Competition and Site Interactions Experiment: Understanding Vegetation Management Treatment Responses

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Vegetation Management Research Cooperative

- Stakeholder driven research organization established in 1993.

- Membership includes both private forest management companies and public land management agencies.

Mission

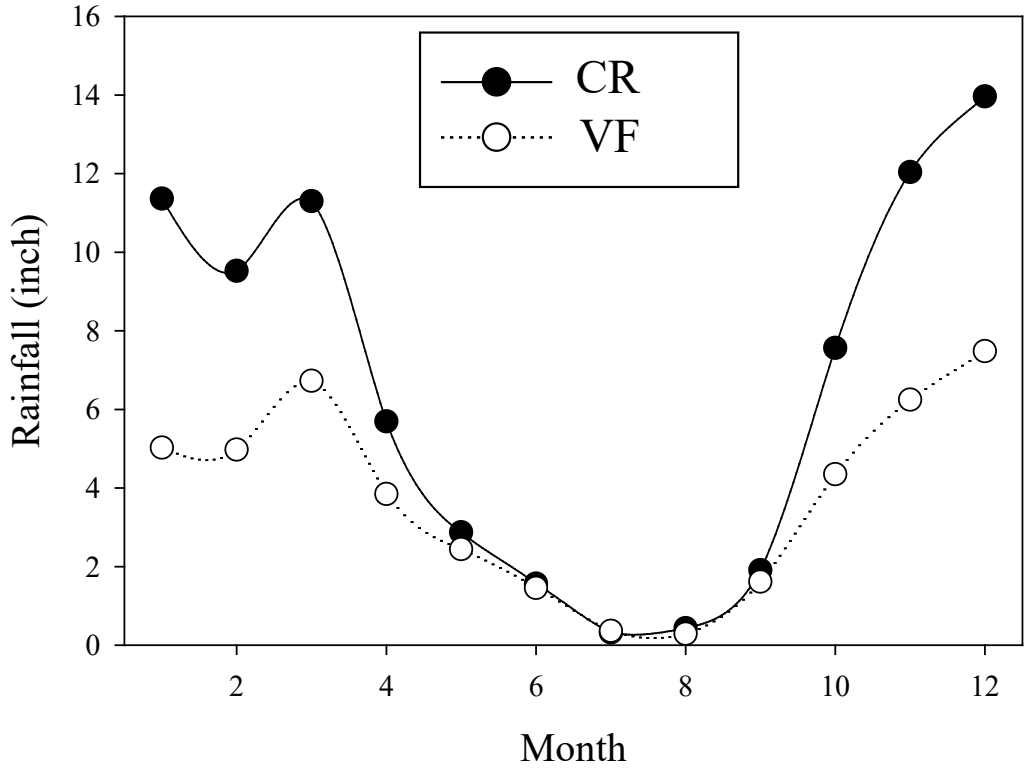
- Conduct applied reforestation research of young plantations from seedling establishment through crown closure with an emphasis on operational vegetation management.

- Promote reforestation success such that survival, wood-crop biomass and growth are maximized while protecting public resources.

Background

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

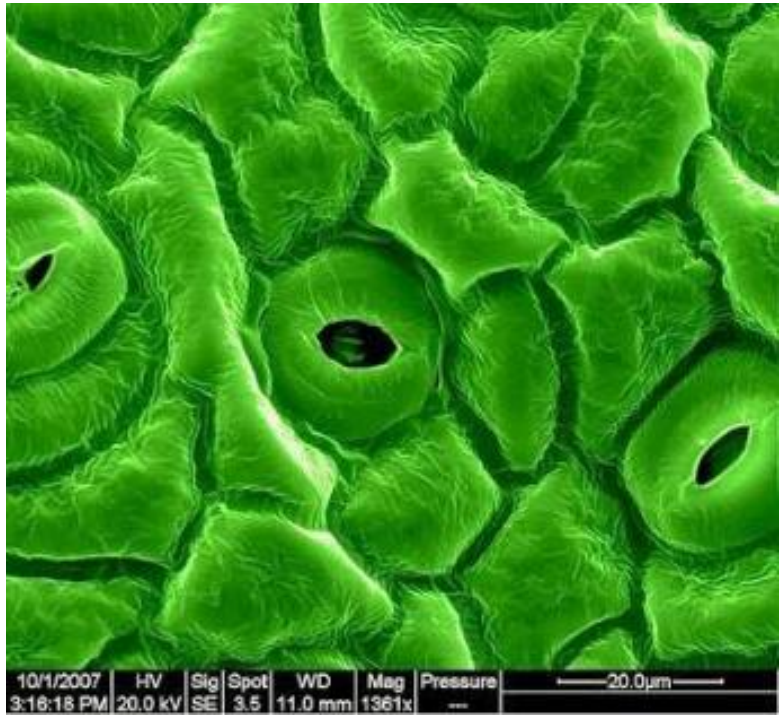
- How do plants respond to changing environmental conditions? (soil moisture, temperature, vapor pressure deficit, etc.)
- In the context of reforestation in the PNW we often focus on tree seedling water relations



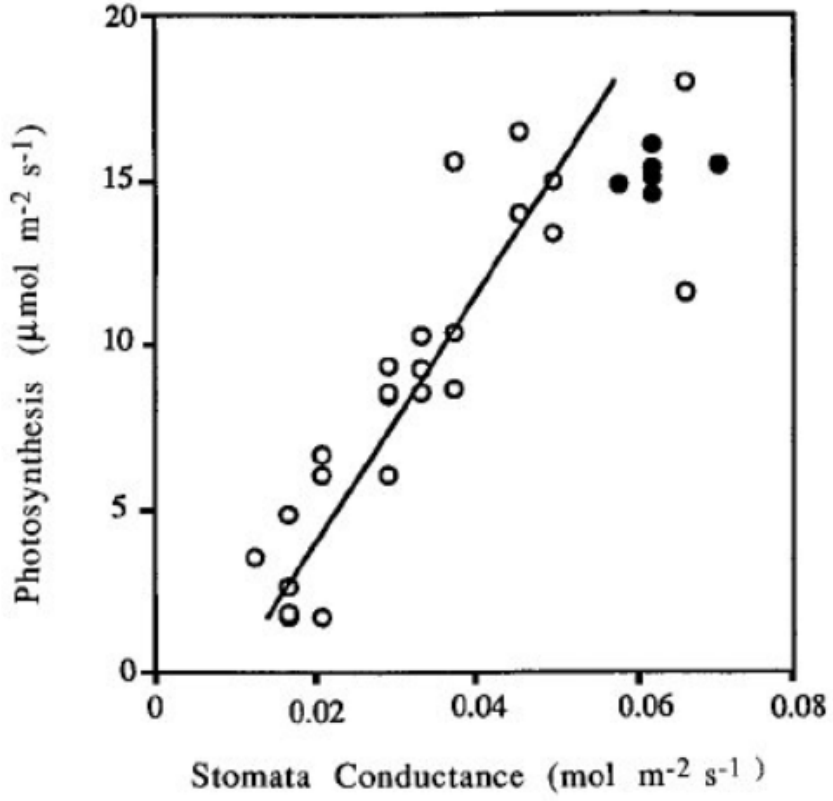
Carbon Gain vs Water Loss

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

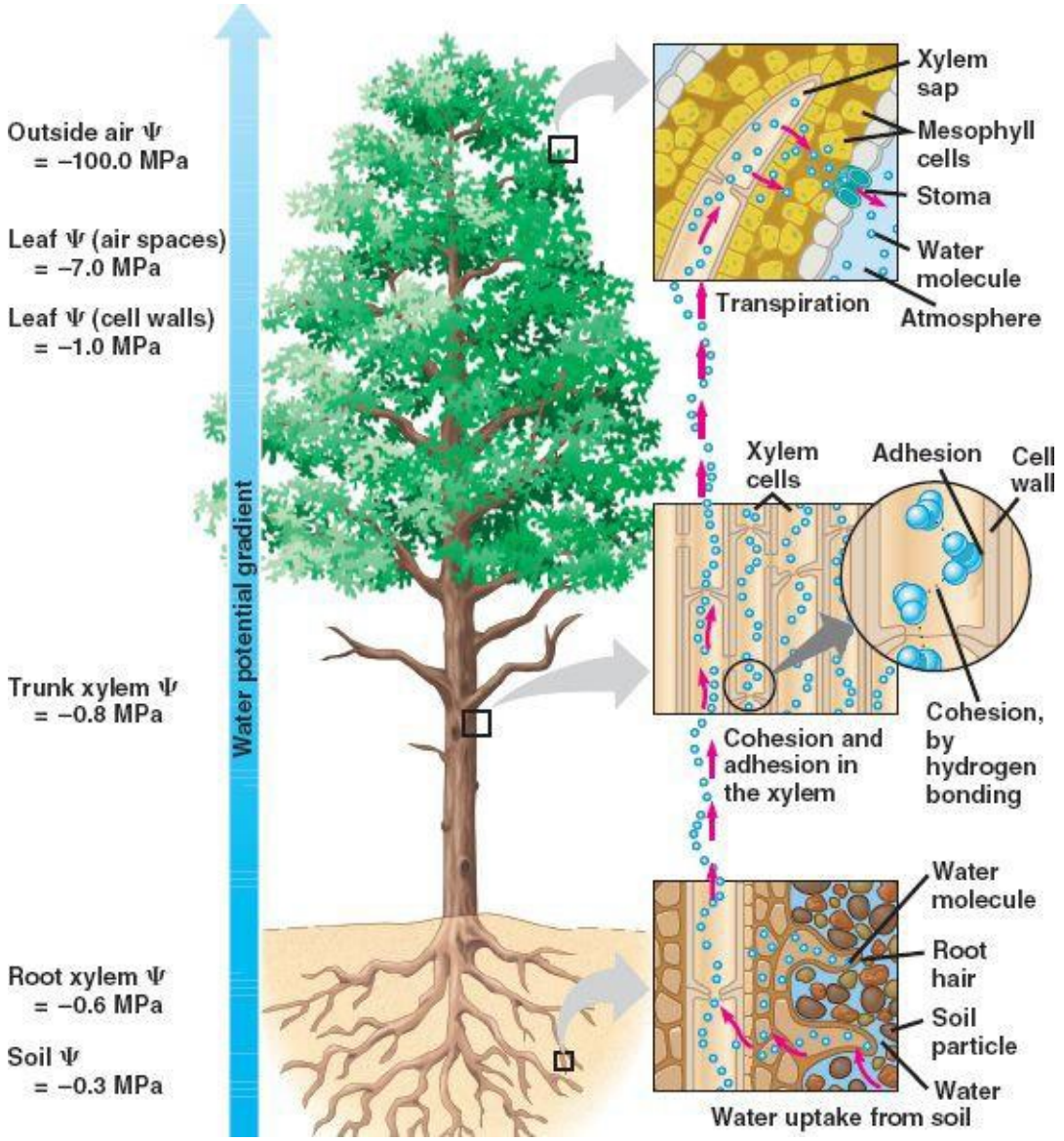


www.quora.com/Are-stomata-cellular-structures-If-yes-then-why-and-if-no-then-also-why



Waring and Silvester 1994

The Cohesion Tension Theory



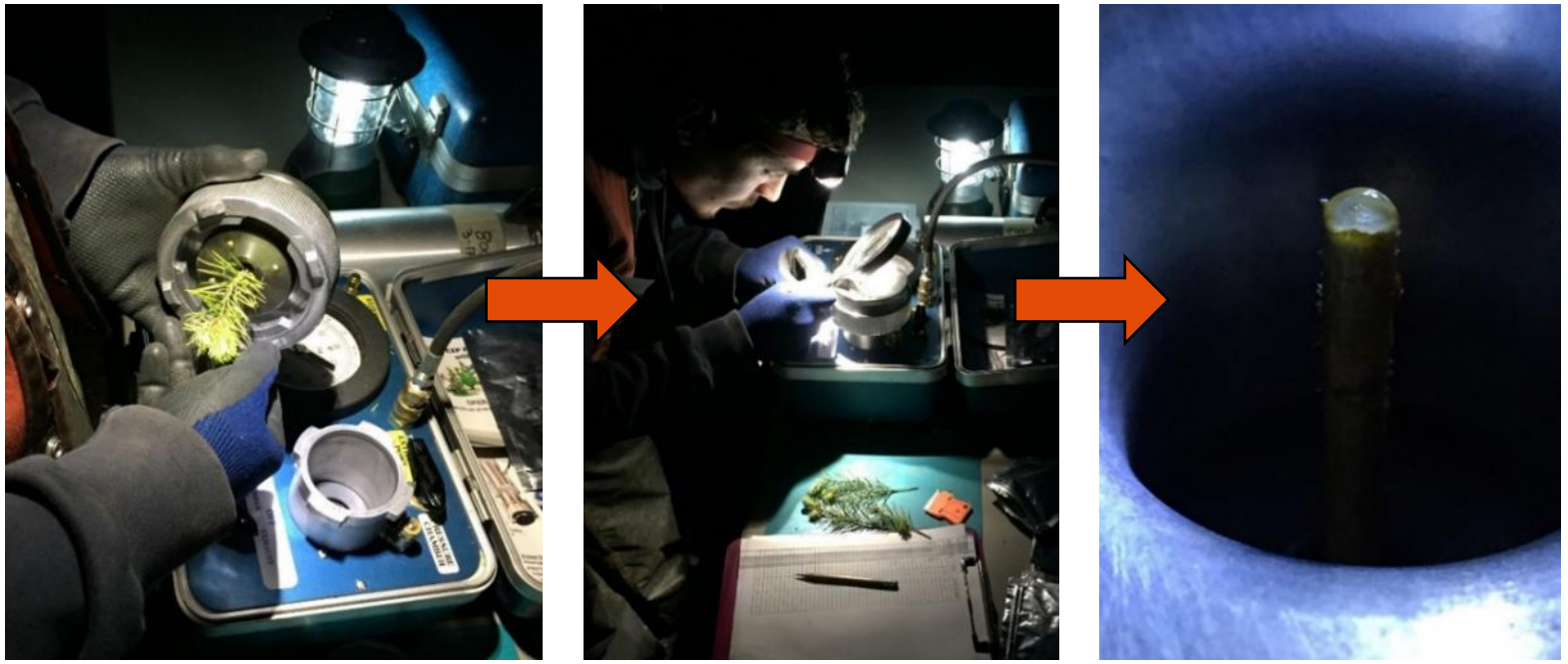
Water transport in plants is a passive process facilitated by large differences between soil and atmospheric water potential.

- 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 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 energy 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

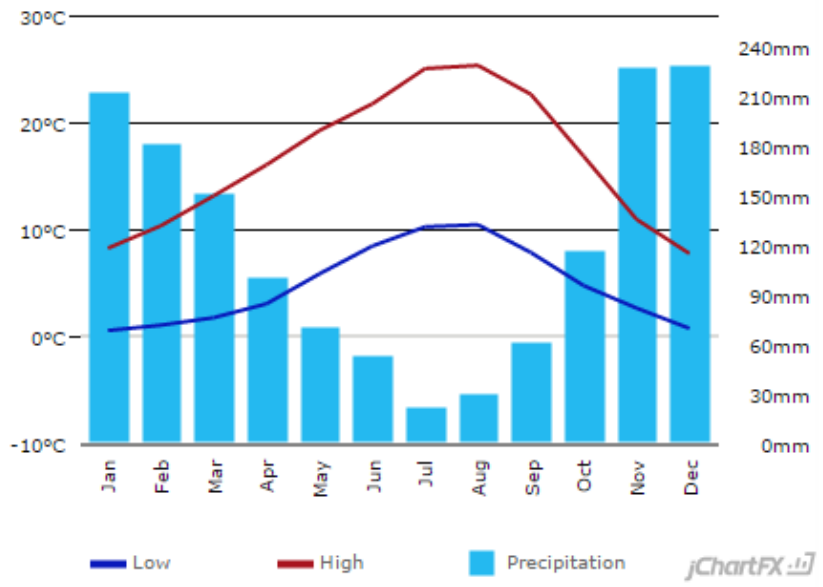
The growth and survival of conifer seedlings in the PNW is significantly impacted by water stress:

- Prolonged summer drought
- Competition with vegetation

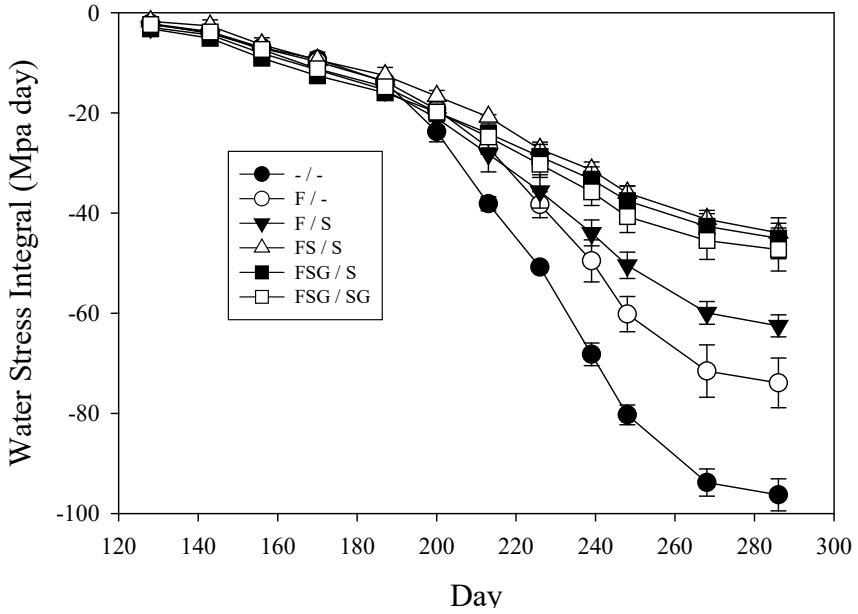
Understanding how VM treatments affect seedling water relations can help us to better understand observed crop tree responses to VM treatments:

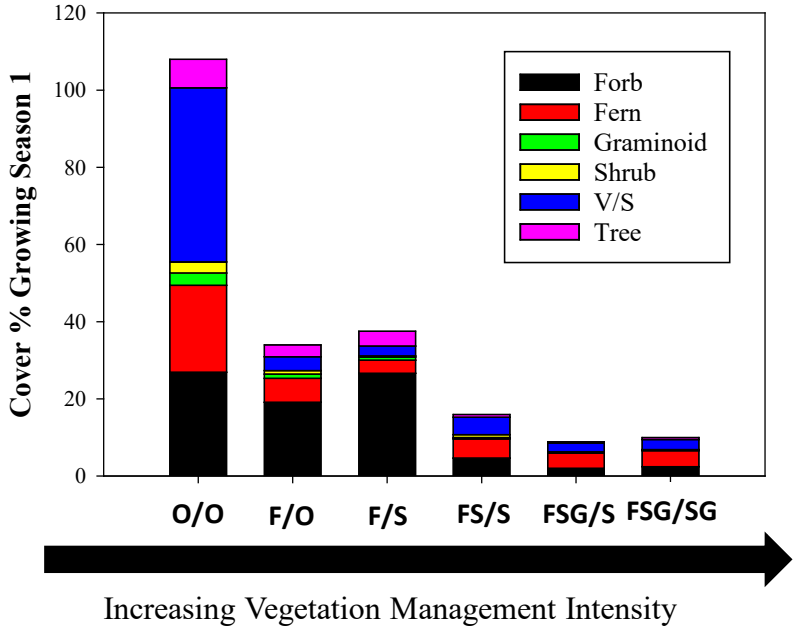
- Why do VM treatment responses vary by site?

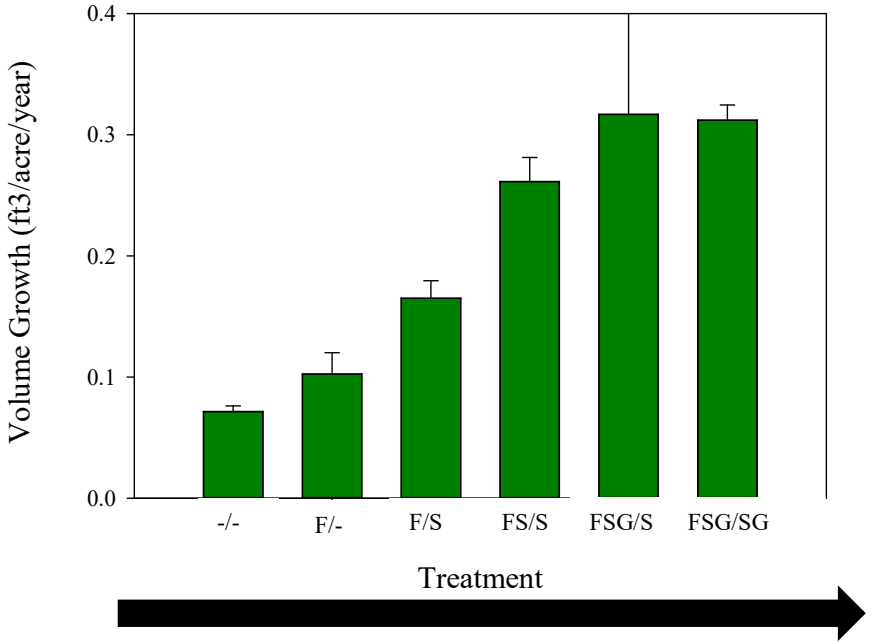
Background



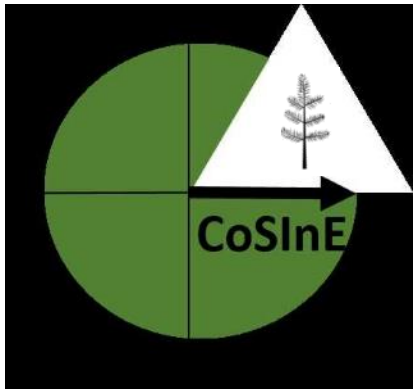
usclimatedata.com







Oregon State University



Vegetation Management Research Cooperative

CoSInE

Competition & Site Interactions Experiment

Study Rational

Vegetation management increases stand survival and growth rates; 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 managers with making site specific VM decisions.

- Create a data network for the development of a G&Y model including FVM responses (CIPS)

The specific objectives are to determine the effect of vegetation management 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
- conifer seedling and understory plant stress physiology

CoSInE Study Methods

CoSInE will 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’ (435 tree $acre^{-1}$)
Treatment plots size: 120’ x 120’
Measurement plot size: 80’ x 80’ (64 measurement trees)

CoSInE Study Methods

The CoSInE study contains 2 different types of sites:

- Tier I sites are intensively measured and used for developing ecophysiological relationships
- Tier II sites are less intensively measure and used for G&Y model development (CIPS).

Activity	Tier I	Tier II
Number of Treatments	8	8
Number of Replicates	4	1
Number of Biomass Plots	8	0
Area (Acres)	11.9	2.7
Soil Moisture Measurements	Yes	No
Tree Biomass Measurements	Yes	No
Vegetation Biomass Measurements	Yes	No
Tree Foliage Nutrient Content	Yes	No

Example of block layout

Biomass	000	011	100	001
Biomass	010	110	101	111

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

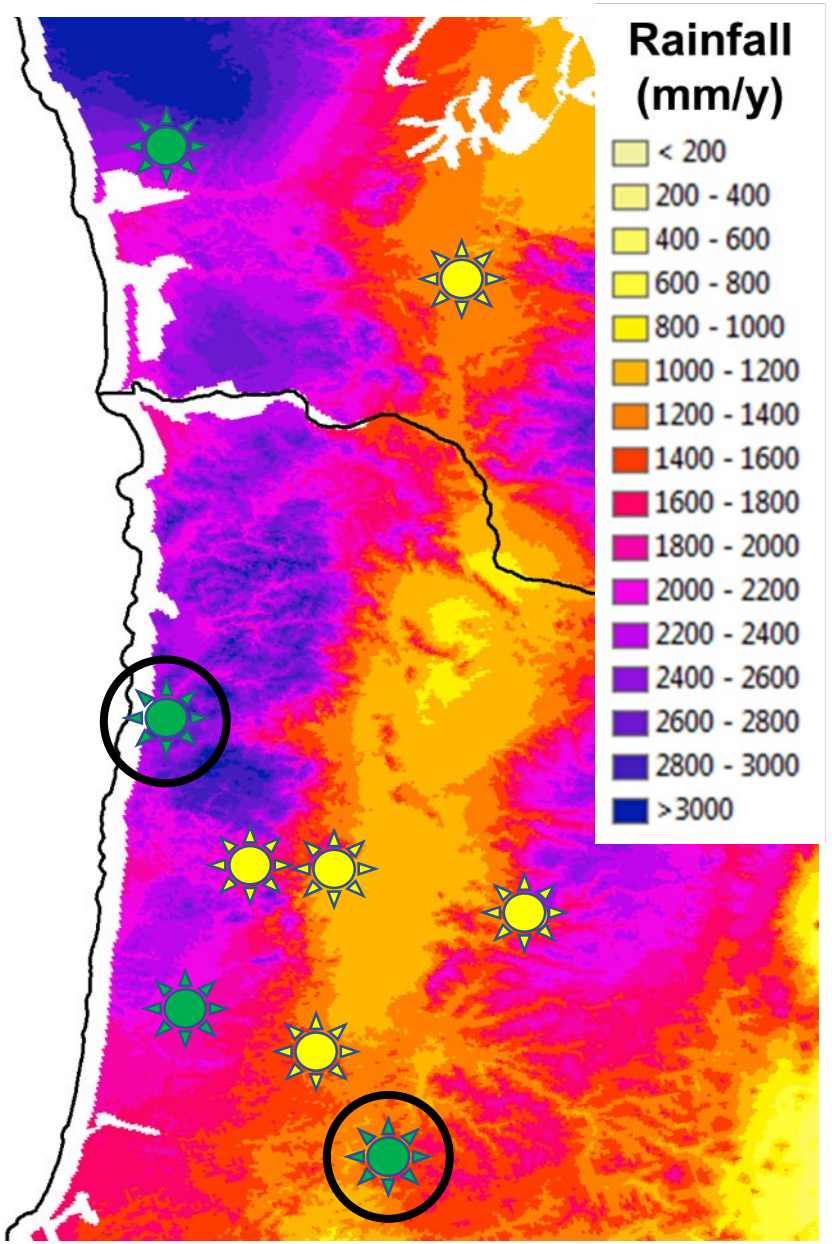
Nine Sites

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



Study Sites

CO101 (coastal wet site) ●

- Western hemlock (2017) near Pacific City, OR
- Hancock Forest Management
- Annual rainfall: 105 inches
- Mean air temperature: 50.2 ˚F

CO102 (dry inland site) ●

- Douglas-fir (2018) near Yoncalla, OR
- Lone Rock Timber Management
- Annual rainfall: 50.7 inches
- Mean air temperature: 51.4 ˚F

Initial Seedling Conditions

Trait	CO101 Plug western hemlock	CO102 Plug + 1 Douglas-fir
Height (cm)	28.9	81
Root collar diameter (mm)	3.6	13.2
Total Biomass (g)	3.75	61.64
Foliage (%)	39	22
Stem (%)	28	44
Roots (%)	33	34
Water potential (MPa)	-0.425	-0.627

Environmental Measurements

Weather station

- Temperature [˚C]
- Rainfall [mm]
- Solar Radiation [W m^{-2}]
- Relative Humidity [%]

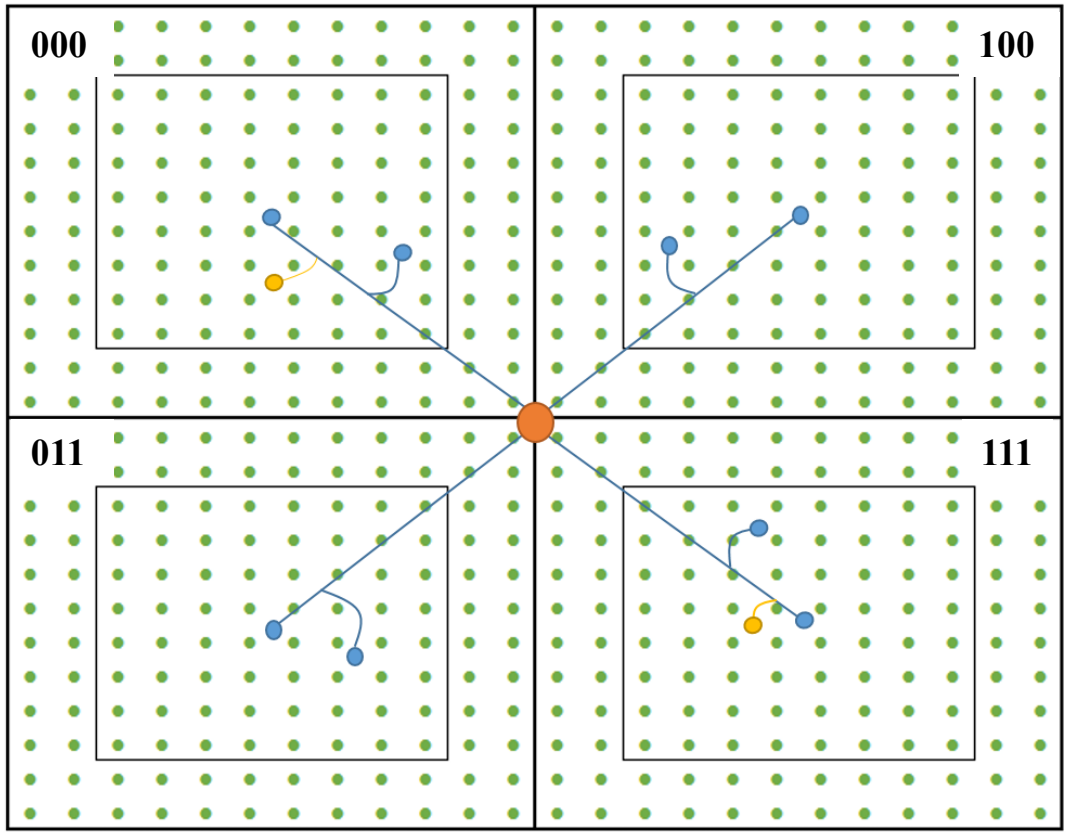
Soil moisture sensors

- Volumetric water content [cm^3 cm^{-3}]

Study Design

Equipment

- Two soil moisture sensors per plot (30 cm long).
- One data logger per block.
- One weather station per site.



Tree Measurements

Monthly (April – Oct):

Seedling height and survival

- In subplot of 25 seedlings

Twice a year:

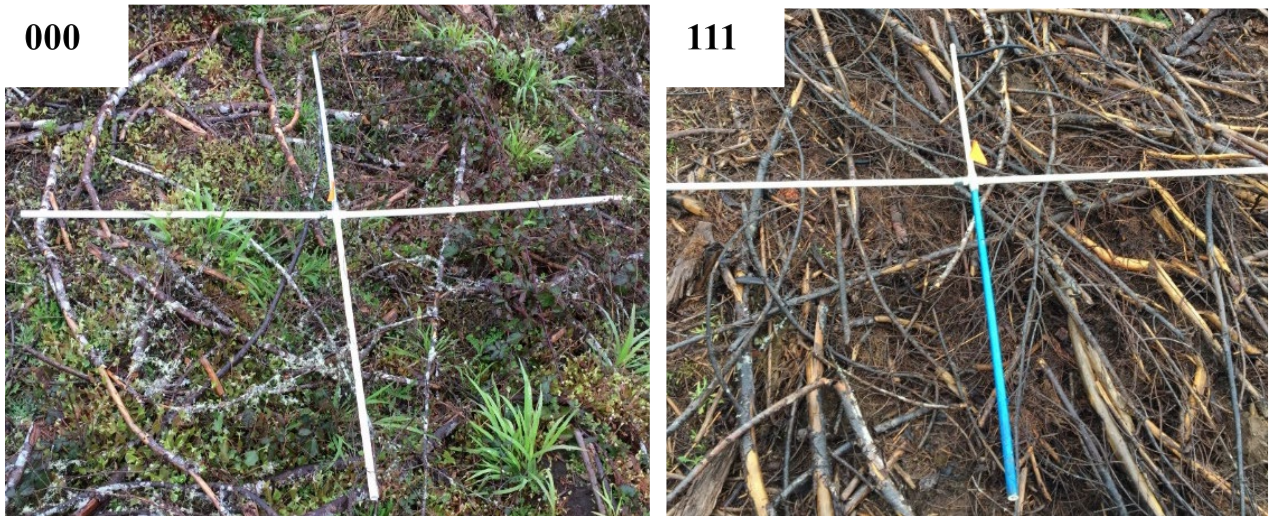
Dry mass of leaves, stem, and roots

- In biomass plot
- Winter – Summer
- Nutritional Content

Vegetation Measurements

Monthly (April – Oct):

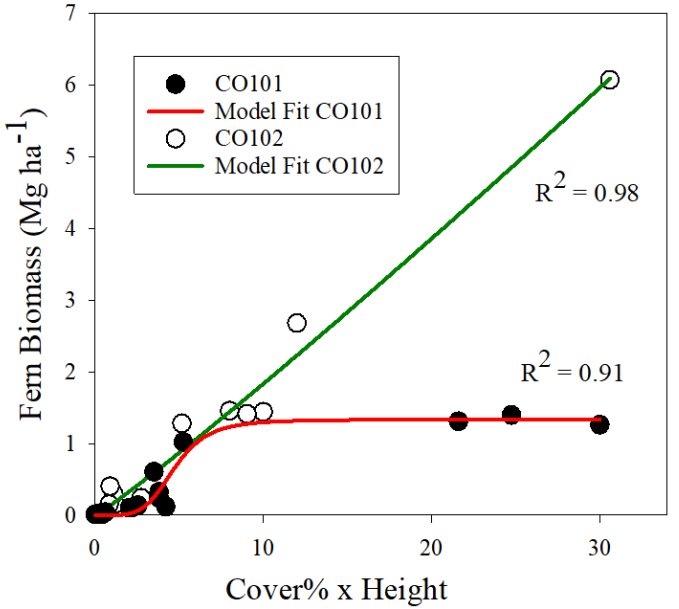
- Height and Cover by growth habit: Forb, fern, graminoid, V/S, and shrub (in main plot)
- Height, Cover, and Biomass by growth habit (in biomass plot)

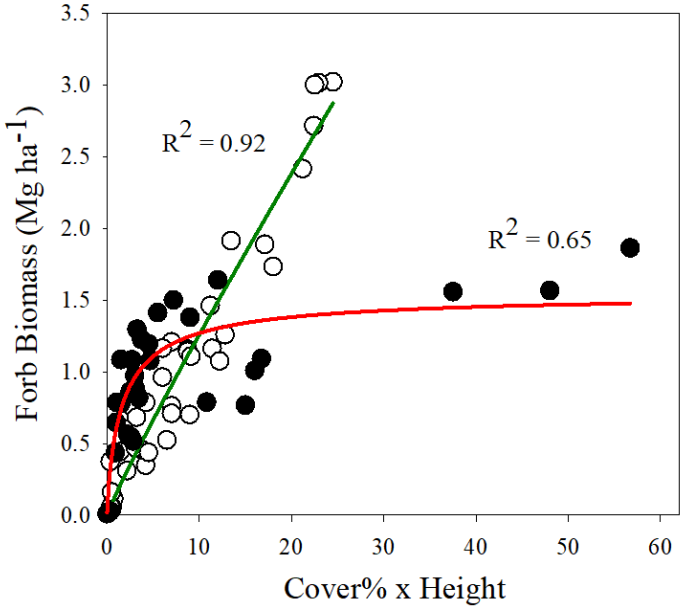


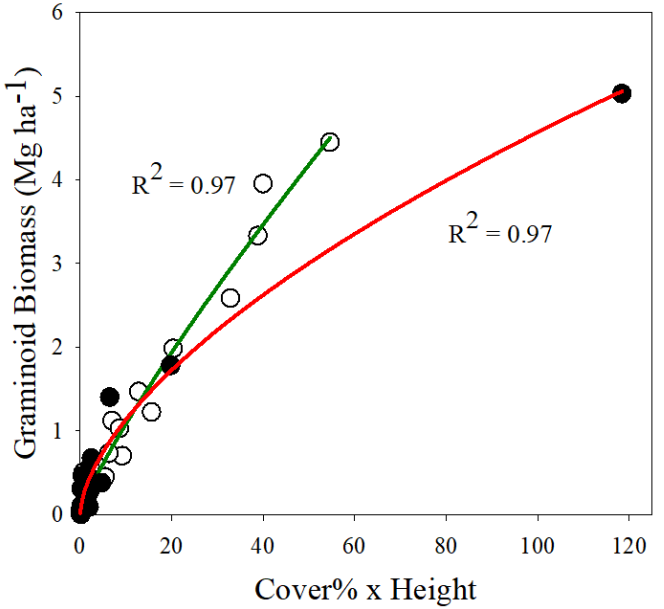
Once a year (July):

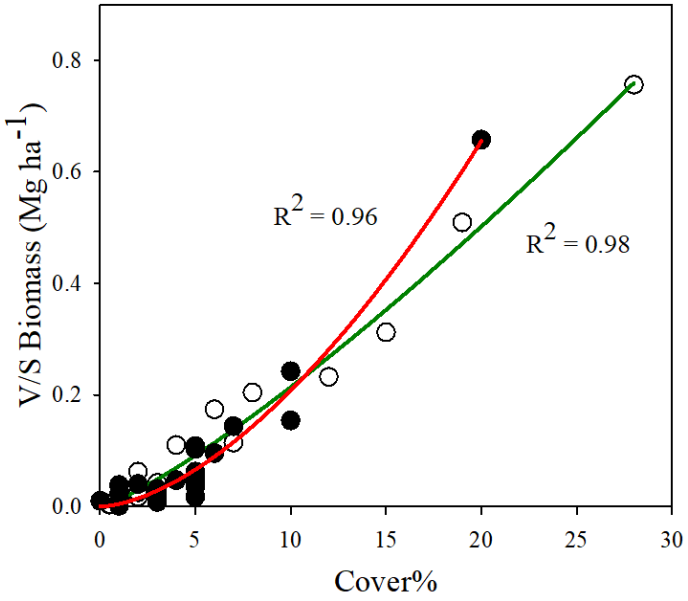
- Biodiversity at species level (richness and abundance, in main plot)

CoSInE Study Methods





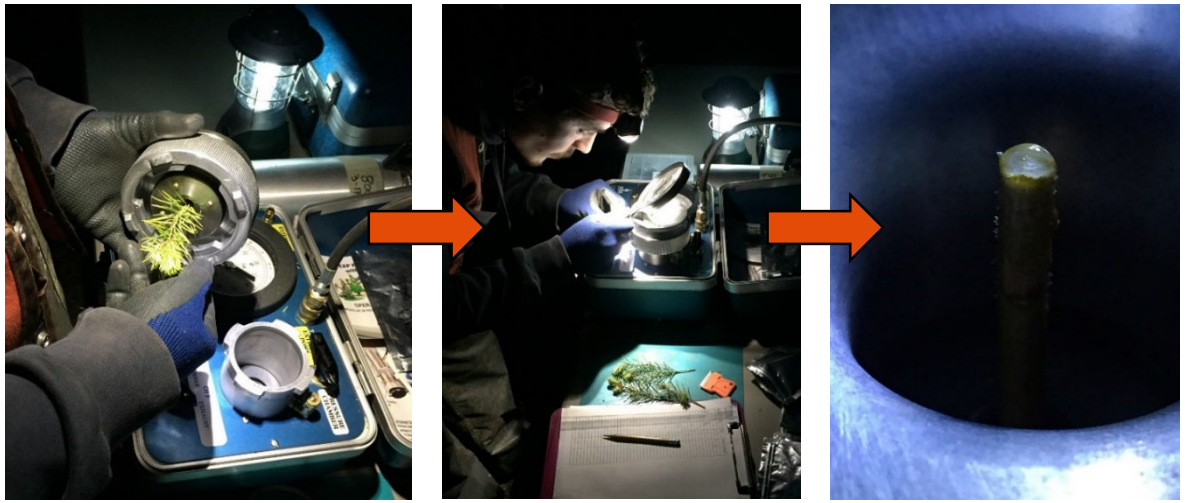




Eco-physiological Measurements

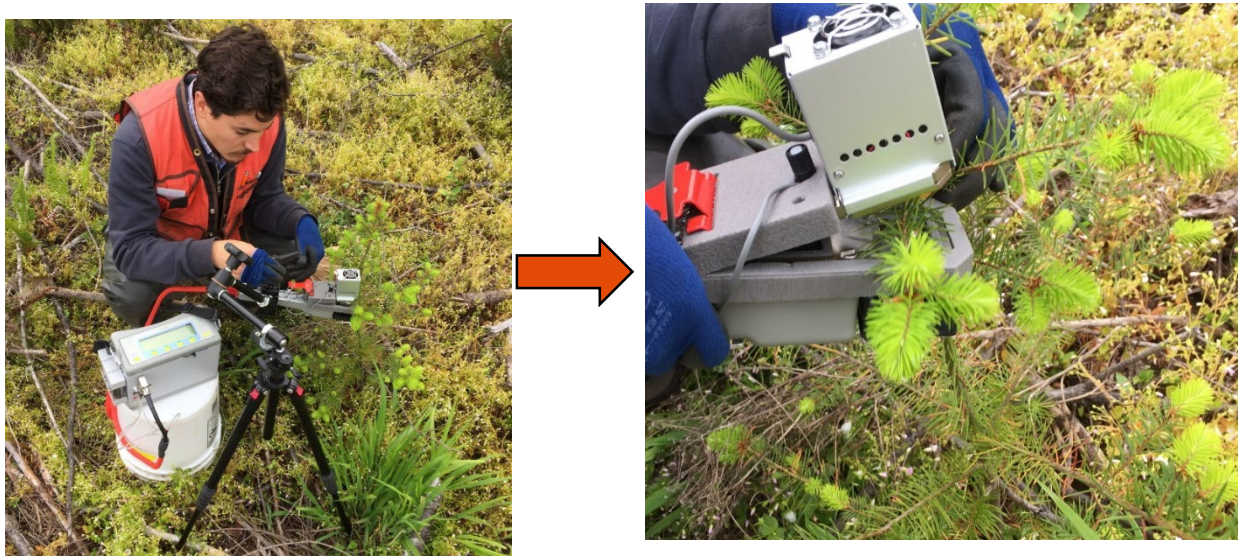
Monthly (April – Oct):

- Xylem water potential [MPa]
  - Pre-dawn
  - Mid-day

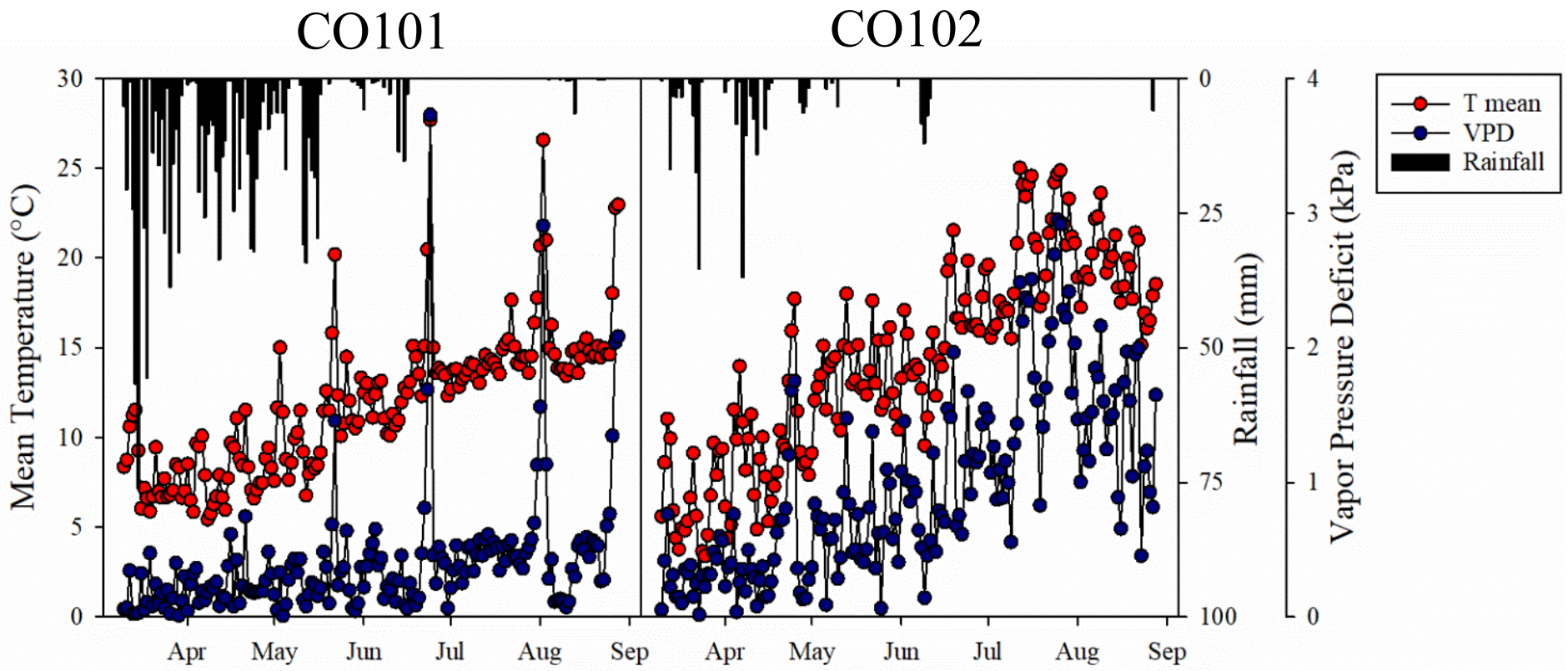


Additional measurements:

- Stem hydraulic conductivity
- Photosynthesis rate and stomatal conductance
- Fluorescence (ΔF/Fm')



Results: Weather conditions (Growing Season 1)

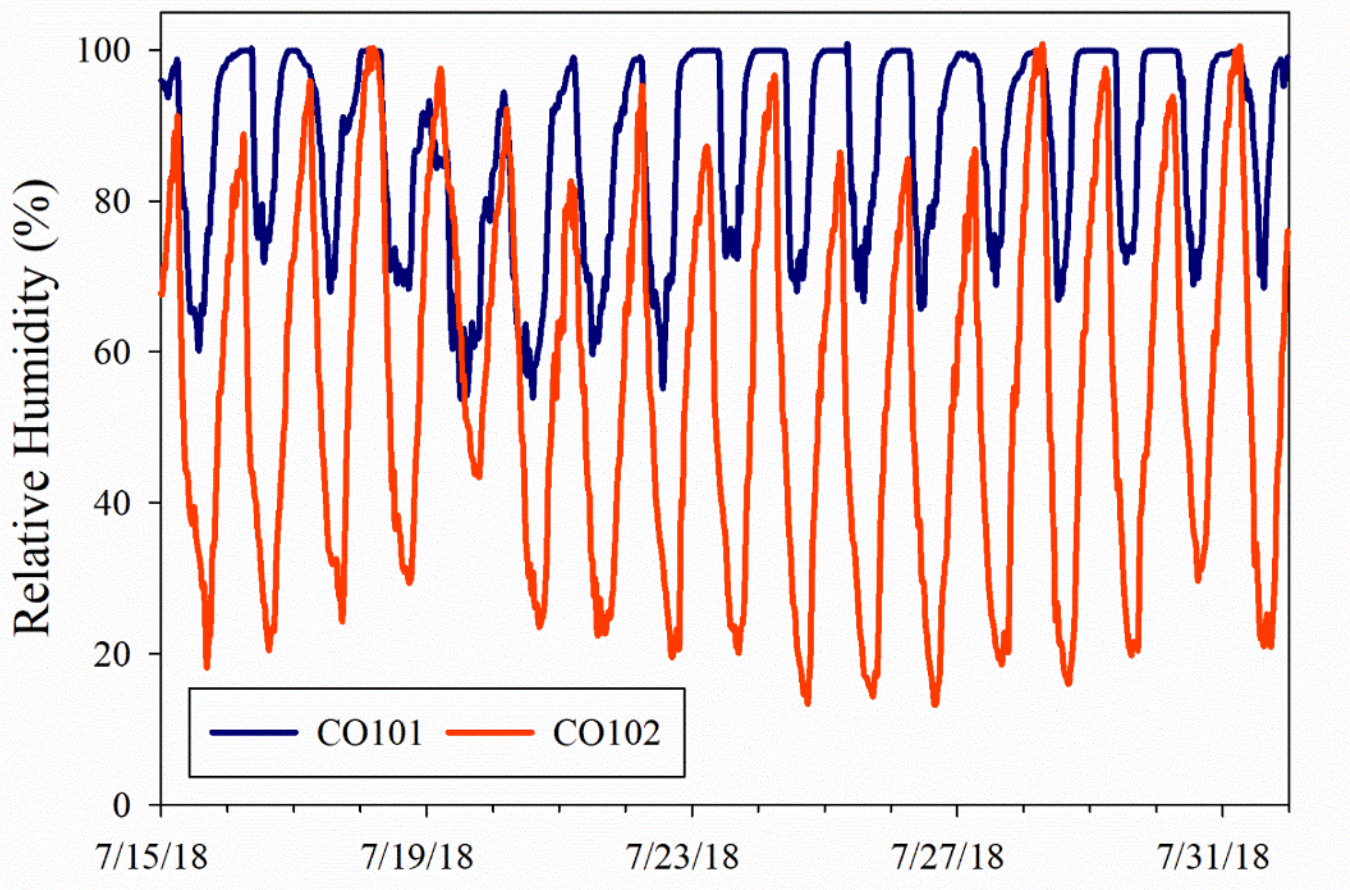


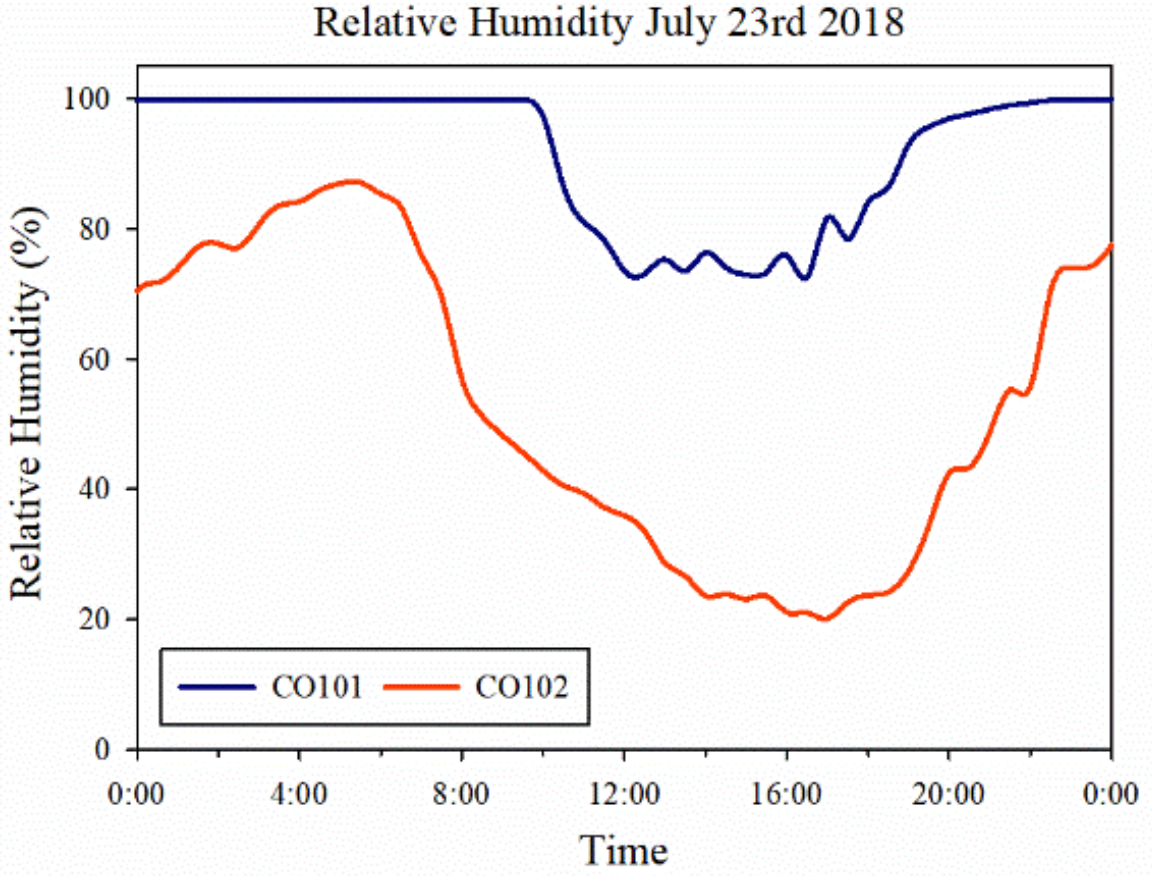
March 10 – Aug 28

2017	2018
Total rainfall: 1020 mm	Total rainfall: 251 mm
Mean Temp: 14.6 ˚C	Mean Temp: 18.4 ˚C
Mean VPD: 0.55 kPa	Mean VPD: 1.4 kPa

Results: Relative Humidity

Example of RH during 2 weeks in July





- CO101 Influence of the ocean
- CO102 higher evaporative demand

Results: Competing vegetation (Growing Season 1)

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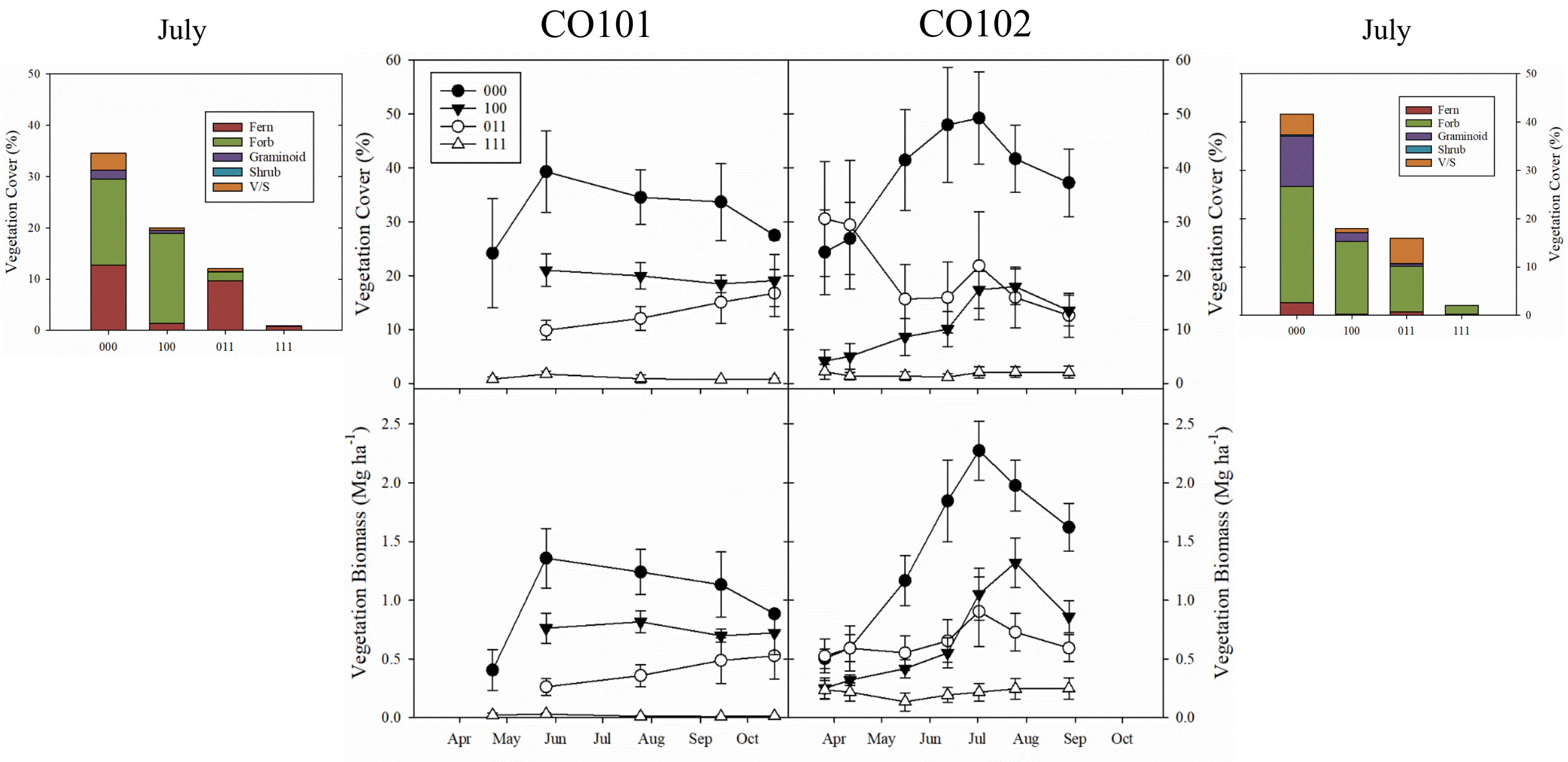
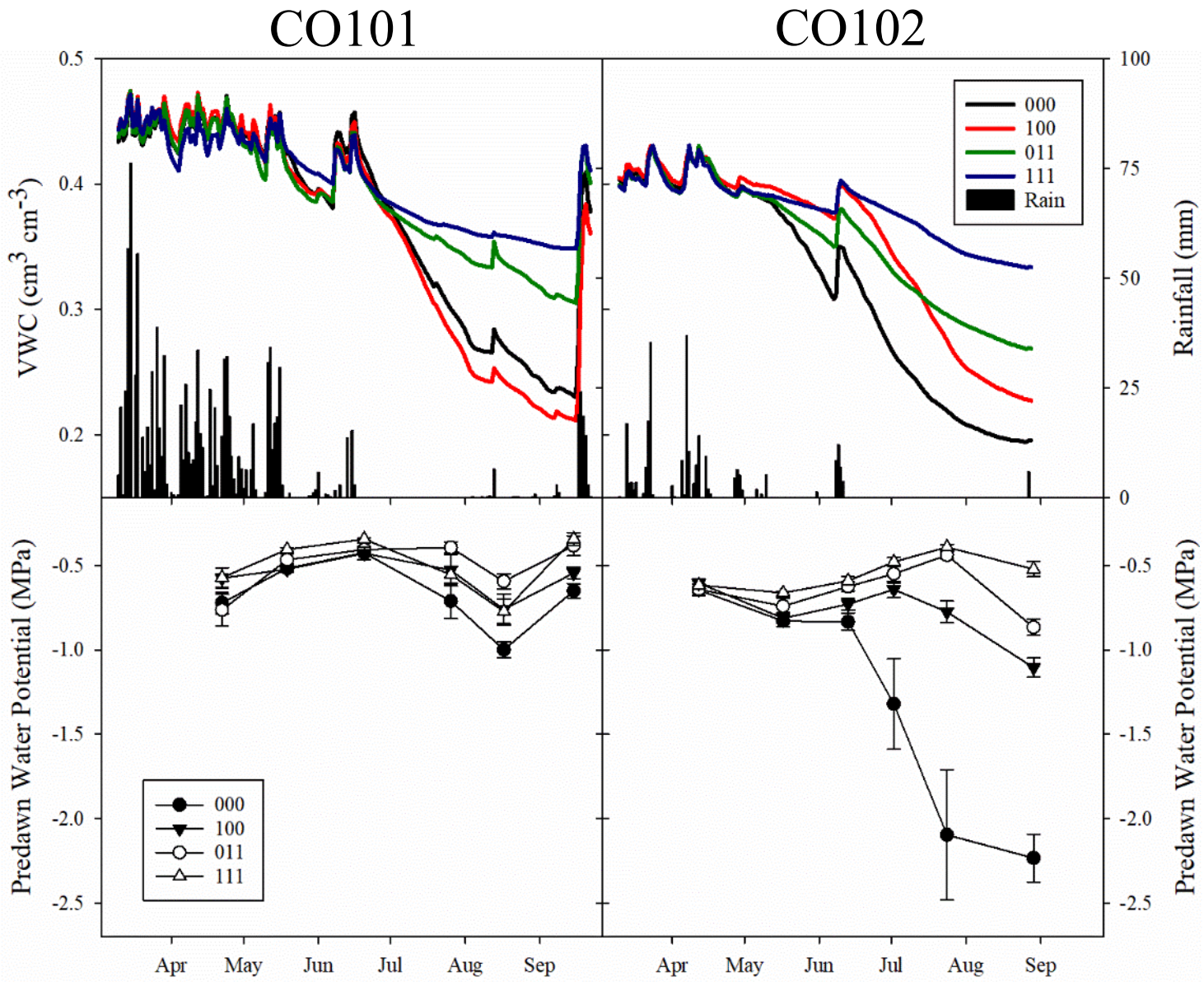
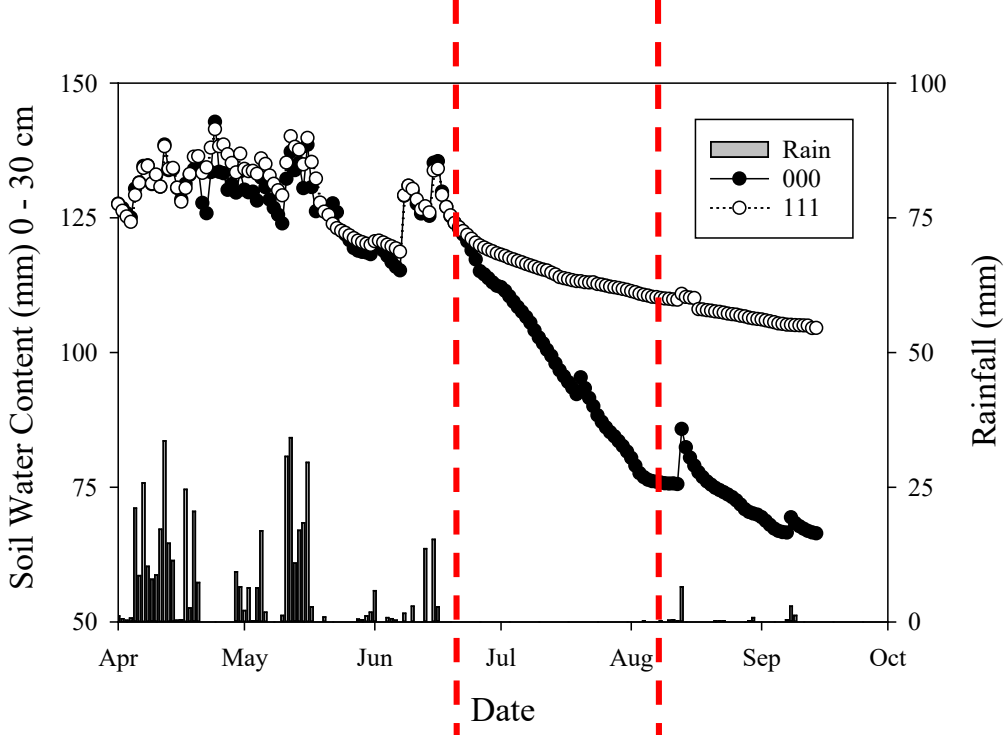


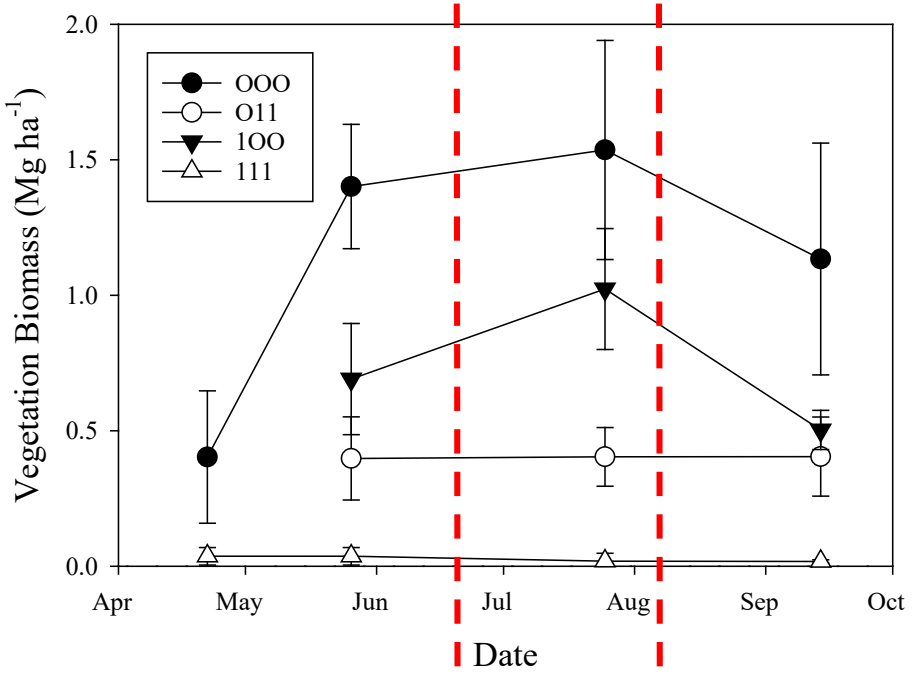
Results: VWC and Pre-dawn Water Potential (Growing Season 1)



Water Use by Vegetation



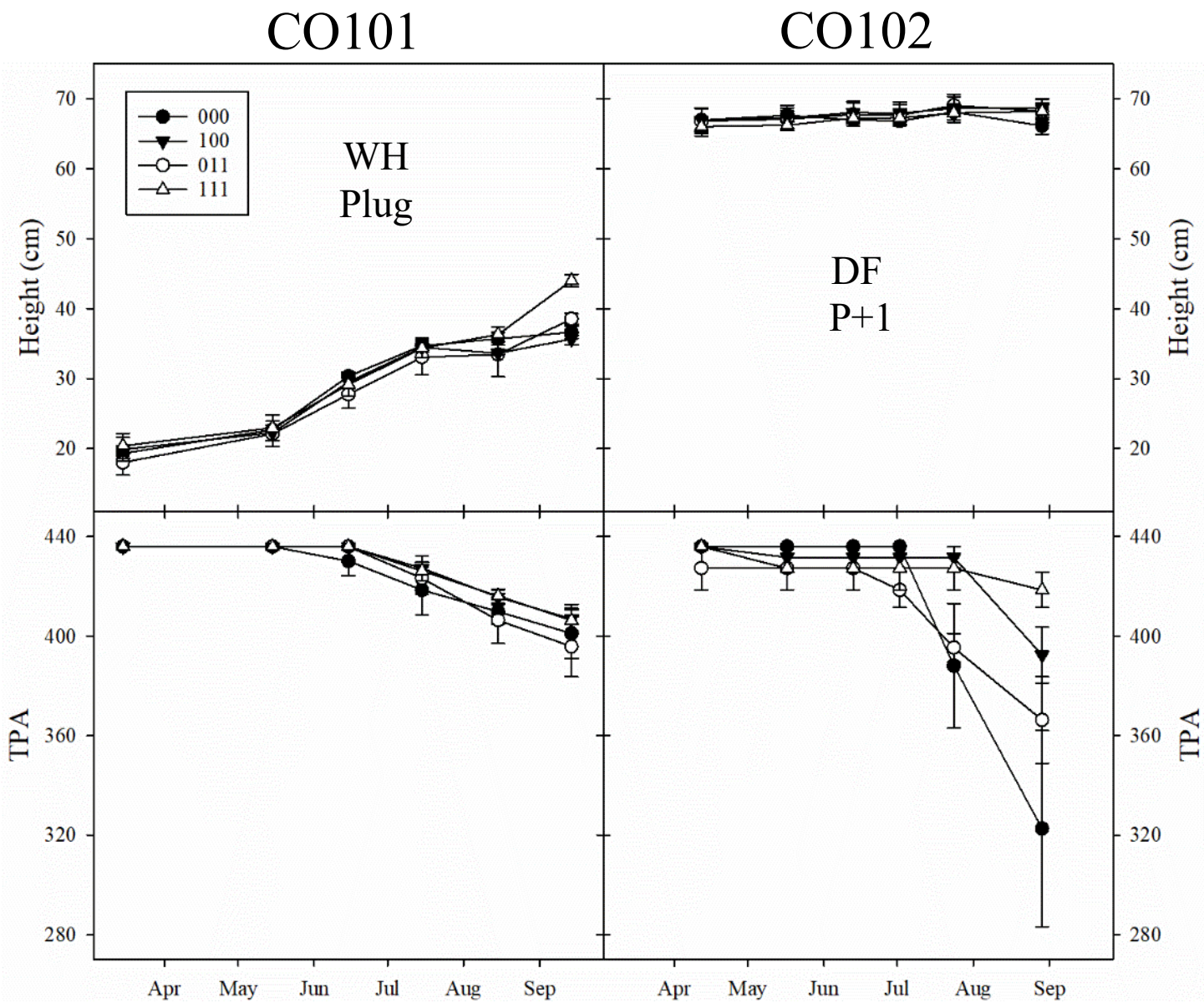
Δ Soil water content (mm in 46 days)
000 = 55 mm



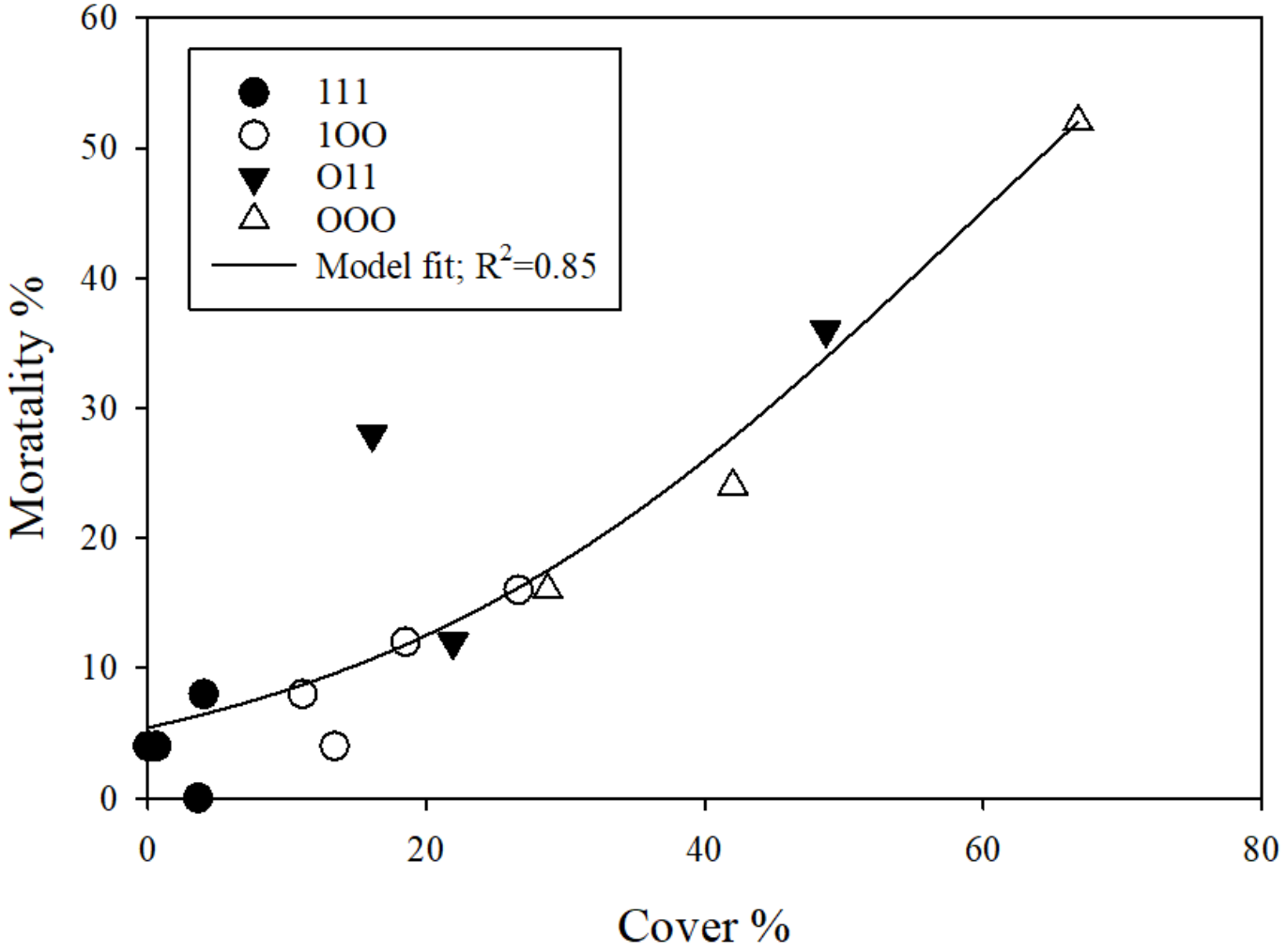
Biomass
000 = 1.48 Mg ha^{-1}

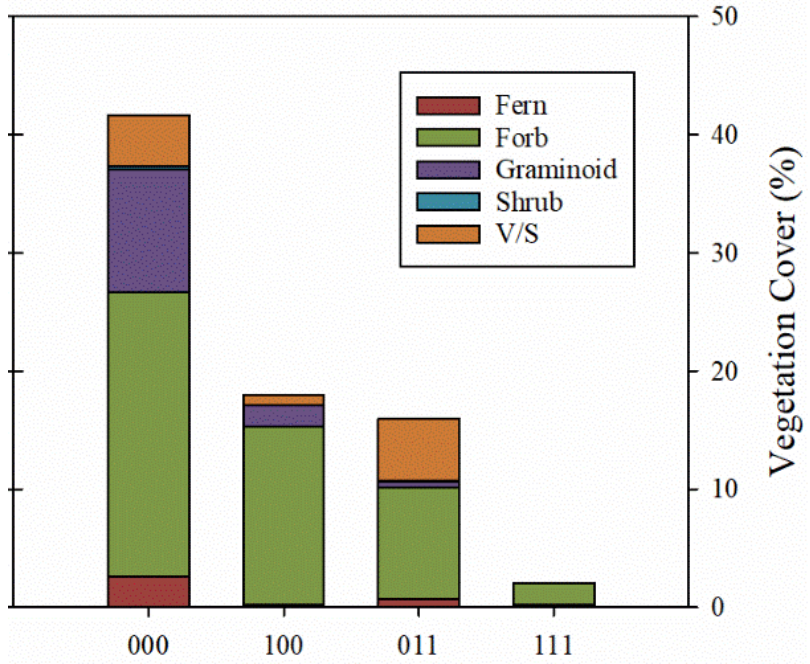
Water Use
000 = 24.7 mm / Mg / month

Results: Seedling Height and Mortality (Growing Season 1)



Effect of Competition on Seedling Morality





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 3-PG until canopy closure)
    - Include effects of climate, soil and FVM

CoSInE Expected Outcomes

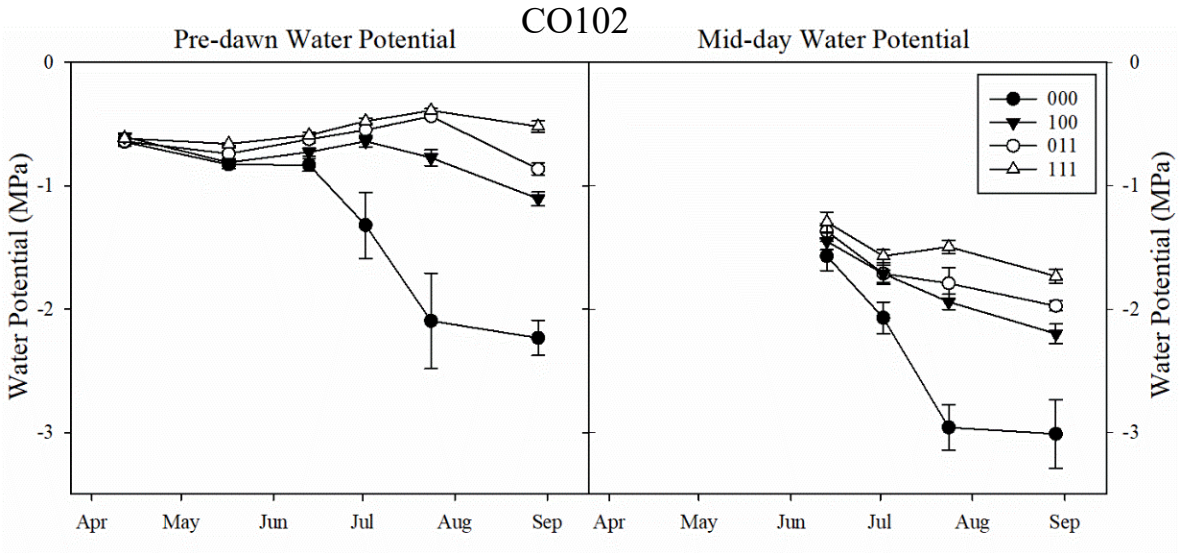
- Determine site specific vegetation cover thresholds for:
  - Minimizing mortality
  - Maximizing growth

- Determine % growth loss for different levels of vegetation cover

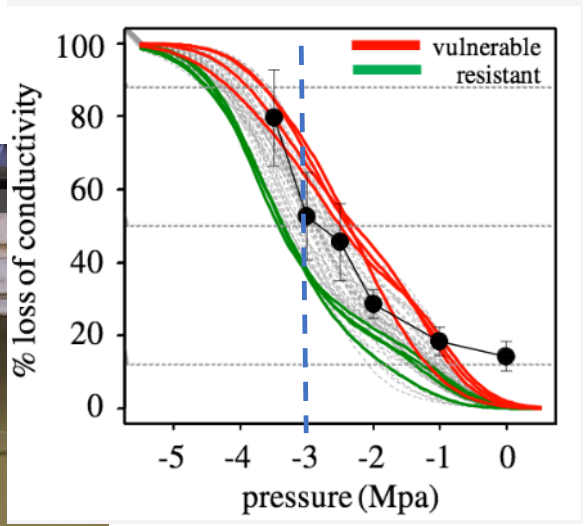
- Model conifer plantation growth and survival under different:
  - VM regimes
  - Climate and soil conditions

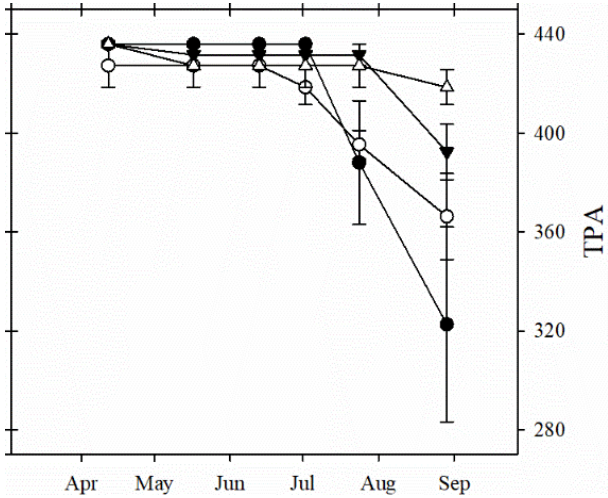
New Measurements

Next year 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

Acknowledgements

Vegetation Management Research Cooperative Members

Cascade Timber Consulting

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Greenwood Resources

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Lone Rock Timber

Olympic Resource Management

Oregon Department of Forestry

Oregon State University

Rayonier Inc.

Roseburg Forests Resources

Silver Butte

Starker Forests, Inc.

Washington Department of Natural Resources

Weyerhaeuser

Supporting Members

Dow Chemical

Helena Chemical

Stuewe and Sons

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Results: Seedling Browsing Damage (Growing Season 1)