GMUG 2026

April 22, 2026
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- **Carbon accounting**
- **VMRC-derived estimates of juvenile mortality**
- **Juvenile plantation height increment**
- **CAFS projects: SAE and enhancing G&Y models with open data**

Carbon accounting within CIPSANON

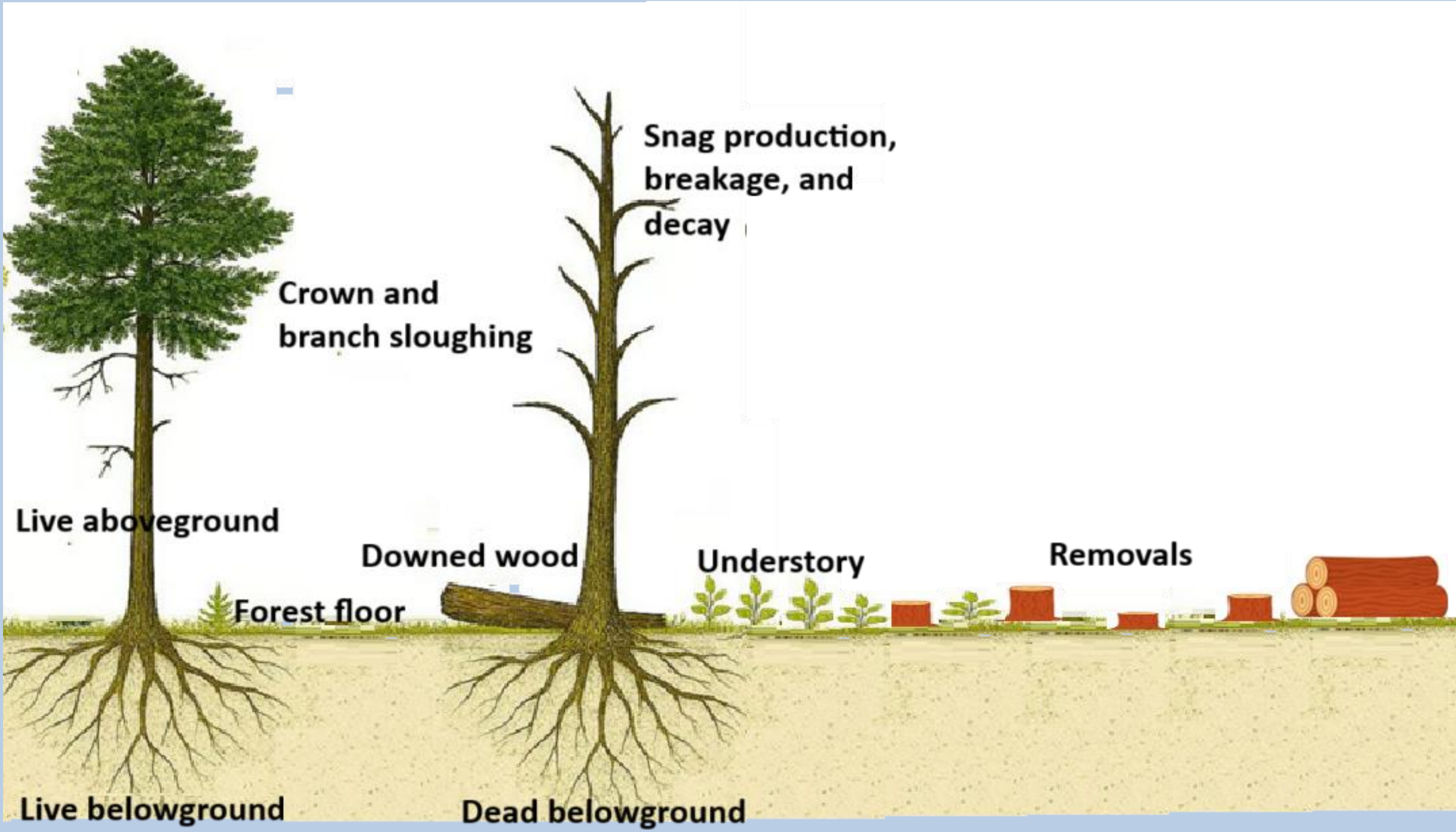
- **CIPS objective: produce carbon accounting methodology and estimates acceptable to ACR**
  - Provides members a potential source of revenue through use of carbon projects
  - American Carbon registry is a carbon crediting program operating in global compliance and voluntary carbon markets
  - ACR-acceptable projects currently requires use of FVS for G&Y and carbon estimates

- **Will require independent 3rd party review to satisfy meeting ACR guidelines**

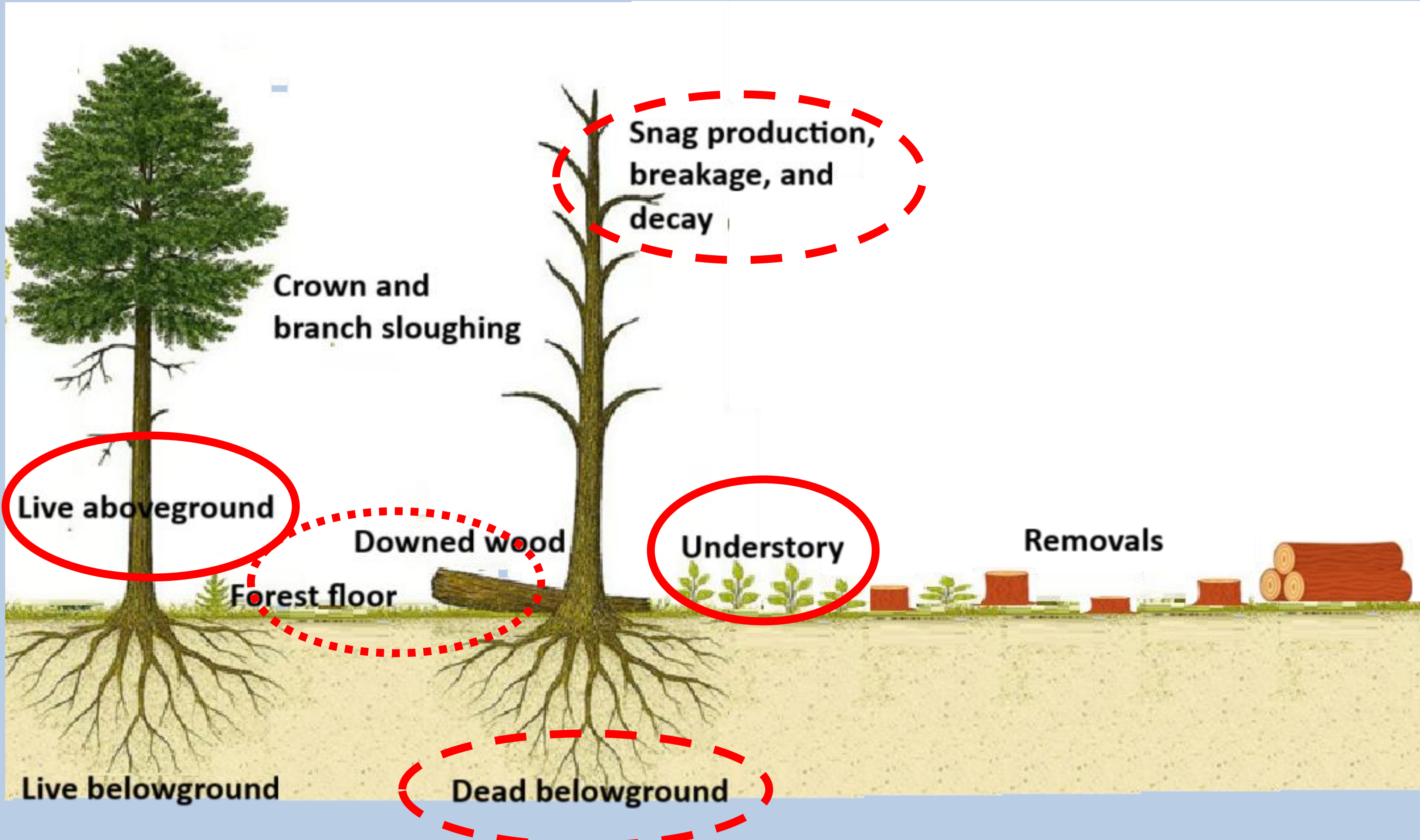
Carbon accounting within CIPSANON

- **Starting point: FVS**
  - FVS methodology/output is currently accepted by ACR
  - Use FVS source code as a guide
  - FVS FORTRAN source code is available on GITHUB
  - Customize code for CIPSANON
    - Replace equations where improvement is possible
    - Add equations where shortcomings are identified
    - Make changes to enable code to work with our system

Carbon accounting components



Carbon accounting components



Carbon accounting within CIPSANON: methods

- **Aboveground live tree carbon**
  - FVS
    - Uses Jenkins et al. (2003) national biomass estimators, based on DBH-only biomass equations
  - CIPSANON
    - Uses NARA biomass equations for Douglas-fir (DBH, height, and crown size)
    - Uses Poudel and Temesgen equations for western hemlock and red alder (DBH and height)
    - Uses DBH-only Jenkins et al. (2003) equations for all other species

Carbon accounting within CIPSANON: methods

- **Understory vegetation carbon**
  - FVS
    - Provides fixed values for herbs and shrubs for stands with 10% canopy cover (CC) and 60% CC
    - Estimates CC of input treelist and calculates linear interpolation of carbon quantity between maximum (10% CC) and minimum (60% CC)
    - Value never drops below minimum (60% CC)
  - CIPSANON
    - Outputs annual estimate of understory cover based on dynamic veg cover equation
    - Understory biomass estimated from percent cover based on data collected in 2012 by Kristin Coons on 8 VMRC sites, aged 1-20 years

Carbon accounting within CIPSANON: methods

- **Snag carbon**
  - FVS
    - Accounts for dead trees, based on 2-inch dbh classes and 2 height classes
  - CIPSANON
    - Accumulates annual list of dead trees, based on 1-inch dbh classes and 10-foot height classes
    - Estimates initial snag carbon, based on prediction of annual “snag production”: predicted from projections of 60 operational treelists of various site productivities
    - Uses FVS rates of fall, breakage and decay from most common conditions of PN variant

Carbon accounting within CIPSANON: methods

- **Belowground dead tree carbon**
  - CIPSANON
    - Uses same 4.25% annual decay rate as FVS for dead trees
    - Also includes estimate of carbon content of decaying root biomass from previous stand

- **Downed wood and forest floor carbon, initial**
  - FVS uses fixed values for downed wood and forest floor by size class for stands with 10% canopy cover (CC) and 60% CC by dominant species type
  - CIPSANON
    - Estimated quantity of downed wood from residuals following clearcut is ~90% of FVS fixed value from 10% CC
    - FVS estimate from 60% CC is 2.2x that of 10% CC

CIPSANON versus FVS carbon output, initial estimates

- **Primary initial differences due to:**
  - Different biomass equations
  - Accounting for dead roots of previous stand
  - Estimating typical snag content due to dying trees
  - Different assumptions about initial downed wood and forest floor
  - Dynamic understory vegetation

System	unit	cycle	stage	AG_TREE	AG_MERCH	LIVE_ROOT	DEAD_ROOT	SNAG	DOWN_WOOD	FOR_FLOOR	UND_VEG	TOTAL
CIPSANON	1	0	6	0.29	0	0.08	17.7	0	13.4	4.62	2.55	38.65
CIPSANON	2	0	15	21.67	6.43	4.73	10.41	0.1	13.4	4.62	0.25	55.19
CIPSANON	3	0	30	44.12	30.16	9.51	6.7	3.09	13.73	4.62	0.17	81.94
CIPSANON	4	0	40	103.81	85.01	22.19	4.23	4.91	14.22	4.62	0.17	154.15
FVS	1	0	6	0.45	0.00	0.05	0.00	0.00	14.25	5.07	1.15	20.97
FVS	2	0	15	17.43	2.70	5.21	0.00	0.00	29.80	13.32	0.20	65.96
FVS	3	0	30	36.18	23.08	9.14	0.00	0.00	29.80	13.32	0.20	88.64
FVS	4	0	40	81.05	60.57	19.45	0.00	0.00	29.80	13.32	0.20	143.82

Testing the VMRC method of estimating site and condition-specific juvenile mortality

- Seedling mortality is driven by drought stress, species physiology, vegetation competition, and climate variability.
- VMRC has developed equations that:
  - Predicts soil water content from soil water capacity, evapotranspiration, competing veg cover, and climate
  - Predicts pre-dawn water potential (PDWP) from soil water content
  - Predicts mid-day water potential (MDWP) from PDWP, relative humidity and max temp
  - Predicts percent loss of hydraulic conductivity (PLC) from MDWP
  - Predicts seedling mortality from PLC
- Question: Is there value to incorporating this method into CIPSANON?

Testing the VMRC method of estimating site and condition-specific juvenile mortality

- **Input data**
  - Climate data from PRISM
  - Climate rasters generated from ClimateNA
  - Plant available water, soil bulk density estimates from NRCS soil raster
  - VMRC equation parameters published in Claudio Guevara’s dissertation

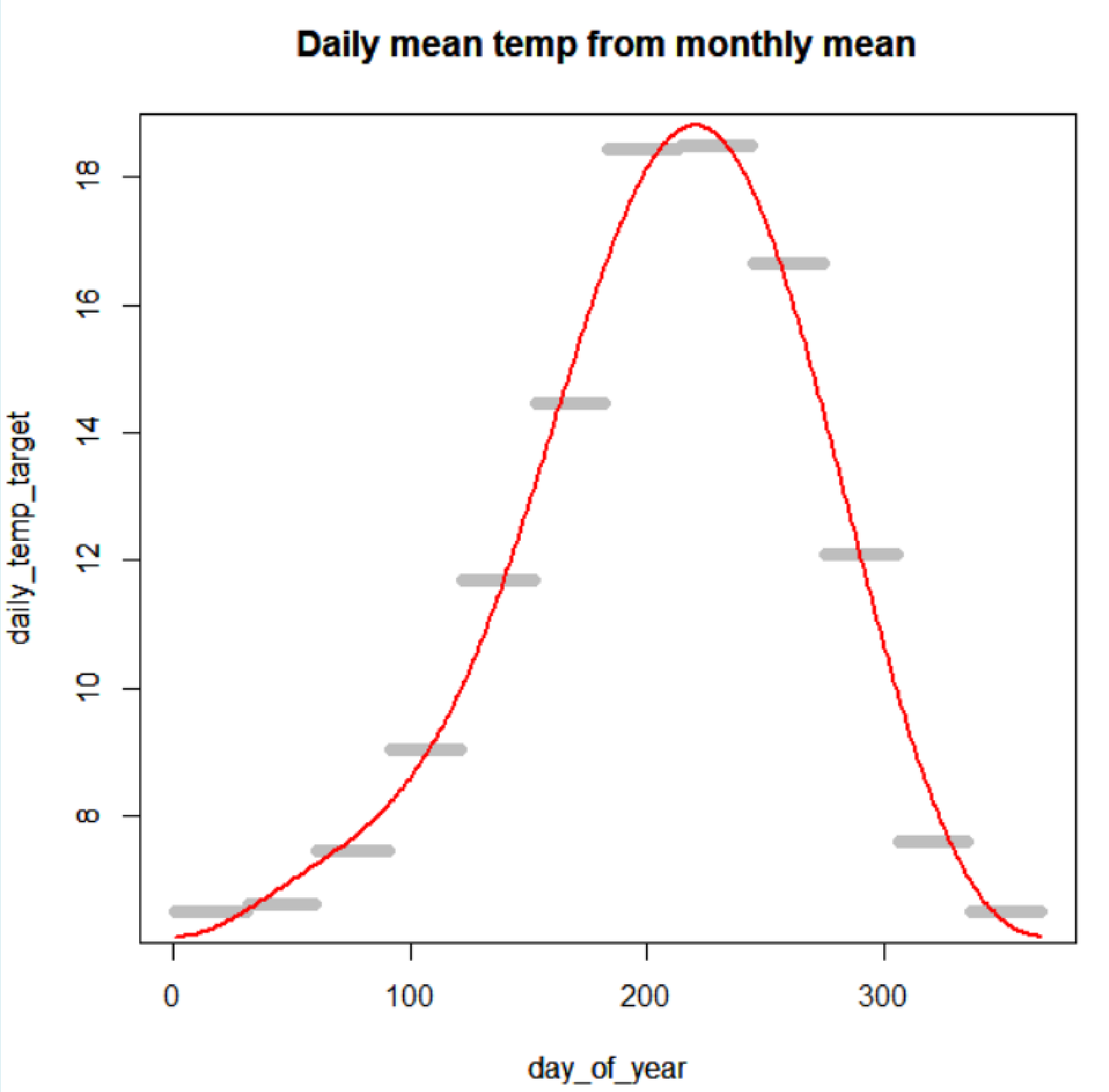
- VMRC method based on daily time step with daily climate data…can this be properly replaced using monthly data?

Testing the VMRC method of estimating juvenile mortality

- For upcoming IUFRO conference, we'll be comparing the relative merits of using daily climate data versus interpolated monthly climate data for predicting juvenile mortality and tree and stand growth

Daily temperature interpolations

- Monthly mean temps extracted from raster based on input lat-longs
- Interpolated daily temps from monthly means using Fourier regression

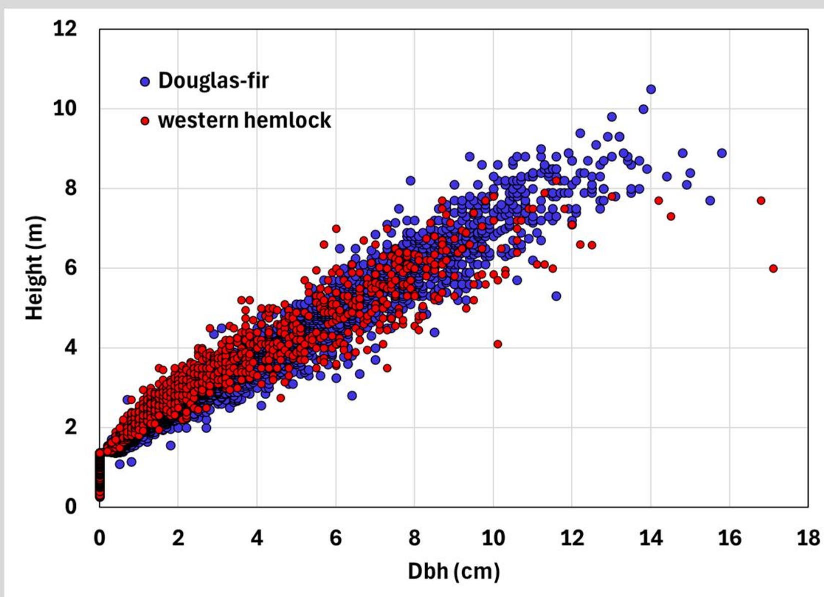


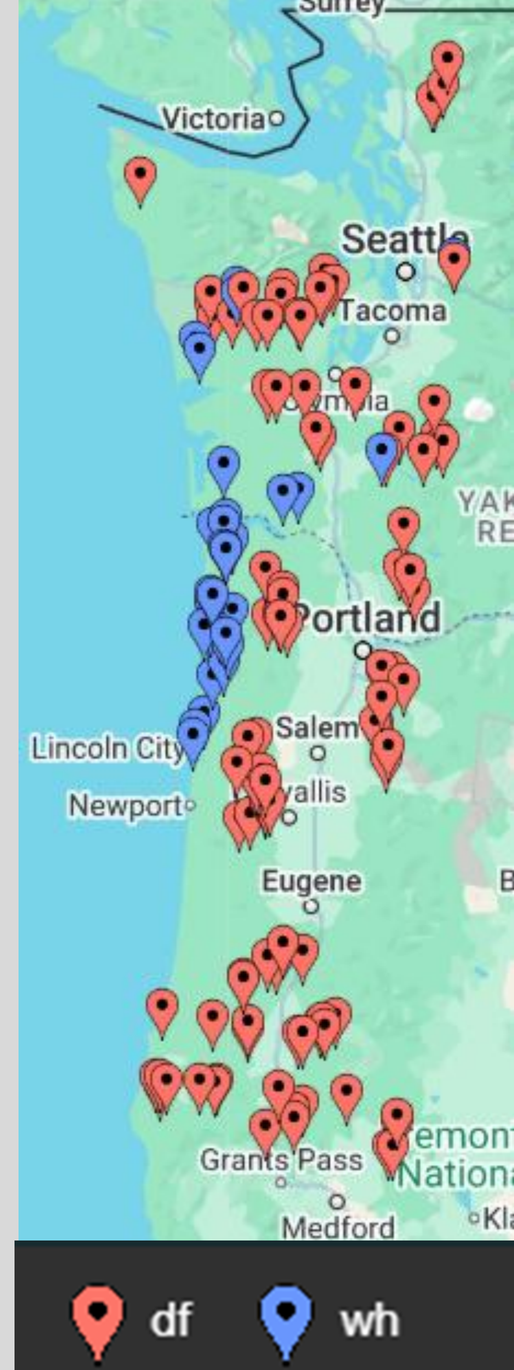
Daily precip interpolations from monthly totals

- Predicted rain days per month by growing season month, climate type (years representing dry, normal or wet conditions), and level 3 ecoregion
- Used exponential distribution to predict daily precip by month, climate type, and level 3 ecoregion
- Used random number generation to assign timing of rain throughout month such that sum of daily equals monthly total
- Quantity of interception depends on whether or not rain days were consecutive
- ***Final testing still to come…***

Operational tree generator

- **Douglas-fir**: 100 sites
- **Western hemlock**: 30 sites
- **Objectives**
  - Produce a treelist generator based on height-diameter distributions found within operational plantations
    - Representing geographic and management range of CIPS members
    - 3-10 year old plantations



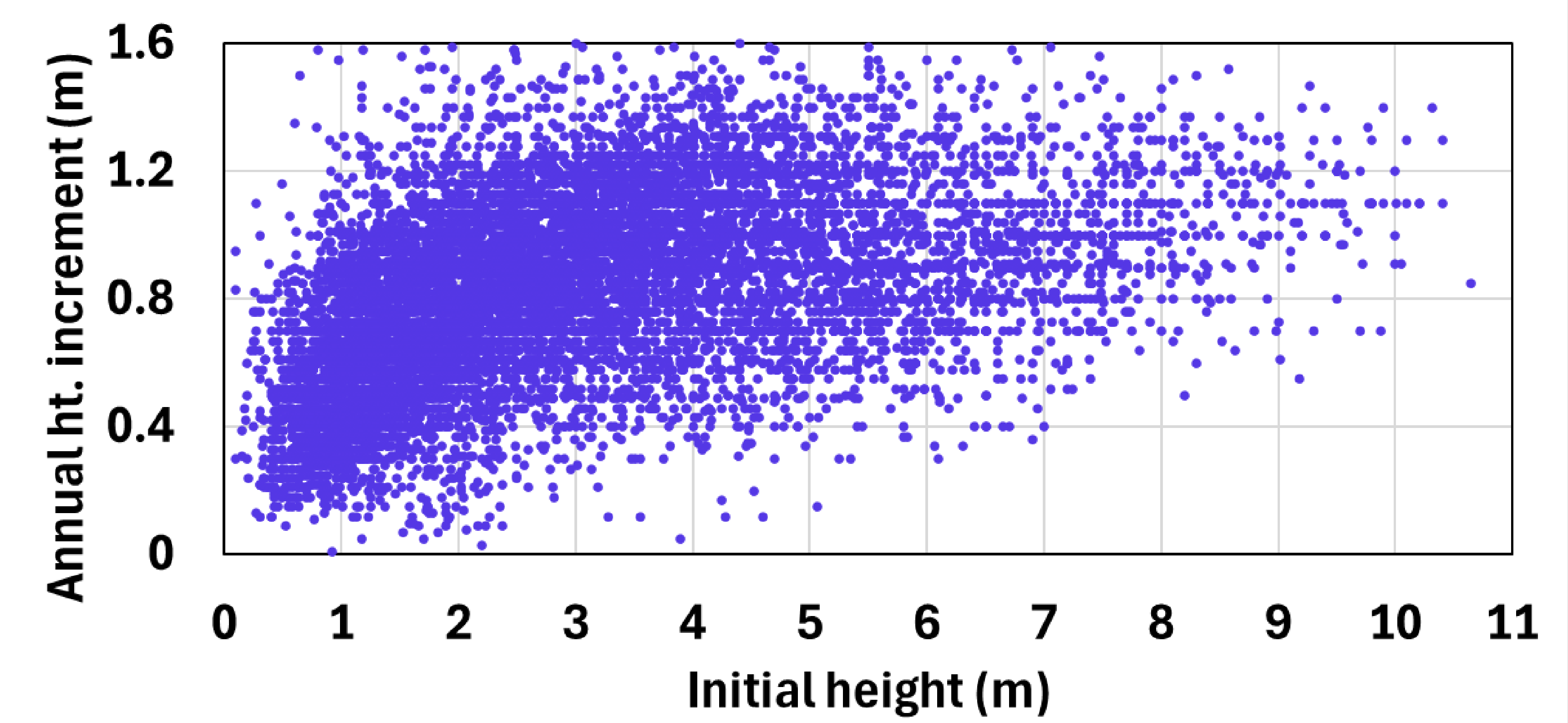


Validation of juvenile increment

- **Remeasurement of tree_gen plots**
  - Construct an independent validation plot network to test fitness of juvenile component of increment equations
  - Measurements:
    - 2-year DBH increment
    - Annual height increment since plot establishment, and annual height increment as far back as possible
  - Plots installed over 2 seasons… group 1 remeasurements now complete

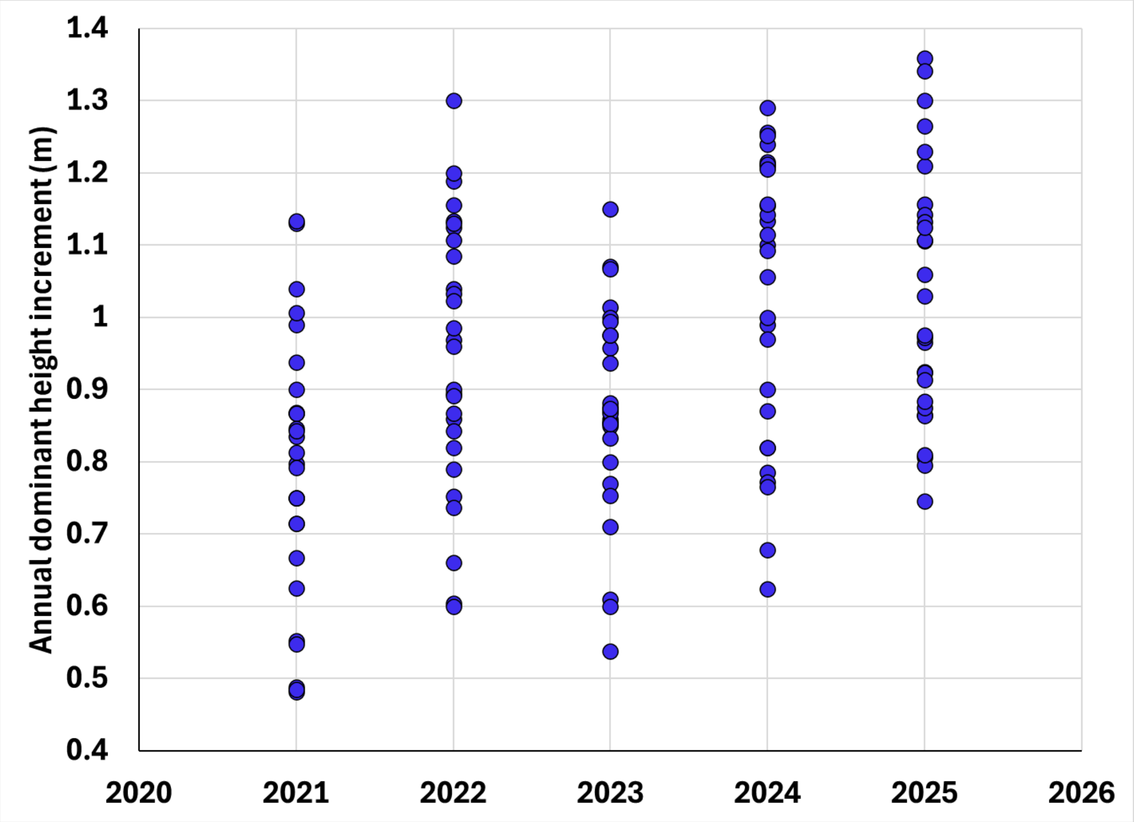
Pre-crown closure annual height increment

- All Douglas-fir trees from 65 plots
- Covers initial plantation ages from 3 to 10 years



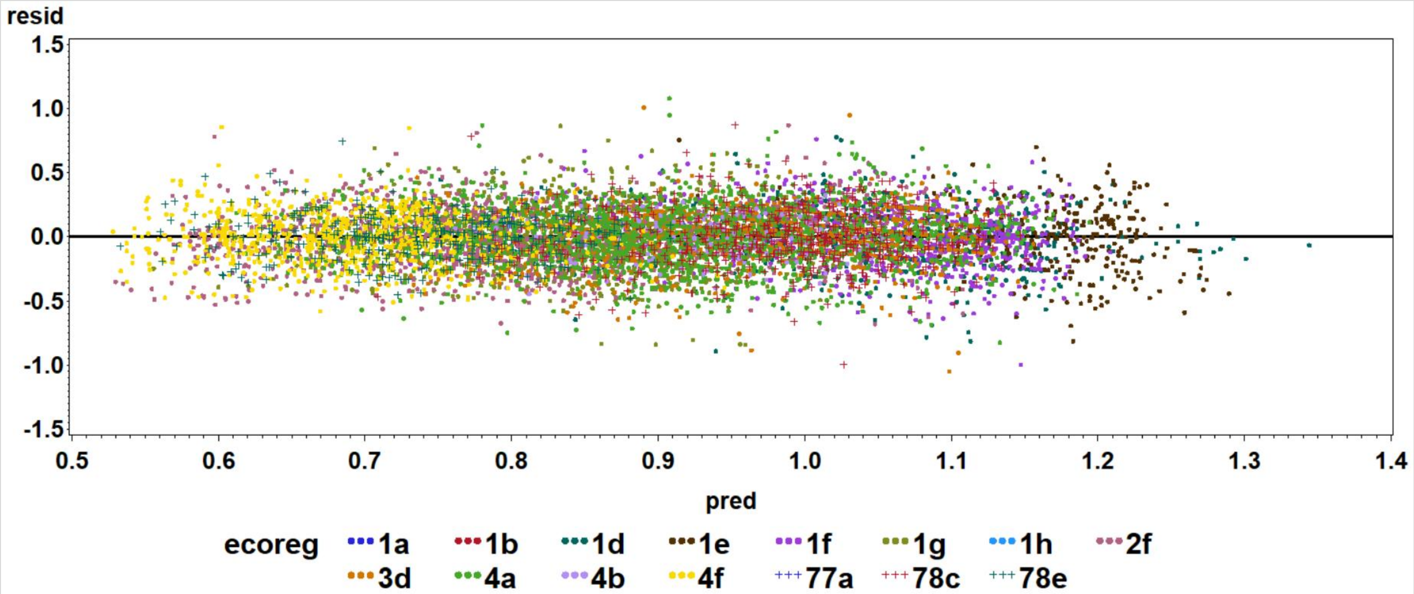
Pre-crown closure dominant height increment: climate dependency

- Dominant height increment on 30 plots for which 5 years of annual height increment is available
- Demonstrates year to year climate-related effects on dominant height increment



Modeled height increment

- Made initial comparisons of CIPSANON-predicted height increment in juvenile plantations to modeled annual measurements
  - CIPSANON prediction based on SI-based potential height increment, CCH, CR from all age dataset
  - **Juvenile height increment = f(relht, soil, climate, ecoreg)·(exp(a_1/initial height))**



Modeled height increment

- Better fit of juvenile model speaks to poor conformity of juvenile increment to current Bruce SI dominant height curve at young ages

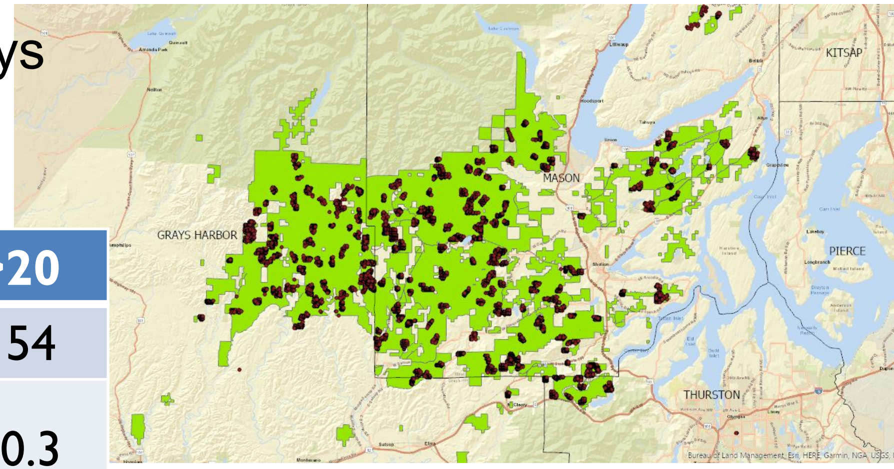
- Size-related bias in CIPSANON estimates of juvenile height increment (compared to tree_gen measurements) affect accurate predictions of differentiation, long term G and Y estimates

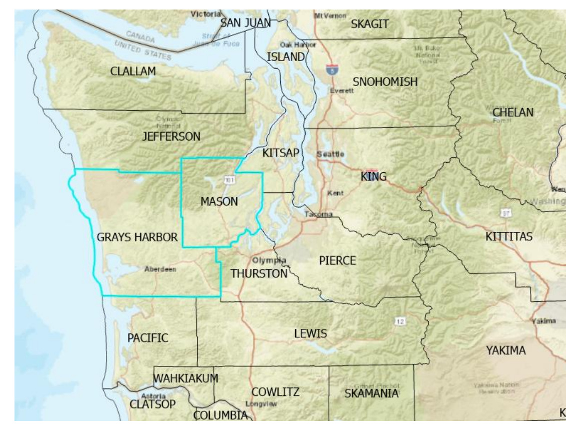
- ***More to come…***

SAE project 1: Multivariate SAE estimation of stand variables

- Washington area focusing on Grays Harbor and Mason Counties
  - Industry data

Plots/Stand	1-5	6-10	11-20	>20
n	1	7	57	154
Percentage (%)	0.5	3.2	26	70.3





- Response variables: TPA, BA (ft²/ac), merchantable volume (CFV, ft³/ac)
- Auxiliary variables: 3D-NAIP and Sentinel-2

SAE project 1: Multivariate SAE of stand variables

Modeling approach

- Joint modeling of TPA, BA, and CFV with a multivariate mixed model
- Trait-specific intercepts, fixed effects and residual variances
- Stand-level random effects modeled jointly as a 3x3 covariance matrix, allowing the model to estimate variable co-variances beyond what's explained by the remote sensing variables
- Plot-level residuals assumed independent across traits

- Results compared to univariate approach

SAE project 1: performance comparison

Method	TPA RMSE	BA RMSE	CFV RMSE	TPA RMSE (%)	BA RMSE (%)	CFV RMSE (%)
Direct	25.3	11.7	369.5	8.4	8.1	9.6
Univariate	20.6	10.1	343.4	6.8	7.0	8.9
Multivariate	20.8	8.6	295.4	6.9	5.9	7.7

- Incorporation of remotely sensed data improved estimate of all variables
- With the exception of TPA, the multivariate model provided better estimates than the univariate model

Additional CIPS SAE projects include:

1) The development of similar models using unfuzzed FIA data across western Washington, validated with independent cruise and stand exam datasets from industry and state partners
2) Statewide (Oregon) estimation of forest biomass

Recent CIPS-related publication in *Forestry (2026)*

A comparison of single-date and multi-date LiDAR-based predictions of Douglas-fir site index in the Western USA

Suchana Aryal[1,*], Hailemariam Temesgen[1], Jacob Strunk[2]

- Assessed remotely-sensed site index estimates in Douglas-fir dominated areas in NW Oregon (Panther Creek) and NW California using:
  - Field-determined age and single scan LiDAR heights
  - Two-scan LiDAR heights (6 or 10 year difference)
  - LiDAR heights were bias-adjusted against field measured canopy heights prior to SI estimate

- Oregon SI RMSE: single 13%; double 12%
- California SI RMSE: single 9%; double 13%
- Both approaches deemed operationally feasible for inventories

CAFS phase 4 project

Enhancing GY Model Accuracy and Transferability Through Open Data

PI: Temesgen Hailemariam (Oregon State University)

Academic/Industry/Federal Partners: Oregon State University, USFS FIA, Green Diamond, University of Maine

- Seeks to improve the accuracy and transferability of growth and yield models by integrating open data sources such as 3D NAIP, lidar-derived terrain, digital soil information, and climate products into modern modeling frameworks.


Questions?