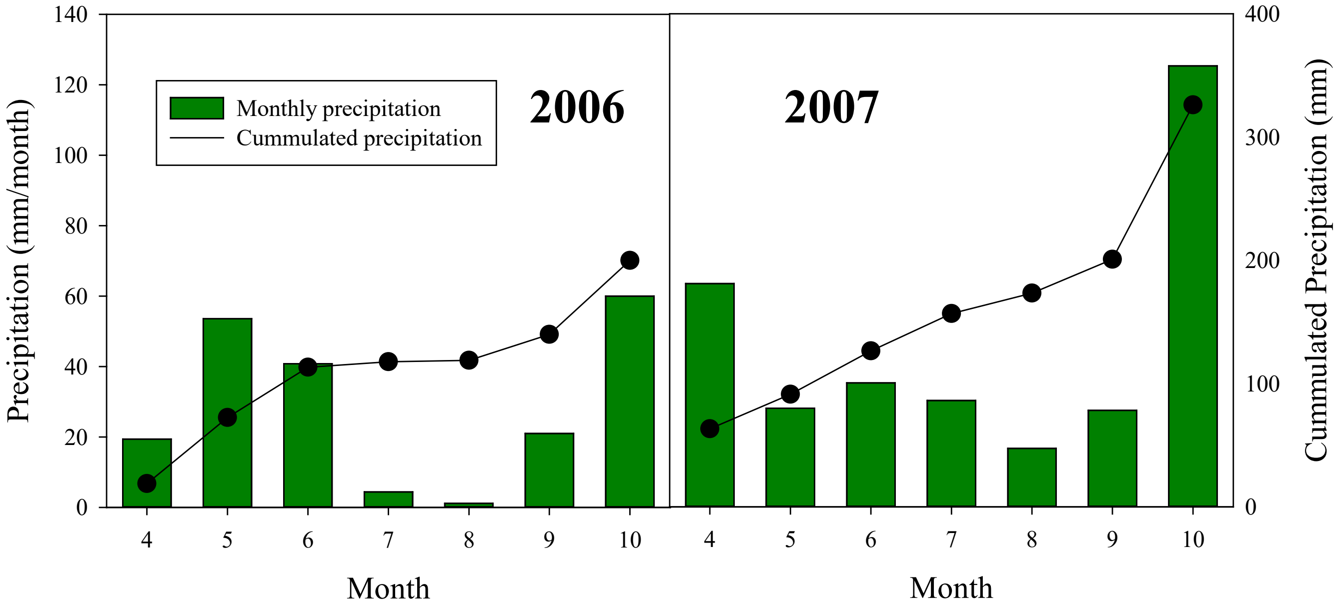
VM Treatment Effects on Soil Moisture

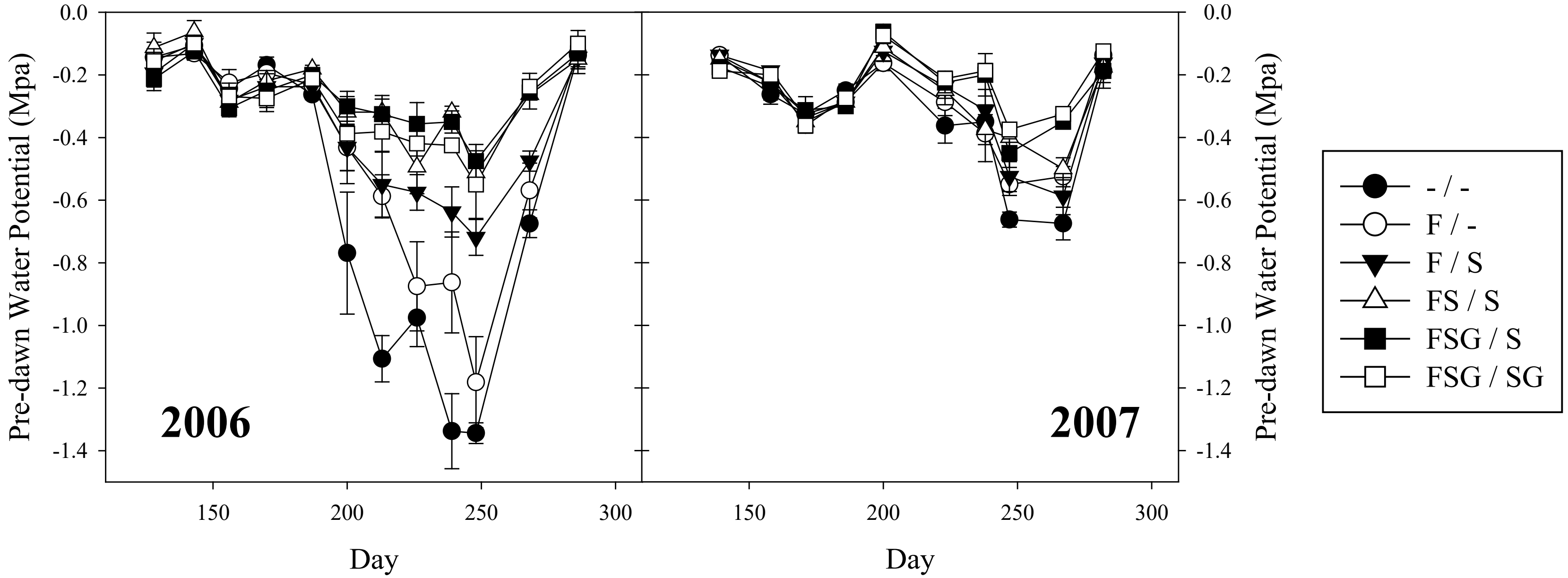




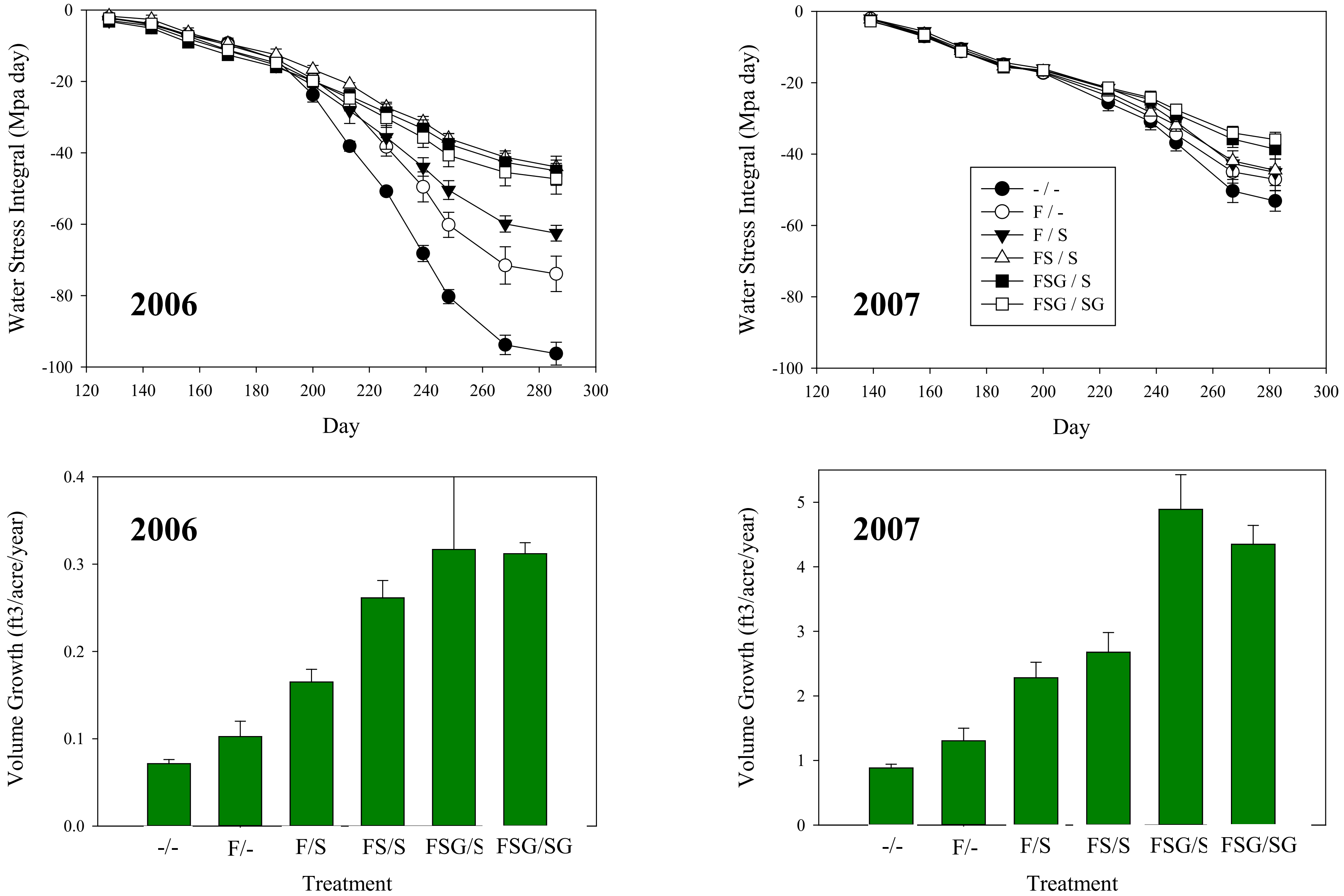
VM Treatment Effects on Water Potential





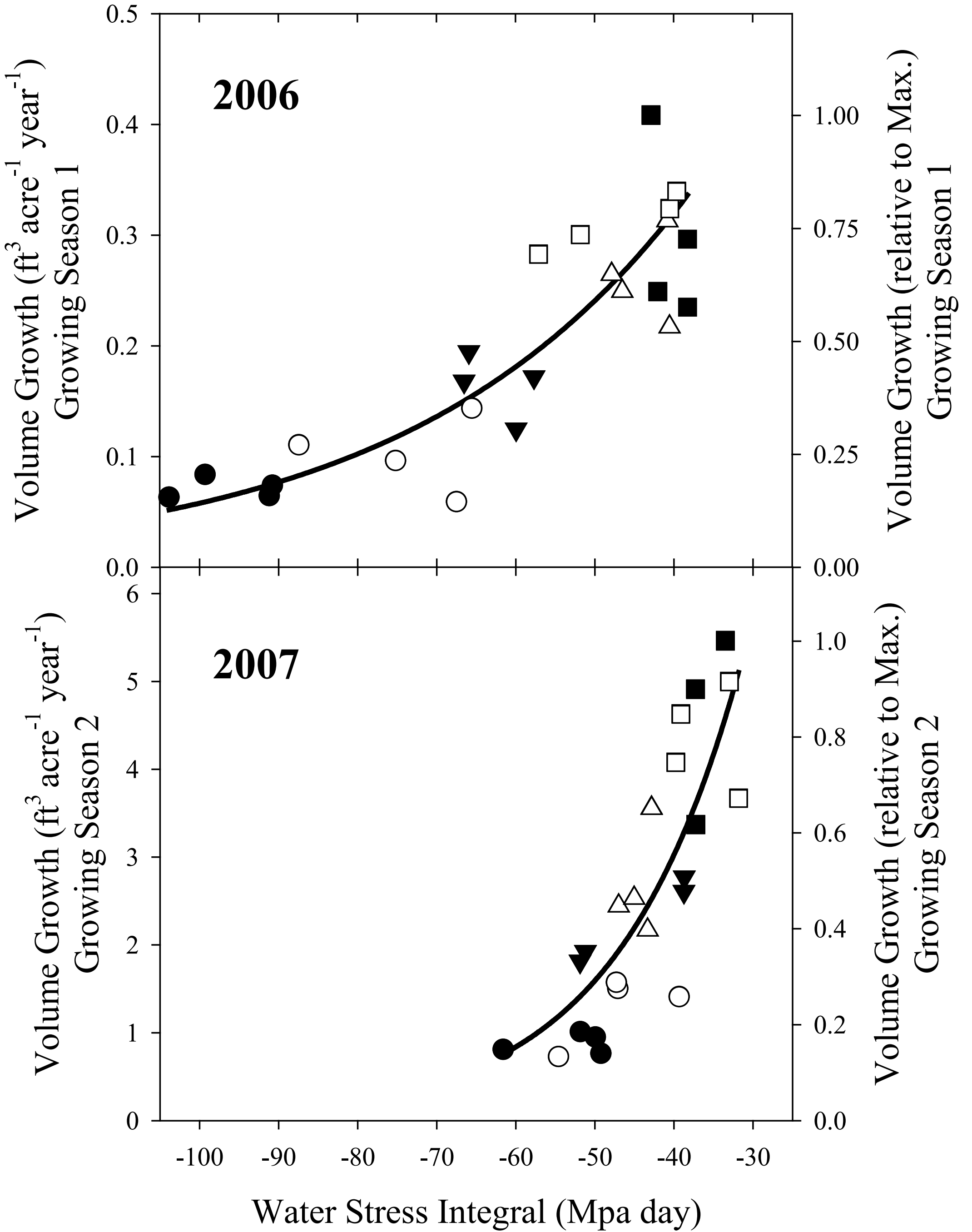


VM Treatment Effects on Water Stress Integral



WSI vs Productivity

Correlation between WSI and Douglas-fir productivity (volume growth)



Conclusions

- Water Stress Integral (WSI) is a practical index of seasonal water stress.

- WSI is correlated with tree growth.

However, these results only reflect VM treatment responses at 1 site for 2 growing seasons