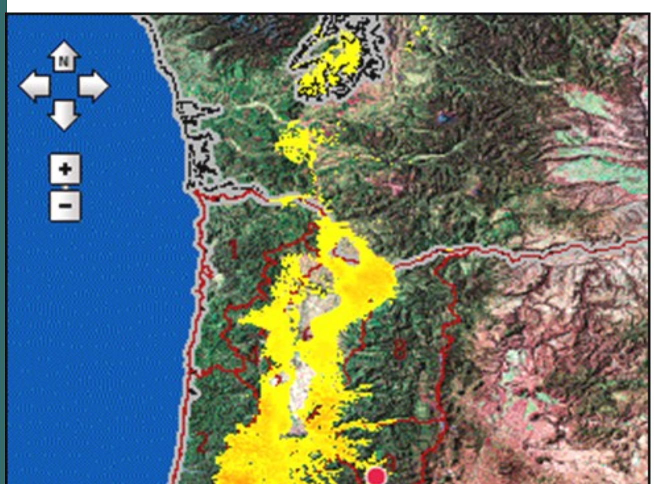
PNWTIRC

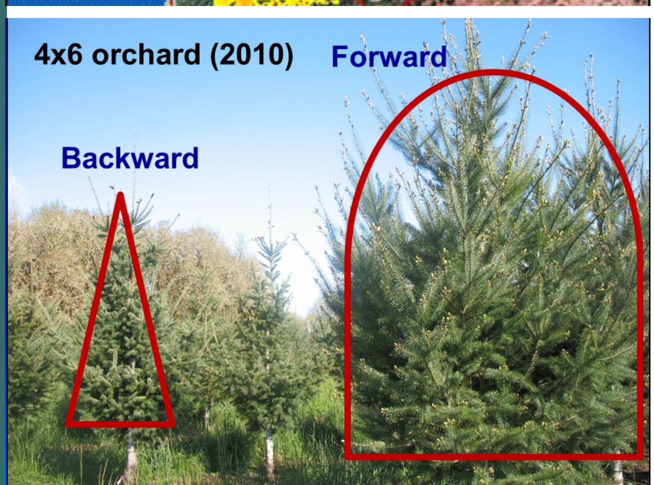
Pacific Northwest Tree Improvement Research Cooperative

Annual Report 2010-2011

Oregon State University College of Forestry
Department of Forest Ecosystems and Society

Glenn Howe, Lauren Magalska, Ron Beloin, J. Bradley St.Clair, Scott Kolpak, Oguz Urhan





http://www.fsl.orst.edu/pnwtirc/

PACIFIC NORTHWEST TREE IMPROVEMENT RESEARCH COOPERATIVE

Oregon State University College of Forestry
Department of Forest Ecosystems and Society

2010-2011 Annual Report

Report authors
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Pacific Northwest Tree Improvement Research Cooperative

Annual Report 2010-2011

The Pacific Northwest Tree Improvement Research Cooperative (PNWTIRC) was formed in 1983 to conduct research in support of operational tree improvement in the Pacific Northwest. Emphasis is on region-wide topics dealing with major coniferous species. Membership has included representatives from public agencies and private forestry companies in western Oregon, western Washington, and coastal British Columbia.

OUR MISSION IS TO:

- Create a knowledge base concerning genetic improvement and breeding of Pacific Northwest tree species.
- Develop reliable, simple, and cost-effective genetic improvement methods and apply these methods to solve tree-breeding problems.
- Promote effective collaboration and communication among public agencies and private industries engaged in tree improvement in the region.

All participants provide guidance and receive early access to research results. Regular and Associate members provide financial and in-kind support and are represented on the Policy/Technical Committee. This committee is responsible for making decisions on program strategy and support, identifying research problems, establishing priorities, and assisting in the planning, implementation and evaluation of studies. Because Contractual Participants provide less financial support, they have no voting rights on the Policy/Technical Committee. Liaison Members provide no financial support and have no voting rights. The PNWTIRC is housed in the Department of Forest Ecosystems and Society at Oregon State University.

PNWTIRC PARTICIPANTS

Regular Members

Cascade Timber Consulting
Bureau of Land Management
Forest Capital Partners
Green Diamond Resource Company
Longview Timber Company
Olympic Resource Management
Oregon Department of Forestry
Oregon State University
Plum Creek Timber Company
Port Blakely Tree Farms
Rayonier
Roseburg Forest Products
Stimson Lumber Company
Washington State Department of Natural Resources

Associate Members

Starker Forests

Contractual Participants

Lone Rock Timber Company

Liaison Members

Inland Empire Tree Improvement Cooperative
Northwest Tree Improvement Cooperative
USDA Forest Service, Pacific Northwest Research Station

CONTENTS

AGENDA – WEDNESDAY SEPTEMBER 14, 2011

– ANNUAL MEETING –
PACIFIC NORTHWEST TREE IMPROVEMENT RESEARCH COOPERATIVE (PNWTIRC)

START TIME: 8:30 AM for coffee; 9:00 AM for presentations
LOCATION: McMenamin’s Edgefield, Troutdale, OR
LUNCH: Lunch provided

Time	**Topic**	**Responsibility**
8:30-9:00	Coffee	
9:00-9:10	Welcome and Introductions	Sara Lipow
9:10-9:30	Overview • *PNWTIRC accomplishments for 2010-11* • *CAFS overview and 2011 proposals* • *PNWTIRC plans for 2011-12*	Glenn Howe
9:30-10:10	Identifying site characteristics that explain variation in Douglas-fir productivity and stem form	Lauren Magalska
10:10-10:30	Break	
10:30-11:00	Early genetic selection for wood stiffness in Douglas-fir and western hemlock	Scott Kolpak Oguz Urhan
11:00-12:00	Updates • *Regional Approaches to Climate Change* • *Seed Transfer Tool* • *Center for Forest Provenance Data* • *CTGN survey*	 Glenn Howe Ron Beloin Brad St.Clair Michael Coe
12:00-1:00	Lunch	
1:00-1:30	Budget and Other Business • Budget presentation and vote • Elect new Policy/Technical Committee Chair	Glenn Howe
1:30-2:10	Conifer Translational Genomics Network • Douglas-fir SNP chip • Future of Douglas-fir genomics research and application	Glenn Howe
2:10-2:30	Break	
2:30-2:55	Miniaturized Seed Orchard Project	Scott Kolpak
2:55-3:00	Wrap-up and adjourn	Glenn Howe

PNWTIRC Annual Meeting 2011

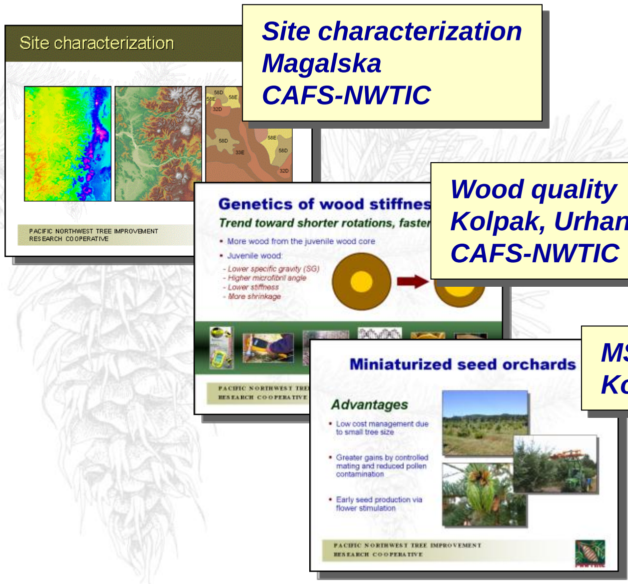
September 14, 2011

Pacific Northwest Tree Improvement Research Cooperative
Department of Forest Ecosystems and Society
Oregon State University

PNWTIRC personnel

2010-2011

- Director – ***Glenn Howe***
- Research Coordinator – ***Scott Kolpak***
- Program Manager – ***Liz Etherington***
- Graduate students – ***Lauren Magalska, Oguz Urhan***
- Policy/Technical Committee Chair – ***Sara Lipow***



Site characterization
Magalska
CAFS-NWTIC

Wood quality
Kolpak, Urhan
CAFS-NWTIC

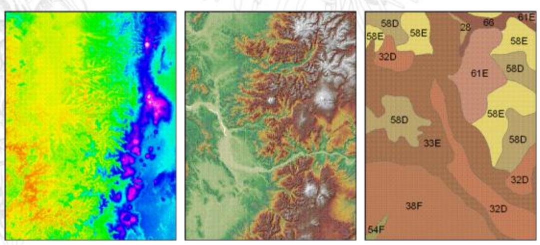
MSOs
Kolpak

PACIFIC NORTHWEST TREE IMPROVEMENT
RESEARCH COOPERATIVE

Highlights of 2010-2011

Site characterization research

- Data analyses and interpretations were completed during the summer
- Lauren will defend her thesis on September 16, 2011
- Lauren will present her conclusions to PNWTIRC members today



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Highlights of 2010-2011

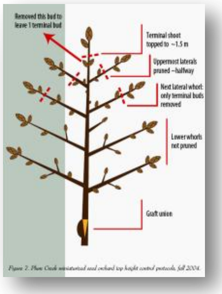
Wood quality research

- Published manuscripts
  - *Vikram, V., Cherry, M.L., Briggs, D., Cress, D.W., Evans R., and Howe, G.T. 2011. Stiffness of Douglas-fir lumber: Effects of wood properties and genetics. Canadian Journal of Forest Research 41:1160-1173.*
  - *Jayawickrama, K.J.S., Ye, T.Z., and Howe, G.T. 2011. Heritabilities, intertrait genetic correlations, GxE interaction and predicted genetic gains for acoustic velocity in mid-rotation coastal Douglas-fir. Silvae Genetica 60:8-18.*
- Funded a CAFS proposal entitled *"Early genetic selection for wood stiffness in Douglas-fir and western hemlock"* and began the associated research
  - *Scott Kolpak and Oguz Urhan will discuss*

Highlights of 2010-2011

Miniaturized Seed Orchard Study

- Trees were stimulated with girdling and calcium nitrate
- We measured the 2011 cone crop and completed the first analyses of crown volume and the cone crops in 2010 and 2011
- Scott will discuss



Plum Creek Miniaturized Seed Orchard

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Highlights of 2010-2011

Publications by PNWTIRC personnel

- Chmura, D.J., Anderson, P.D., Howe, G.T., Harrington, C.A., Halofsky, J.E., Peterson, D.L., Shaw, D.C., and St.Clair, J.B. 2011. Forest responses to climate change in the northwestern United States: Ecophysiological foundations for adaptive management. Forest Ecology and Management 261:1121-1142.
- Chmura, D.J., Howe, G.T., Anderson, P.D., and St.Clair, J.B. 2010. Adaptation of trees, forests and forestry to climate change. Sylwan 154:587-602.
- Jayawickrama, K.J.S., Ye, T.Z., and Howe, G.T. 2011. Heritabilities, intertrait genetic correlations, GxE interaction and predicted genetic gains for acoustic velocity in mid-rotation coastal Douglas-fir. Silvae Genetica 60:8-18.
- Vikram, V., Cherry, M.L., Briggs, D., Cress, D.W., Evans R., and Howe, G.T. 2011. Stiffness of Douglas-fir lumber: Effects of wood properties and genetics. Canadian Journal of Forest Research 41:1160-1173.

Highlights of 2010-2011

Presentations by PNWTIRC personnel

- Cronn, R., Kolpak, S., Jennings, T. 2011. Spatial patterns of genetic variation in Port-Orford-cedar: a view from the genome. Port-Orford-cedar Technical Team meeting. National Estuarine Research Reserve. Charleston, OR. May 16-17, 2011.
- Howe, G.T. 2011. Marker-informed program management: Concepts, benefits, and examples. International Symposium: Genomics-Based Breeding in Forest Trees, 22-24 June 2011, University of California, Davis, CA.
- Howe, G.T., Yu, J, and Kolpak, S. 2011. Genotype × phenotype association validation in Douglas-fir. Conifer Translational Genomics Network Annual Meeting, 21 June 2011, University of California, Davis, CA.
- Howe, G.T., Magalska, L.*, Jayawickrama, K., Ye, T., Fox, T., Burkhart, H., and Maguire, D. 2011. Effects of site and genetics on Douglas-fir growth, stem quality, and adaptability. Annual Meeting of the Center for Advanced Forestry Systems, 14-16 June 2011, Seattle, WA.
  *Presenter

Highlights of 2010-2011

Presentations by PNWTIRC personnel

- Howe, G.T., Kolpak, S.*, Urhan, O., Cress, D., Jayawickrama, K., and Ye, T. 2011. Early genetic selection for wood stiffness in Douglas-fir and western hemlock. Proposal poster presentation at the Annual Meeting of the Center for Advanced Forestry Systems, 14-16 June 2011, Seattle, WA. *Presenter
- Howe, G.T., Kolpak, S., Urhan, O*, Cress, D., Jayawickrama, K., and Ye, T. 2011. Early genetic selection for wood stiffness in Douglas-fir and western hemlock. Poster presentation at the Annual Meeting of the Western Forest Genetics Association Meeting, 25-28 July 2011, Troutdale, OR. *Presenter
- Magalska, L.E., Howe, G.T., Maguire, D. 2011. Douglas-fir Productivity and Near-Term Climate Change. National Workshop on Climate and Forests. Flagstaff, AZ. , May 16-18 2011.

Collaborations and grants

- **CAFS** ***Center for Advanced Forestry Systems.*** B. Goldfarb; H. Allen; H. Burkhart; T. Fox; G. Howe; K. Jayawickrama; R. Meilan; C. Michler; S. Strauss. NSF Industry- University Cooperative Research Center Program, 2007-2012, $1,450,000 (total), $250,000 (OSU).
- **CTGN** ***Conifer Translational Genomics Network.*** D. Neale; T. Byram; D. Harry; G. Howe; D. Huber; S. McKeand; J. Lee; N. Wheeler; J. Wegrzyn. USDA NRI Coordinated Agricultural Project Program. 2007-2011, $5,900,000 (total), $1,043,594 (OSU).
- **USFS Climate Change Research Program** ***Decision support tools for determining appropriate provenances for future climates.*** St.Clair, J.B., Howe, G.T., Crookston, N.L., Steigerwald, D., and Wright, J.W. USDA-Forest Service Climate Change Research Program, $328,560 (2008-present).

PACIFIC NORTHWEST TREE IMPROVEMENT RESEARCH COOPERATIVE

Collaborations and grants

- **USDA AFRI.** ***Western conifer forest systems: Strategies for climate change adaptation and mitigation.*** Howe, G.T., Tesch. S., Johnson, J., and Laurence, J. 2010. National Institute of Food and Agriculture, Agriculture and Food Research Initiative Climate Change Planning Grant, $50,000 (2010-2011).
- **USFS Rocky Mountain Research Station**. ***Developing a SNP panel for interior*** Douglas fir. Howe, G.T, and Cushman, S. USDA-Forest Service Joint Venture Agreement, $28,755 (2011-2012).

PACIFIC NORTHWEST TREE IMPROVEMENT
RESEARCH COOPERATIVE

CAFS

National Science Foundation
Industrial Innovation Partnership (IIP) Division
Industry / University Cooperative Research Centers

Center for Advanced Forestry Systems

North Carolina State University – Jose Stape
Oregon State University – Glenn Howe
Purdue University – Charles Michler
University of Florida – Eric Jokela
University of Georgia – Michael Kane
University of Idaho – Mark Coleman
University of Maine – Robert Wagner
University of Washington – David Briggs
Virginia Tech – Thomas Fox

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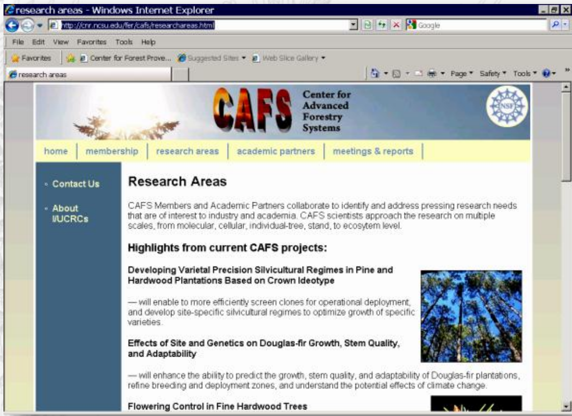

http://cnr.ncsu.edu/fer/cafs/researchareas.html

PACIFIC NORTHWEST TREE IMPROVEMENT
RESEARCH COOPERATIVE

Funding formula update

First 5 years

- $50K/yr ($26.9K operating funds) for dues of 150-300K
- $70K/yr ($37.7 operating funds) for dues >300K

Second five years

- $25K/yr ($13.4K operating funds) for dues of 150-300K
- $35K/yr ($18.8K operating funds) for dues >300K

Matching funds

- OSU reached the 300K threshold through contributions to PNWTIRC (Howe), TBGRC (Strauss), CIPS (Maguire), and BLM Density Management Study (Puettmann)

PACIFIC NORTHWEST TREE IMPROVEMENT
RESEARCH COOPERATIVE

OSU CAFS proposals in 2011

Proposed continuing proposals

- Effects of site and genetics on Douglas-fir growth, stem quality, and adaptability (Howe)
- Early genetic selection for wood stiffness in Douglas-fir and western hemlock (Howe)
- Overstory cover dynamics in thinned stands and riparian areas (Puettmann)
- Floral transcriptomics of eucalypts (Strauss)

PNWTIRC plans for 2011-2012

Site characterization study (PNWTIRC/CAFS/NWTIC)

- Defend thesis and publish results

Miniaturized seed orchard study

- Develop work plan and outline for final MSO report
- Measure flowering, bud phenology, and crown volume
- Measure cone and seed yields in the fall of 2012

Wood quality (PNWTIRC/CAFS/NWTIC)

- Complete the field work for the PNWTIRC/CAFS study entitled *"Early genetic selection for wood stiffness in young Douglas-fir and western hemlock"*

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PNWTIRC plans for 2011-2012

SNP-based marker-assisted selection in Douglas-fir

- Write a proposal for a new PNWTIRC study to investigate the potential for SNP-based marker-assisted selection in Douglas-fir
- Test new SNP chip and begin genotyping second-cycle selections

Cold hardiness testing

- Facilitate cold hardiness testing by the NWTIC

Climate change subproject (TAFCC)

- Continue to facilitate the activities of the Taskforce on Adapting Forests to Climate Change
- Submit a proposal to the AFRI Climate Change Program with PNWTIRC participation

PACIFIC NORTHWEST TREE IMPROVEMENT
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Identifying Site Characteristics that Explain Variation in Douglas-fir Productivity and Stem Form

Lauren Magalska
Department of Forest Ecosystems and Society
College of Forestry
Oregon State University

Agenda

- Introduction
- Project Objectives
- Materials and Methods
- Results and Discussion
- Future Work
- Conclusions

Introduction

- What did I do?
- Why did I do it?
- Why is it unique?
- How does it fit into the bigger picture?

What I Did…

- Identified site characteristics that explain variation in Douglas-fir site productivity and stem form
- Site characteristics include climate, soils, and topography
- Site productivity was measured as
  - Mean individual tree height and diameter increments
  - Total volume and basal area per hectare
  - Site mortality (%)

What I Did…

- Stem form was measured as incidents/tree of stem forking and ramicorn branching, and % stem deflect/tree (sinuosity)

Why I Did It

- Site productivity and stem form are directly related to:
  - Profitability of owning forestland
  - Return on silvicultural investment
- Current methods of assessing site productivity have limitations
- Douglas-fir response to near-term climate change needs to be better understood
- Availability of NWTIC genetic tests

Forest Productivity Models

- Empirical Growth and Yield Models
- Mechanistic Models

Climate Change

- Projections
  - Uncertain changes to precipitation
  - Summer warming, more pronounced inland
  - Greater winter warming than summer warming in the western Cascades
  - Increased CO_2
- How will Douglas-fir respond?
- Which climate site characteristics should be investigated in detail?

Why is it unique?

- Tree improvement programs
  - Breeding zones
  - Parent trees (families)
  - Progeny trees
  - Progeny test sites
- Site characteristic relationships with stem form
- Unique geographic study area

The Big Picture

- Douglas-fir is an economically important species in OR and WA
- Competitive market
  - Low cost imports
  - Alternative land uses
- Maintenance and improvement of timber quantity and quality will help OR and WA timber producers remain competitive
- Understanding the relationships among Douglas-fir productivity, stem form and site characteristics is key

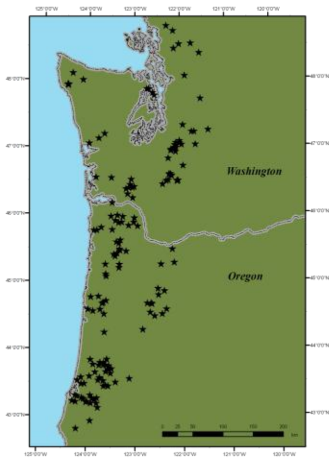
Materials and Methods

- Progeny Test Sites
- Site Characteristics
- Variable Selection

Progeny Test Sites

- Site locations
- Measurements of trees at each site
- Site characteristics

Site Locations



- 191 NWTIC progeny test sites in Oregon and Washington
- Measured between 1967 and 2005
- Elevation 15 to 1090 meters
- Average of 3500 trees per site (400 to 9400)

Site Measurements

- Measured variables
  - Height at three ages (~ages 5, 10, 15)
  - DBH at three ages (~ages 5, 10, 15)
  - Mortality at three ages (~ages 5, 10, 15)
  - Stem forking
  - Ramicorn branching
  - Sinuosity
- Calculated variables
  - Individual tree periodic annual growth rates for height and DBH over 6 growth periods
  - Total volume/ha (~ages 5, 10, 15)
  - Total BA/ha (~ages 5, 10, 15)

Photo courtesy of NWTIC

Site Measurements

- Site means were calculated by program
- Adjusted to remove mean genetic differences among sites
- Site means were calculated for
  - HT response group (6 periodic annual height growth rates)
  - DBH response group (6 periodic annual DBH growth rates)
  - Biomass response group (Total volume and total BA at 3 ages)
  - Site mortality at 3 ages (Mortality response group)
  - Incidents of stem forking, ramicorn branching and sinuosity per tree

Site Characteristics

- Climate
  - ClimateWNA
  - 35 climate site characteristics
  - 7 periodic growth climates
- Soils
  - NRCS SSURGO
  - 3 soils site characteristics
- Topography
  - USGS DEM
  - 2 topographic site characteristics
- Total of 40 site characteristics

Data Summary

- Across-program data
  - 7 datasets
  - 24 response variables (DBH, HT, stem forking, etc.)
  - 40 independent variables (MAT, slope, AWC, etc.)
- Within-program data
  - Variation explained by program and sowing year has been removed

Variable Selection

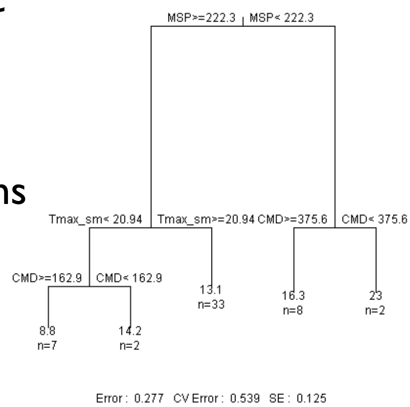
- Variable importance study
- Issues
  - Nature of relationships
  - Interactions
  - Colinearity
  - Strength of the biological signal

Approach

- Hierarchical clustering of site characteristics
- Three-pronged variable selection
  - Simple correlation (Corr)
  - Linear regression (LR)
  - Random forest (RF)

A Few Words on Random Forests

- Non-parametric analysis
- Automatically incorporates interaction terms
- Robust to colinearity among the independent variables



Issues

- Nature of relationships – Use analytical methods that describe both linear and non-linear relationships (LR and RF)
- Interactions – automatically included by RF
- Colinearity – RF is robust, Corr captures simple relationships
- Biological signal – separate real from artifacts using three-pronged approach, importance scores and rank correlations

Importance Scores

		SIN										
	Site	RF (13.7)			LR (34.55)			Corr (10.20)			Total	
SCG	characteristic	VI	Score	#	GDI	Score	#	r^2_{rel}	Score	#	Score	#
PRECIP	MAP	-	-	-	-	-	-	-	-	-	0.00	18
	MSP	-	-	-	-	-	-	-	-	-	0.00	18
	PPT_at	-	-	-	-	-	-	-	-	-	0.00	18
	PPT_sm	-	-	-	-	-	-	-	-	-	0.00	18
	PPT_sp	-	-	-	-	-	-	-	-	-	0.00	18
	PPT_wt	-	-	-	0.006	0.211	10	-	-	-	0.21	15
TEMP1	bFFP	0.098	1.343	5	0.124	4.274	4	-	-	-	5.62	4
	DD < 0°C	-	-	-	-	-	-	-	-	-	0.00	18
	DD < 18°C	-	-	-	0.050	1.744	8	-	-	-	1.74	9
	PAS	-	-	-	-	-	-	0.065	0.659	8	0.66	17
	TD	0.115	1.573	4	-	-	-	0.127	1.295	2	2.87	10
TEMP2	DD > 5°C	-	-	-	-	-	-	-	-	-	0.00	18
	eFFP	-	-	-	-	-	-	-	-	-	0.00	18
	EMT	-	-	-	-	-	-	-	-	-	0.00	18
	FFP	-	-	-	-	-	-	-	-	-	0.00	18
	MAT	-	-	-	0.052	1.803	7	-	-	-	1.80	8
	MCMT	0.134	1.841	1	0.147	5.072	2	0.076	0.777	6	7.69	2
	NFFD	0.093	1.273	7	0.064	2.218	6	-	-	-	3.49	6
	Tave_at	-	-	-	-	-	-	-	-	-	0.00	18

$$s_m = \sum_{i=1}^{n} r_{rel}^2 * R_{corr}^2 + VI * R_{RF}^2 + GDI * R_{LR}^2$$

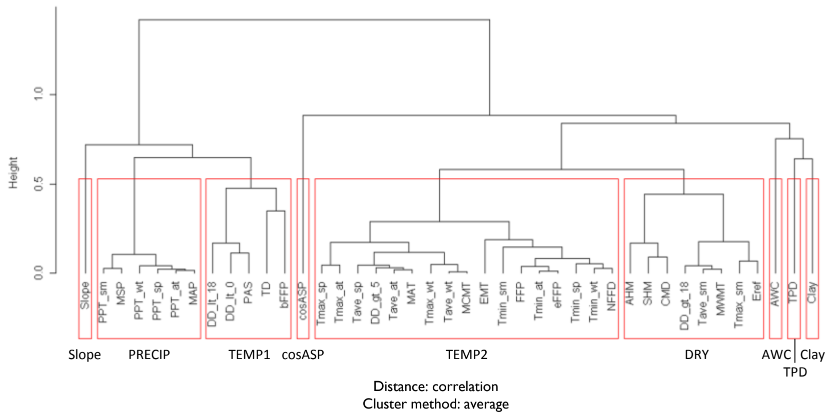
Consistency

- Each response group had a Corr, RF, LR and total importance score for both the across- and within-program data
- Spearman's rank correlations were used to judge consistency of importance scores among analytical methods and response groups for the productivity measures

Results and Discussion

- Site Characteristic Groups
- Consistency
- Site Productivity
- Stem Form

Site Characteristic Groups



PRECIP

- Amount and timing
- Adequate water supplies required for growth
- Late season precipitation may lead to multiple flushing
- Expected to explain variation in site productivity, specifically MAP

MAP
MSP
PPT_sp
PPT_sm
PPT_at
PPT_wt

TEMP1

- Temperatures affect the induction and release of endodormancy
- Expected to explain variation in site productivity, specifically DD<0°C

Image from gardengrumblesandcrossstitchfumbles.blogspot.com

bFFP
DD<0°C
DD<18°C
PAS
TD

TEMP2

- Growing season temperatures and length affect growth
- NFFD and MAT may explain variation in productivity
- Extreme temperatures may cause injury and mortality
- eFFP and EMT may explain variation in stem form

Image from http://rocknrunner.blogspot.com

DD<5°C, eFFP, EMT, FFP, MAT, MCMT, NFFD, Tave_sp, Tave_at, Tave_wt, Tmax_sp, Tmax_at, Tmax_wt, Tmin_sp, Tmin_sm, Tmin_at, Tmin_wt

DRY

- Summer drought and relationships between temperature and precipitation
- Critical in this region
- Early ecodormancy, reduced photosynthesis and growth
- Expected to explain variation in site productivity, specifically SHM

Image from forestry-dev.org

AHM
CMD
DD>18°C
Eref
MWMT
SHM
Tave_sm
Tmax_sm

Topography

- Slope and cosASP did not cluster with any other site characteristics
- Influences light intensity, PAR, temperature and drought stress
- Ability of slope and cosASP to explain variation in site productivity is dependent on importance of other site characteristics

Soils

- AWC, TPD and clay did not cluster with any other site characteristics
- Douglas-fir productivity has been linked to soil moisture
- AWC expected to explain variation in site productivity
- TPD and clay influence AWC
- TPD and clay expected to have diminished importance if AWC explains variation in site productivity

Moderate to Low Consistency

Rank correlations between analytical methods

Response	Corr vs RF	Corr vs LR	RF vs LR
Across-program			
Biomass	-0.07 (0.66)	-0.27 (0.09)	-0.01 (0.96)
DBH	0.39 (0.01)	-0.06 (0.70)	0.47 (<0.01)
HT	0.05 (0.74)	-0.03 (0.87)	0.48 (<0.01)
Mortality	0.33 (0.03)	0.28 (0.07)	0.08 (0.62)
Within-program			
Biomass	0.11 (0.48)	-0.13 (0.43)	0.02 (0.91)
DBH	0.26 (0.10)	0.09 (0.57)	0.13 (0.42)
HT	0.33 (0.03)	0.15 (0.34)	0.32 (0.04)
Mortality	0.08 (0.63)	-0.01 (0.93)	0.09 (0.57)

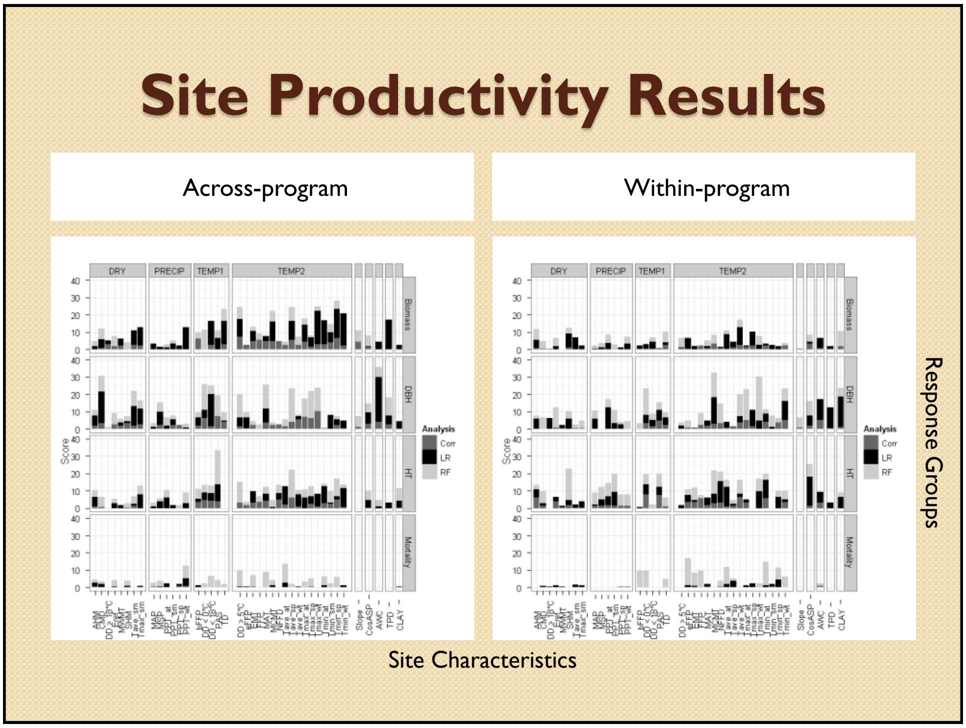
Moderate Consistency

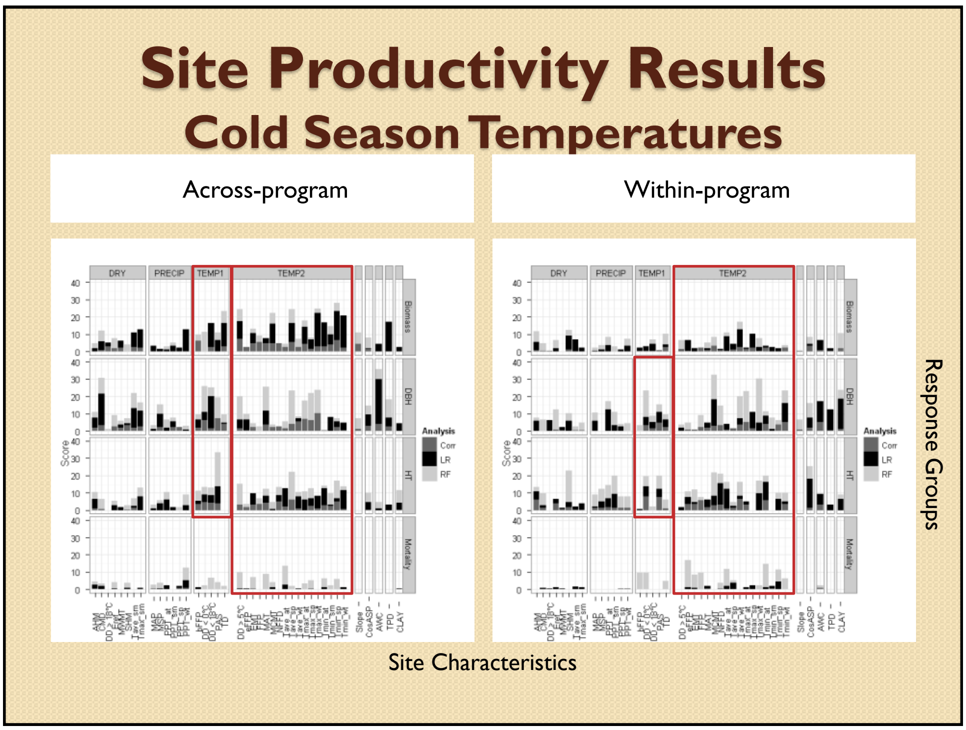
Rank correlations between response groups

Response	Across-program	Within-program
DBH vs HT	0.24 (0.12)	0.52 (<0.01)
DBH vs Biomass	0.24 (0.13)	0.25 (0.11)
DBH vs Mortality	0.02 (0.92)	-0.20 (0.20)
HT vs Biomass	0.35 (0.02)	0.41 (0.01)
HT vs Mortality	0.44 (<0.01)	-0.09 (0.59)
Biomass vs Mortality	0.16 (0.31)	-0.18 (0.26)

Consistency… or lack thereof

- Weak biological signals over a relatively narrow range of site characteristics
- Sources of inaccuracy and random variation
  - ClimateWNA
  - SSURGO
- Differences in analytical methods
- Large number of independent variables in relation to the number of observations
- Some responses may not be explained by the site characteristics


Site Productivity Results
Across-program
Within-program
DRY
PRECIP
TEMP1
TEMP2
Biomass
DBH
HT
Mortality
Score
Analysis
Corr
LR
RF
Site Characteristics
Response Groups


Site Productivity Results
Cold Season Temperatures
Across-program
Within-program
DRY
PRECIP
TEMP1
TEMP2
Biomass
DBH
HT
Mortality
Score
Analysis
Corr
LR
RF
Site Characteristics
Response Groups

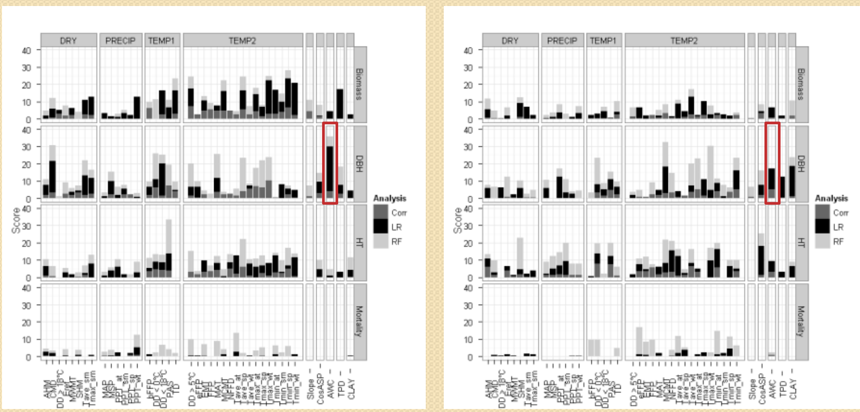
Cold Season Temperatures

- Most consistently important
  - TEMP1
    - DD<0°C for DBH and HT response groups
    - TD for biomass response group
  - TEMP2
    - Tmax_wt for DBH and biomass response groups
    - NFFD for HT response group
    - Temperatures at the beginning and end of the growing season for mortality response group

Site Productivity Results

Available Water Capacity

Across-program	Within-program



Response Groups

Site Characteristics

Available Water Capacity

- Explained variation in DBH response group
- PRECIP and DRY did not consistently explain variation

Why Would AWC Explain Variation?

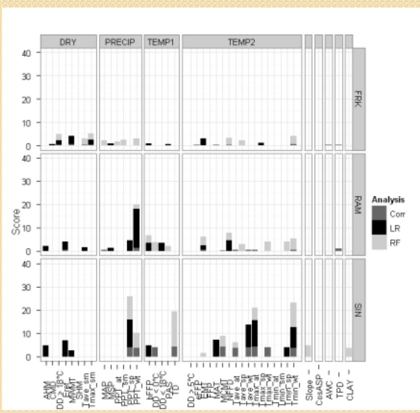
- More accurately – why would AWC explain variation but PRECIP and DRY do not?
- Amount of precipitation may not be as important as the ability to store it
- High AWC potentially mitigates summer drought stress
- Temporal resolution of response and independent variables may influence the importance of precipitation and summer dryness
- ClimateWNA may not model PRECIP and DRY site characteristics well

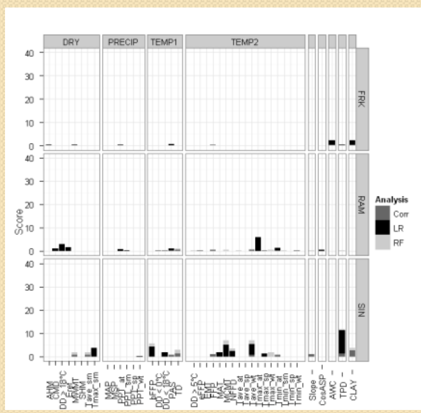
Slope, cosASP, TPD, Clay

- No evidence to support that these site characteristics explain variation in site productivity
- Importance may be masked by interactions with other site characteristics

Stem Form Results

Across-program	Within-program





FRK

RAM

SIN

Site Characteristics

Stem Form

- No evidence to suggest that any of the SCGs or individual site characteristics explained variation in stem form
- Small amount of variation explained
- Lack of consistency
- Different set of site characteristic may be important (insect, disease, mechanical damage)

Future Work

- General relationships have been identified, but there is ample opportunity for continued work
- Continue to refine the analytical approach
- Define approaches for reducing the number of independent variables
- Increase the sample size
  - Conducting analysis without soils data, increase sample size by 97 sites
  - Continue mapping NWTIC progeny test sites

Future Work

- After important site characteristics are identified, predictive modeling under future climate scenarios
- Environmental transfer distances
  - GxE
  - Adaptability
  - Seed transfer guidelines

Conclusions

- Identified site characteristics that explain variation in Douglas-fir site productivity
  - Cold season temperatures
  - Available water capacity
- Attempted to identify site characteristics that explain variation in Douglas-fir stem form, but results were inconsistent
- Understanding the relationships among Douglas-fir site productivity, stem form and site characteristics is essential to the maintenance and improvement of the timber industry in OR and WA

Conclusions

- Study identified general relationships
- Laid the groundwork for future studies on Douglas-fir productivity, stem form and related site characteristics

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Early genetic selection for wood stiffness in juvenile Douglas-fir and western hemlock

Scott Kolpak[1], Oguz Urhan[1], Glenn Howe[1]

[1]*Pacific Northwest Tree Improvement Research Cooperative*
Department of Forest Ecosystems and Society
Oregon State University

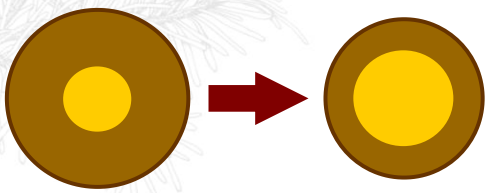
PACIFIC NORTHWEST TREE IMPROVEMENT
RESEARCH COOPERATIVE

Genetics of wood stiffness

Trend toward shorter rotations, faster growth

- More wood from the juvenile wood core
- Juvenile wood:

- *Lower wood density*
- *Higher microfibril angle*
- *Lower stiffness*
- *More shrinkage*



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Past research on wood quality traits of 'mature' Douglas-fir (25 years old)

- Stiffness is heritable and **substantial gains** are possible
- HM200 MOE has a high genetic correlation (r_g = 0.92) with bending MOE
- ST300 MOE has a moderate genetic correlation (r_g = 0.57) with bending MOE
- **Acoustic velocity** can be used instead of acoustic MOE to evaluate wood stiffness (**no strong need to measure density**)
- Selection for bending stiffness or **acoustic velocity = no large adverse effects on growth**

Wood stiffness publications:

Cherry et al. 2008. Genetic variation in direct and indirect measures of wood stiffness in coastal Douglas-fir. Can. J. For Res. 38(9): 2476-2486.

Jayawickrama et al. 2011. Heritabilities, intertrait genetic correlations, GxE interaction and predicted gains for acoustic velocity in mid-rotation coastal Douglas-fir. Silvae Genetica 60: 8-19.

Vikas et al. 2011. Stiffness of Douglas-fir lumber: effects of wood properties and genetics. Can. J. For Res 41: 1160-1173.

Wood stiffness in juvenile Douglas-fir and western hemlock

There is a strong interest in improving stiffness in younger trees (e.g. 6 – 12)

- Trees of these ages are being measured for inclusion into seed orchards and future breeding
- No wood quality traits have been incorporated beyond 1st cycle breeding populations

There are challenges to applying research tools and methods from older trees to younger trees, and to western hemlock

PACIFIC NORTHWEST TREE IMPROVEMENT RESEARCH COOPERATIVE

Wood stiffness in young trees: Challenges and unknowns

Phenotype

- Wood anatomy is different, mostly juvenile wood and sapwood
- Branches on small trees may adversely affect 'standard' measurement protocols
  - *Secondary branches in hemlock*
- Acoustic tools may not work well on small trees
- Differences between Douglas-fir and western hemlock

Genetics (young trees)

- Heritabilities, genetic gains, juvenile-mature wood correlations are unknown

Project goals

Project goals	Progress	Location
(1) Evaluate alternative methods for measuring wood stiffness on young trees of Douglas-fir (DF) and western hemlock (WH)	Field work done Analysis ongoing	Operational plantations
(2) Estimate genetic parameters and genetic gains for juvenile wood stiffness in DF and WH	Ongoing	Progeny sites
(3) Develop optimal measurement and selection scenarios for improving juvenile wood stiffness in DF and WH		
4) Estimate age-age correlations for DF wood properties		

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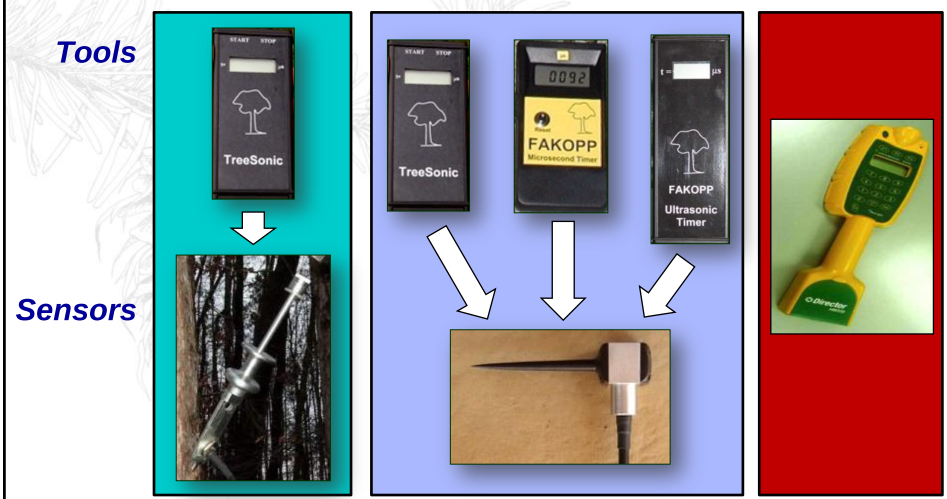
Acoustic tools being tested



Standing-tree tools
Fakopp Enterprises, Hungary

Log tool
Fibre-gen, NZ

Juvenile stiffness work phases

Phase 1: Phenotype – Evaluate acoustic tools and techniques in operational plantations

Phase 2: Genetics

- Estimate genetic parameters and genetic gains for juvenile wood stiffness in progeny sites
- Develop measurement protocols and selection scenarios for improving juvenile wood stiffness in operational programs

Phase 3: Age-age correlations – Estimate age-age correlations for Douglas-fir wood properties

PACIFIC NORTHWEST TREE IMPROVEMENT
RESEARCH COOPERATIVE

Phase 1 objectives

Tools - Evaluate standing-tree acoustic tools for measuring acoustic velocity (AV) in young trees

- Robustness
- Correlations with log-based tools (HM200)

Methods - Evaluate the same-face method of probe placement versus the opposite-face method

Whorls - Compare alternative standing-tree stress wave target areas

- Interwhorls = shorter flight-paths (<< 1 meter), more clear wood
- Across whorls = longer flight-paths (~ 1 meter), spans branch whorls

Phase 1: Materials and methods

5 – Operational plantations

4 – Standing-tree tools

3 – Measurement areas

- Interwhorl 1, interwhorl 2, $whorl_{1,2}$

2 – Measurement techniques

- Probes same-face or opposite-face

1 – Log-based tool

PACIFIC NORTHWEST TREE IMPROVEMENT RESEARCH COOPERATIVE

Young tree phenotypic study

5 plantations spanning ages 6 – 15 years

Table 1: Operational plantations

Plantations (Starker Forest's)	Years planted (tree age)	DBH (cm)	No. of Douglas-fir	No. of Western hemlock
Peeler Greene	2004-05 **(7)**	4.5	12	13
Rhubarb 2	2002-03 **(9)**	6.9	13	12
Ellmaker Parkview	2001-02 **(10)**	6.2	12	13
Edward Spring	1998-99 **(13)**	13.4	12	9
Elephant Foot	1996-1997 **(15)**	14.4	13	14

Phase 1: Materials and methods

5 plantations ages 6 – 15 years

Time-of-flight measurements per tree:

- 4 tools x 3 locations x 2 sensor placements x 3 TOFs = 72 TOFs / tree

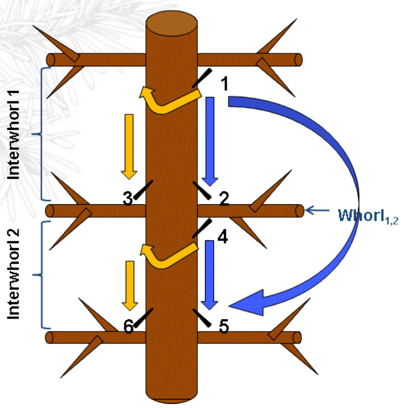
Calculate alternative flight paths

- Sensor distance and tree diameter

Resonance acoustic velocities taken using the HM200

- Minimum log length 2 m

Tree measurement diagram



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Which tools are best?

Objective: Evaluate standing-tree tools for measuring AV in young trees

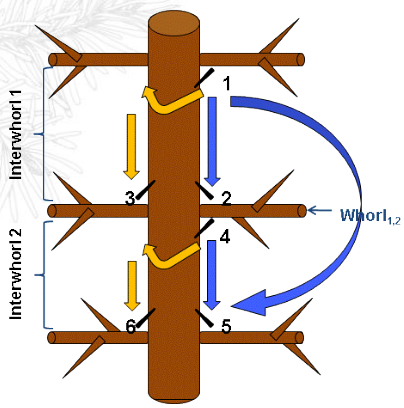
Effective tools have high correlations with other tools

Method: Compare correlations among tools (using the same-face and opposite-face methods)

Same-face = Average $r_{1,2}$ & $r_{4,5}$

Opposite-face = Average $r_{1,3}$ & $r_{4,6}$

Tree measurement diagram



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Which tools are best?

Objective. Evaluate standing-tree tools for measuring AV. Effective tools have high correlations with other tools

Method. Compare tool correlations <u>within</u> (1) same-face method and (2) opposite-face method

Results

- Ultra Timer = some poor correlations
- MicroTimer, TreeSonic 1, and TreeSonic 2 = no clear differences

Conclusions

- No need to consider TreeSonic 2 (sliding hammer is awkward and physically demanding)
- Drop the UltraSonic Timer

Table 2. Correlations among acoustic tools and sensor placements for Douglas-fir and western hemlock pooled across five sites. Douglas-fir correlations are below the diagonal and western hemlock are above the diagonal.

Sensor Placement	Acoustic tool	Opposite face sensors: Micro Timer	Tree-Sonic 1	Tree-Sonic 2	Ultra Timer	Same face sensors: Micro Timer	Tree-Sonic 1	Tree-Sonic 2	Ultra Timer
Opposite	Micro Timer	–	0.76	0.44	0.36				
Opposite	TreeSonic 1	0.34	–	0.52	0.25				
Opposite	TreeSonic 2	0.42	0.39	–	0.10				
Opposite	Ultra Timer	0.04	-0.07	-0.04	–				
Same	Micro Timer					–	0.65	0.46	0.53
Same	TreeSonic 1					0.45	–	0.48	0.50
Same	TreeSonic 2					0.42	0.60	–	0.36
Same	Ultra Timer					0.46	0.51	0.39	–

Correlation coefficients (r) are among averages for interwhorls 1 and 2.

TreeSonic 1 = TreeSonic + SD02 sensor
TreeSonic 2 = TreeSonic + sliding hammer sensor

Which probe placement is best?

Which tools?

- TreeSonic
- Microsecond timer
- UltraSonic timer

Whorls a problem?

Which methods?

- Same-face method
- Opposite-face method

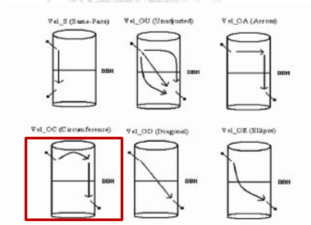
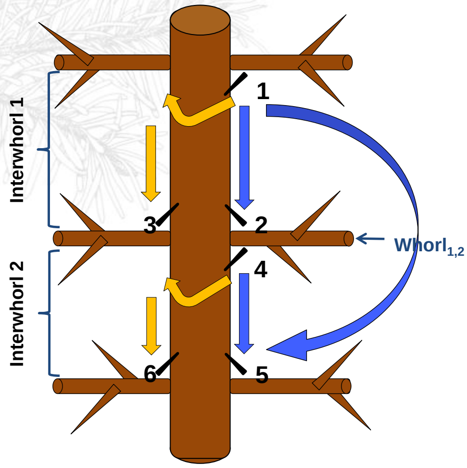


Figure 1. Hypothesized stress wave flight paths for the same-face and distance adjusted values (Mohan et al 2008)

Tree measurement diagram



Which probe placement is best?

Objective. Evaluate the same-face method of probe placement versus the opposite-face method

Method. Which tool correlations are higher (1) same-face method or (2) opposite-face method?

Results

- Same-face correlations are slightly higher than opposite-face
- But…only one flight path examined

Conclusions

- Test same-face and opposite-face methods in progeny tests

Table 2. Correlations among acoustic tools and sensor placements for Douglas-fir and western hemlock pooled across five sites. Douglas-fir correlations are below the diagonal and western hemlock are above the diagonal.

Sensor Placement	Acoustic tool	Opposite face sensors: Micro Timer	Opposite face sensors: Tree-Sonic 1	Opposite face sensors: Tree-Sonic 2	Opposite face sensors: Ultra Timer	Same face sensors: Micro Timer	Same face sensors: Tree-Sonic 1	Same face sensors: Tree-Sonic 2	Same face sensors: Ultra Timer
Opposite	Micro Timer	–	0.76	0.44	0.36				
Opposite	TreeSonic 1	0.34	–	0.52	0.25				
Opposite	TreeSonic 2	0.42	0.39	–	0.10				
Opposite	Ultra Timer	0.04	-0.07	-0.04	–				
Same	Micro Timer					–	0.65	0.46	0.53
Same	TreeSonic 1					0.45	–	0.48	0.50
Same	TreeSonic 2					0.42	0.60	–	0.36
Same	Ultra Timer					0.46	0.51	0.39	–

Correlation coefficients (r) are among averages for interwhorls 1 and 2.

TreeSonic 1 = TreeSonic + SD02 sensor
TreeSonic 2 = TreeSonic + sliding hammer sensor

Is measuring across whorls a problem?

Objective. Test the effects of whorls

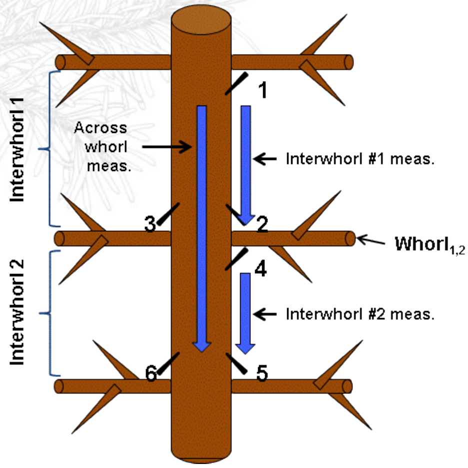
If whorls affect AV, then correlations between two interwhorl measurements will be larger than correlations involving across-whorl measurements

Method. Do these two types of correlations differ?

- Interwhorl #1 versus interwhorl #2
- Across-whorl versus interwhorl*

*average of interwhorls 1 and 2

Tree measurement diagram



Is measuring across whorls a problem?

Objective. Test the effect of whorls

If whorls affect AV, then correlations between two interwhorl measurements will be larger than correlations involving across-whorl measurements

Method. Do these two types of correlations differ?

- Interwhorl #1 versus interwhorl #2
- Across-whorl versus interwhorl

Conclusion. No adverse effect of measuring across whorls in either Douglas-fir or western hemlock

Table 3. Repeatability of tools and methods between interwhorls and whorls. Correlations between acoustic velocities measured on (1) two successive interwhorls and (2) interwhorls versus the intervening whorl in Douglas-fir and western hemlock.

Sensor Placement	Acoustic tool	Douglas-fir: Interwhorl 1 versus interwhorl 2	Douglas-fir: Whorl versus interwhorls	Western hemlock: Interwhorl 1 versus interwhorl 2	Western hemlock: Whorl versus interwhorls
Opposite	Micro Timer	0.26	0.44	0.66	0.72
Opposite	TreeSonic 1	0.14	0.43	0.53	0.60
Opposite	TreeSonic 2	0.17	0.48	0.30	0.45
Opposite	Ultra Timer	-0.08	0.11	0.64	0.58
Same	Micro Timer	0.44	0.53	0.68	0.67
Same	TreeSonic 1	0.59	0.70	0.60	0.46
Same	TreeSonic 2	0.44	0.71	0.29	0.58
Same	Ultra Timer	0.42	0.44	0.43	0.37

TreeSonic 1 = TreeSonic + SD02 sensor
TreeSonic 2 = TreeSonic + sliding hammer sensor

Phenotype study conclusions (preliminary)

- **We dropped the UltraSonic Timer.** UltraSonic correlations are weak, and measurement distances between sensors are short
- **We dropped the TreeSonic with 'standard' sliding hammers.** The TreeSonic or Microsecond Timer with SD02 sensors have good correlations and are easier to use
- **Measuring across whorls isn't a problem**
- **We will continue to study sensor placement.** We don't have adequate information to judge effectiveness, so we will study sensor placement in progeny tests

PACIFIC NORTHWEST TREE IMPROVEMENT
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Genetics of wood stiffness

Oguz Urhan – Master's candidate

Figure1:TreeSonic 1 (SDO2 sensor)

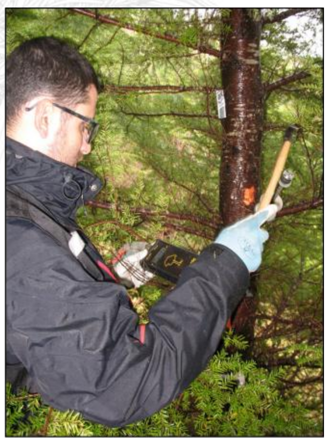

Figure2:TreeSonic 2 (TS sensor)

Phase-2 - Genetic improvement of wood stiffness in young Douglas-fir and western hemlock

Goals and objectives

Long-term goal

- Genetically improve juvenile wood stiffness in 6- to12-year-old Douglas-fir and western hemlock trees

Objectives

- Determine optimal approaches (tools and methods) for measuring and selecting for juvenile wood stiffness at young ages
- Estimate genetic gains for wood stiffness for 6- to 12-year-old Douglas-fir and western hemlock trees using the most promising standing-tree acoustic tools

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Remaining questions

Tool and sensors

- Microsecond timer?
- TreeSonic (with SD-02 sensors)?

Method

- Same-face method?
- Opposite-face method?

Measurement production

Genetic parameters

- Heritabilities
- Potential genetic gains

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Methods and tools

Which tools?

- Microsecond Timer
- TreeSonic

Advantages/disadvantages of tools?

Table.1 Advantage and disadvantage of the tools

	Advantage	Disadvantage
Microsecond timer	▪ Smaller and more practical	▪ On/off switch and reset button ▪ Reset last reading each time ▪ SD-02 probe bending
TreeSonic	▪ Faster ▪ Automatically switch on/off ▪ No button on the unit ▪ SD-02 sensor more practical than original TreeSonic	▪ Bigger and heavier ▪ SD-02 probe bending

Which methods?

- Same-face method
- Opposite-face method

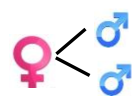
PACIFIC NORTHWEST TREE IMPROVEMENT RESEARCH COOPERATIVE

Young tree genetic study

Table.2 Progeny test sites

Program	Site	Species	Age	# of families	Mating design
Noctic (Pruned)	Roaring river	Douglas-fir	12	78	Nested
Hemtic (Not pruned)	Toledo	Western hemlock	10	80	Nested
Trask inland	Fir grove	Douglas-fir	8	-	-

Males nested in females



Females nested in males

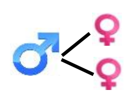


Table.3 Measurement production

	Same-face and Opposite-face		Same-face (Estimated)	
	Pruned site	Not pruned site	Pruned site	Not pruned site
Microsecond Timer	27 tree/h	15 tree/h	41 tree/h	23 tree/h
TreeSonic	32 tree/h	19 tree/h	49 tree/h	29 tree/h

Application of probes and measurements

Placement of probes and penetration depth

- Always on the same aspect
- 45 +/- 15 degree angle
- 20 – 25 mm penetration depth

Distance

- No fixed distance

Diameter

SD-02 starting sensor

SD-02 receiving sensor

Preliminary results and conclusions

Table.4 Approximate individual-tree narrow-sense heritabilities		
	Same-face	Opposite-face
Microsecond timer	0.507	0.418
TreeSonic	0.525	0.445

Preliminary conclusions

- Standing-tree acoustic velocity measurements in juvenile trees are heritable
- Same-face is better than opposite-face. No difference between tools

Opposite-side method

- I used circumferential opposite-face method
- Test other approaches

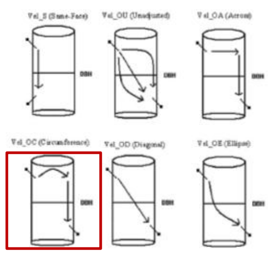


Figure 1. Hypothesized stress wave flight paths for the same-face and opposite face methods (Mohan et al 2008)

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Progress

- Completed measurements of the Roaring River progeny test site. Measured 12-year-old Douglas-fir with the Microsecond Timer and TreeSonic – analyses are underway
- Now measuring the Toledo progeny test site. Measurements of 10-year-old western hemlock are completed for the Microsecond Timer and are underway for the TreeSonic
- Fir Grove progeny test site is the next step (8-year-old Douglas-fir)

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Ron Rhatigan, OSU
Cameron Muir, Starker Forests

PACIFIC NORTHWEST TREE IMPROVEMENT
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Western Conifer Climate Change Consortium (WCCCC)

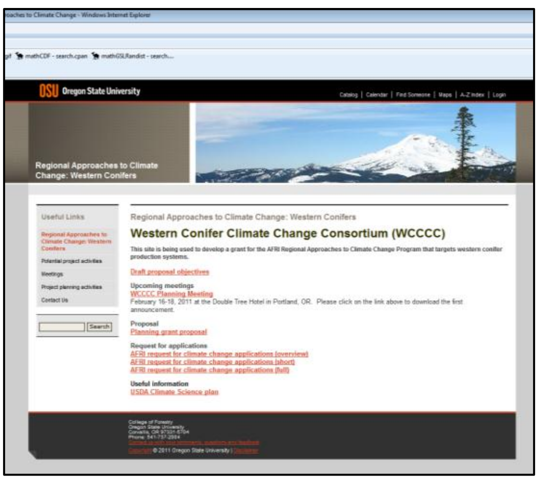
USDA Coordinated Agricultural Project

Western Conifer Forest Systems: Strategies for Climate Change Adaptation and Mitigation

WCCC Western Conifer Climate Change Consortium

WCCCC (WC4)

Western Conifer Climate Change Consortium



http://racc.forestry.oregonstate.edu/

Regional CAP for 2011 – delayed?

Regional approaches to Climate Change: CAP

- Application deadline – July 16, 2011?
- $4,000,000 per year ($20 million total) for up to 5 years
- Anticipates making 5 to 8 awards in FY 2011?
- Regional integrated CAP focusing on mitigation and adaptation, involving research, education, and outreach in:
  - *Cropping systems: Legume or forage production systems*
  - *Animal systems: Ruminant livestock and dairy*
  - ***Forest systems: Western conifers***
  - *Grassland, pastureland, and rangeland systems*

WCCC Western Conifer Climate Change Consortium

Long-term goal

Synthesize existing knowledge and develop new knowledge on the impacts of climate change on western forest production systems, and then design, convey, and implement management strategies that maximize forest health, forest productivity, and greenhouse gas mitigation under changing climates

WCCC Western Conifer Climate Change Consortium

Stakeholders are critical

- *"Demonstrate the **adoption of approaches and practices** across the region…"*
- **Stakeholders are** seed orchard managers, nursery managers, silviculturists, managers of forest operations, wood products manufacturers, managers of carbon offsets programs, policy makers, teachers, and students
- **Organizations are** forest industry, governmental agencies, tribes, small private landowners, NGOs, and universities
- Included in project **advisory groups**

WCCC Western Conifer Climate Change Consortium

PNW regional meeting

Table 1. Rankings of Topic Importance by Stakeholders and Potential Project Partners

Rank	Stakeholders "Very important" or "top priority" topics		Potential Project Partners "Very important" or "top priority" topics	
1	Effects on fire, insects, pests	82.3 %	Effects on fire, insects, pests	88.9 %
2	Monitoring	76.5	Forest modeling	83.3
3	Silviculture	64.7	Monitoring	76.5
4	Economics	58.8	Regional climate science	76.4
5	Forest genetics & tree improvement	58.8	Effects on tree physiology	76.4
6	Regional climate science	52.9	Silviculture	66.7
7	Extension	52.9	Forest genetics & tree improvement	66.6
8	Forest modeling	47.0	Social science	61.1
9	Social science	43.8	Forest carbon	58.8
10	Non-forest carbon	41.2	Economics	55.5
11	Effects on tree physiology	41.1	Non-forest carbon	50.0
12	Forest carbon	35.3	Extension	38.9
13	Education	29.4	Education	38.9

Inland Empire regional meeting

Table 1. Rankings of Topic Importance by Stakeholders and Potential Project Partners

Rank	Stakeholders "Very important" or "top priority" topics	
1	Silviculture	77.8 %
2	Effects on fire, insects, pests	66.7
2	Economics	66.7
2	Forest genetics & tree improvement	66.7
5	Regional climate science	55.6
5	Water Resources	55.6
5	Extension	55.6
8	Social science	44.4
9	Education	37.5
10	Effects on tree physiology	33.3
10	Monitoring	33.3
10	Non-forest carbon	33.3
13	Forest carbon	11.1
14	Forest modeling	0.0

Rank	Potential Project Partners "Very important" or "top priority" topics	
1	Effects on fire, insects, pests	80.0 %
2	Education	78.9
3	Regional climate science	76.4
4	Silviculture	75.0
4	Water Resources	75.0
4	Extension	75.0
7	Forest genetics & tree improvement	68.4
8	Forest modeling	65.0
9	Monitoring	60.0
10	Economics	55.0
10	Effects on tree physiology	55.0
12	Social science	50.0
12	Forest carbon	50.0
12	Non-forest carbon	50.0

Southwest regional meeting

Table 1. Rankings of Topic Importance by Stakeholders and Potential Project Partners

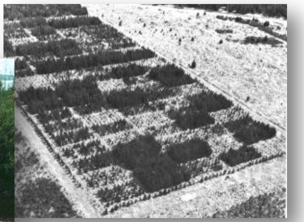
Rank	Stakeholders "Very important" or "top priority" topics	
1	Effects on fire, insects, pests	85.7%
1	Extension	85.7
1	Water Resources	85.7
4	Economics	78.6
4	Effects on tree physiology	78.6
6	Regional climate science	64.3
6	Monitoring	64.3
8	Social science	57.1
9	Education	46.2
10	Forest genetics & tree improvement	42.9
10	Silviculture	42.9
12	Forest carbon	30.8
13	Forest modeling	28.6
14	Non-forest carbon	14.3

Rank	Potential Project Partners "Very important" or "top priority" topics	
1	Extension	100.0%
2	Effects on fire, insects, pests	93.3
3	Economics	86.7
3	Social science	86.7
5	Water Resources	80
5	Monitoring	80
5	Forest modeling	80
5	Silviculture	80
9	Education	73.3
10	Regional climate science	64.3
11	Forest carbon	60.0
12	Forest genetics & tree improvement	53.3
13	Effects on tree physiology	46.7
13	Non-forest carbon	46.7

Seed source adaptability is critical

Superior adaptability of a Douglas-fir seed source from California growing in Spain (Hernandez et al 1993)

Lodgepole pine provenances from maritime areas are not adapted to the winters of eastern Finland



Lodgepole pine provenance test in New Zealand (Wright 1976)

- Large climatic transfer distances can result in maladapted plantations
- Transfer limits can be determined directly from provenance tests
- Sufficiently large provenance tests are rare
- Sufficiently large transfer distances are rarely tested

Seedlot Selection Tool
Step by step example

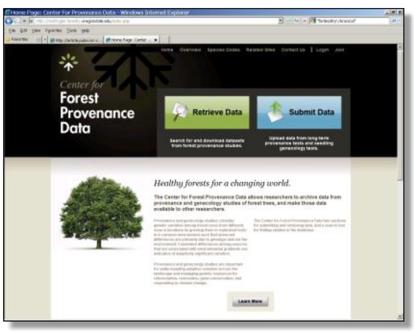
Ronald Beloin[1], J. Bradley St.Clair[2], and Glenn T. Howe[1]

[1]Department of Forest Ecosystems and Society, Oregon State University, Corvallis, OR

[2]USDA Forest Service Pacific Northwest Research Station, Corvallis, Oregon

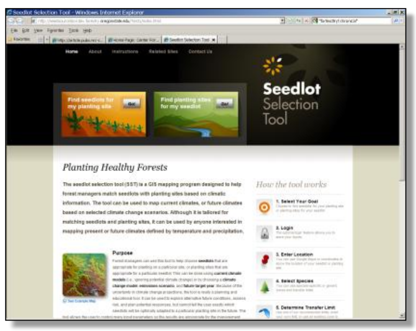
USFS Climate Change Research Program

Center for Forest Provenance Data



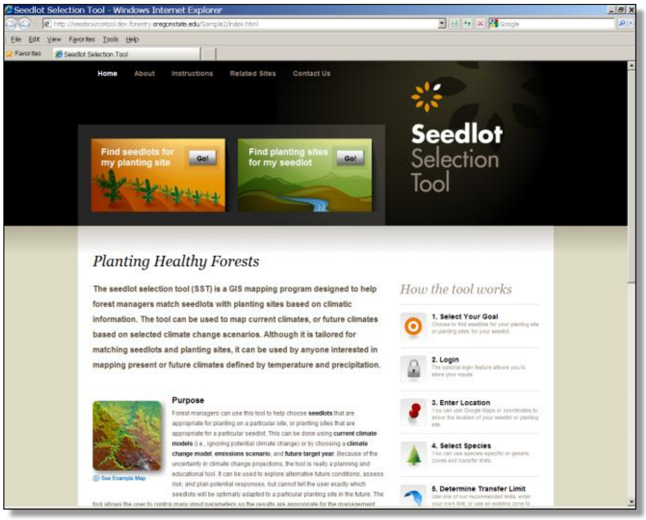
USFS Pacific Northwest Research Station

Seedlot Selection Tool



College of Forestry, Oregon State University

Seedlot Selection Tool (SST)



Why develop a dynamic tool?

- New genetic research can be incorporated easily
- Climate change models and emissions scenarios can be updated easily
- Results can reflect the user's assumptions about climate change and their risk tolerance
- The tool can be used to map any climate that is defined by temperature and precipitation (e.g., risk of Swiss Needle Cast disease)
- Many, many scenarios can be studied because the analyses are conducted by a large community

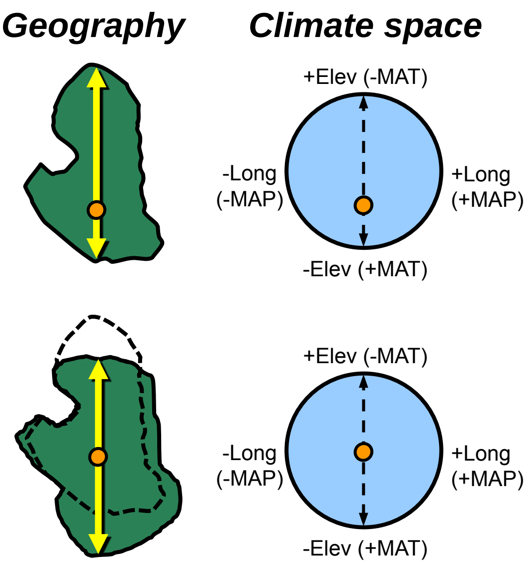
Types of zones

Traditional zones

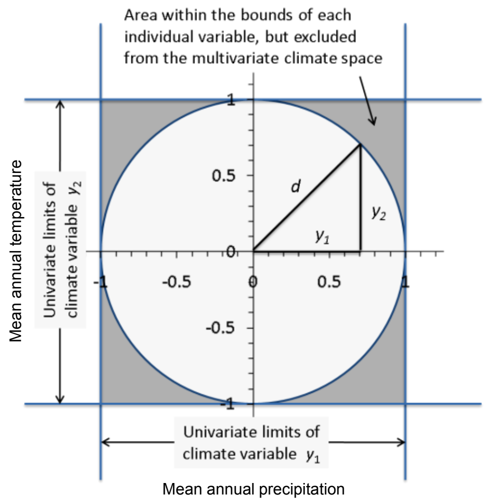
- Defined 'circles on a map'
- Transfers in different geographic directions may be limited at different climatic distances

Focal point zones

- Zones 'float'
- Centered on your focal point
- Transfers are always limited at the same climatic distance



Climate space and transfer limit



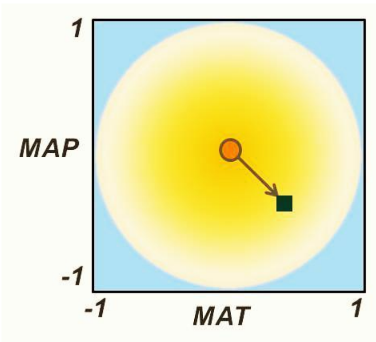
Transfer limit = radius

On the standardized scale, the transfer limit = 1.0

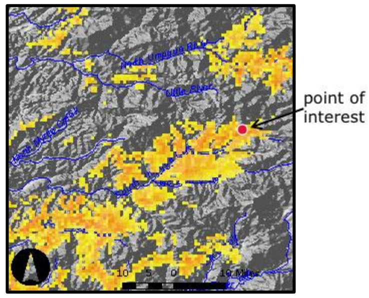
Transfer distance = d

$$d = \sqrt{(y_1^2 + y_2^2)}$$

Mapping the focal point zone



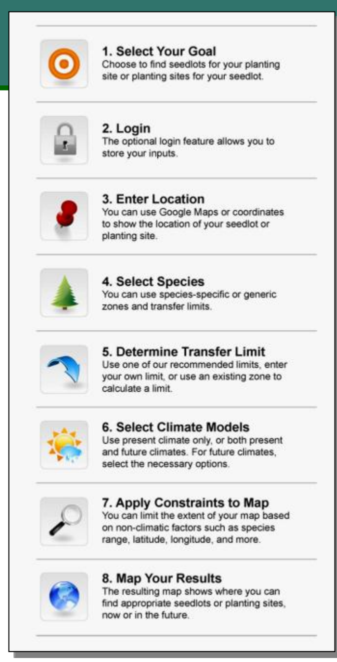
Euclidian climate distance is calculated from the focal point, normalized to a score of 0 to 100, and represented as color intensity.



Normalized scores that are greater than zero are mapped in the region, creating a focal point seed zone

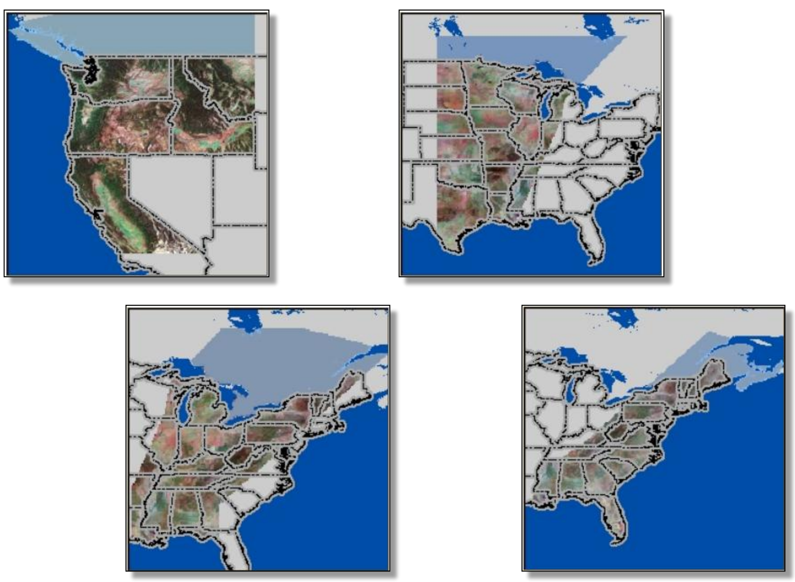
How the tool works

- Select your goal
- Login
- Enter location
- Select species
- Determine transfer limit
- Select climate models
- Apply constraints
- Map your results



sst.forestry.oregonstate.edu

Current regions



Seedlot Selection Tool (SST)

Given a specific <u>planting site</u> …

<u>Which seedlot</u> is well adapted today?…

And in the future given a climate change scenario?

sst.forestry.oregonstate.edu

Seedlot Selection Tool (SST)

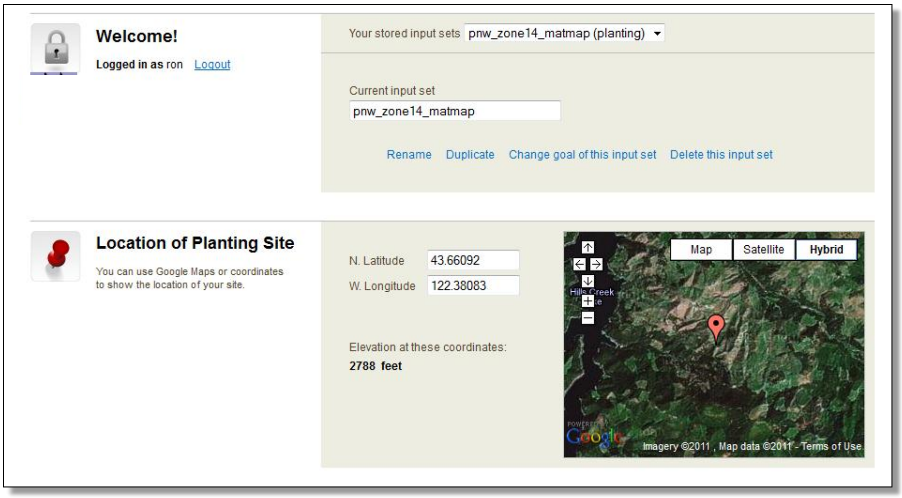
Given a specific <u>seedlot</u> …

Where is it expected to be well adapted today?…

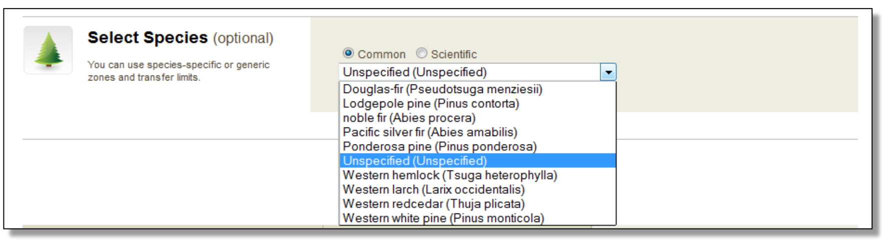
And in the future given a climate change scenario?

sst.forestry.oregonstate.edu

Data inputs: location



Data inputs: species



Data inputs: transfer limit

Transfer Limit

Use a recommended limit, enter your own limit, or use an existing zone to calculate a limit.

Select a recommended transfer model and limit | ***Select my own climate variables and limits*** | **Use a zone to calculate a limit**

Mean annual Precip (MAP) [mm]

Description: mean annual precipitation millimeters

Add variable

Climate Variables Table Method for determining transfer limit: *Select my own climate variables and limits*

	Name of climate variable	Present climate value	Climate value in target year	Target year	Transfer limit	Ready to Map?
Edit Delete	Mean annual Temp (MAT)	103	103	Present	-	☐
Edit Delete	Mean annual Precip (MAP)	1360	1360	Present	-	☐

Data inputs: transfer limit

Select a recommended transfer model and limit | **Select my own climate variables and limits** | ***Use a zone to calculate a limit***

Mean annual Temp (MAT) [°C/10]

Details of Climate Variable

Description: mean annual temperature 10ths deg C

Add variable

Select the zone to use for calculating the transfer limit

	Name	Feature	Low elevation	High elevation
Select	**Basic OR modified (1996)**	**9**	**2001**	**3000**
Select	Original OR/WA (1973)	482	2001	3000
Select	NWTIC-ROSETIC 2nd Gen Breeding	ROSEBURG	2501	4000

Choose the center of the zone to be mapped

- (•) Use your location coordinates
- ( ) Use the climatic center of your input zone

Calculate transfer limit

Data inputs: transfer limit

Select the zone to use for calculating the transfer limit

	Name	Feature	Low elevation	High elevation
Select	**Basic OR modified (1996)**	**9**	**2001**	**3000**
Select	Original OR/WA (1973)	482	2001	3000
Select	NWTIC-ROSETIC 2nd Gen Breeding	ROSEBURG	2501	4000

Choose the center of the zone to be mapped

- (•) Use your location coordinates
- ( ) Use the climatic center of your input zone

[Calculate transfer limit]

Climate Variables Table Method for determining transfer limit: *Zone : Location coordinates used as the climatic center of output map*

	Name of climate variable	Present climate value	Climate value in target year	Target year	Transfer limit	Ready to Map?
Edit Delete	Mean annual Temp (MAT)	103	126	2050	20	☑
Edit Delete	Mean annual Precip (MAP)	1360	1390	2050	403	☑

Data inputs: climate variables table

	Name of climate variable	Present climate value	Climate value in target year	Target year	Transfer limit	Ready to Map?
Edit Delete	Mean annual Temp (MAT)	116	116	Present	19	☑
Edit Delete	Mean annual Precip (MAP)	3202	3202	Present	1587	☑

Goal: Find planting sites. Climate space is defined for seedlot in present climate. Map can be produced for present or future climates.

Produce map

Enter a title: My seedlot

Choose a data set: pnw_zone3s

Change the target year: 2050 (Present / 2020 / 2050)

[Submit]

	Name of climate variable	Present climate value	Climate value in target year	Target year	Transfer limit	Ready to Map?
Edit Delete	Mean annual Temp (MAT)	103	126	2050	20	☑
Edit Delete	Mean annual Precip (MAP)	1360	1390	2050	403	☑

Goal: Find seedlots. Climate space is defined for planting site in future climate. Map can be produced only for present climates.

Produce map

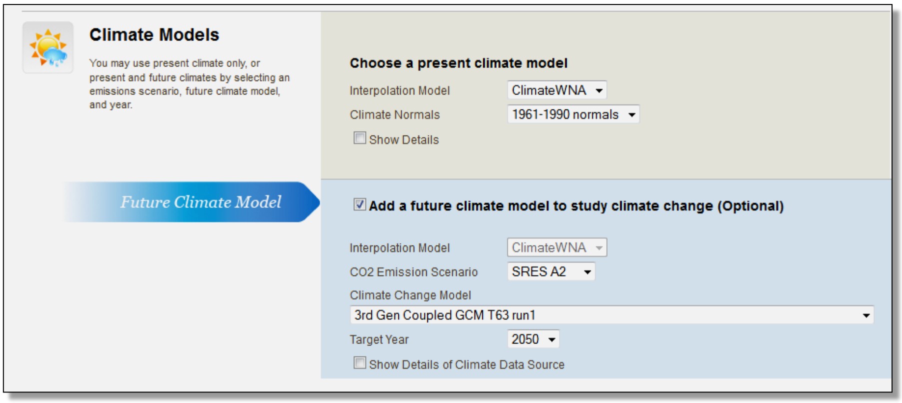
Enter a title: My planting site

Choose a data set: pnw_zone14_matmap

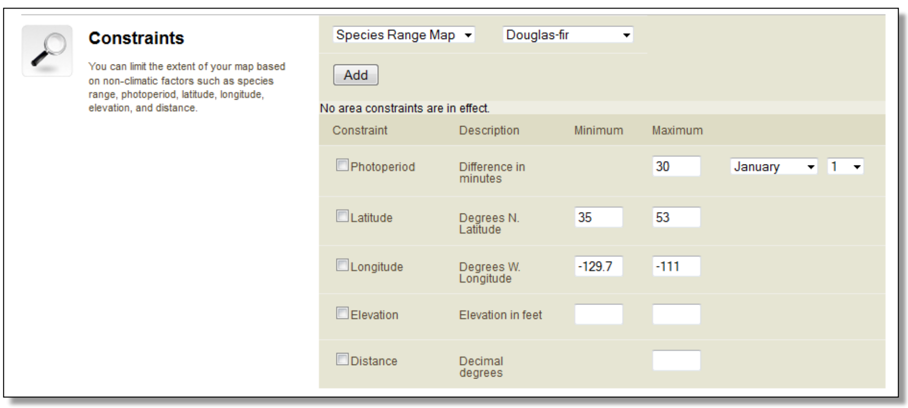
Target year: 2050. For the 'Find Seedlots' mode, change the target year on the inputs page.

[Submit]

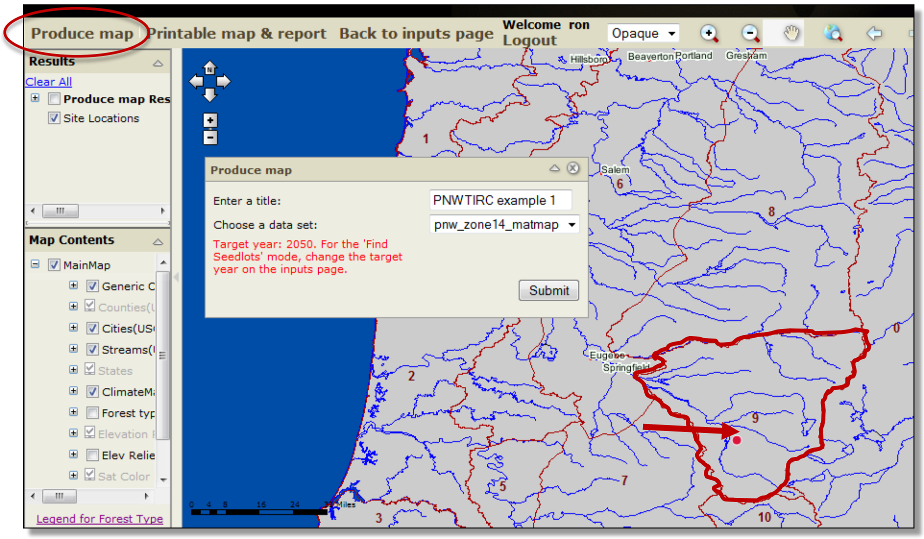
Data inputs: climate models



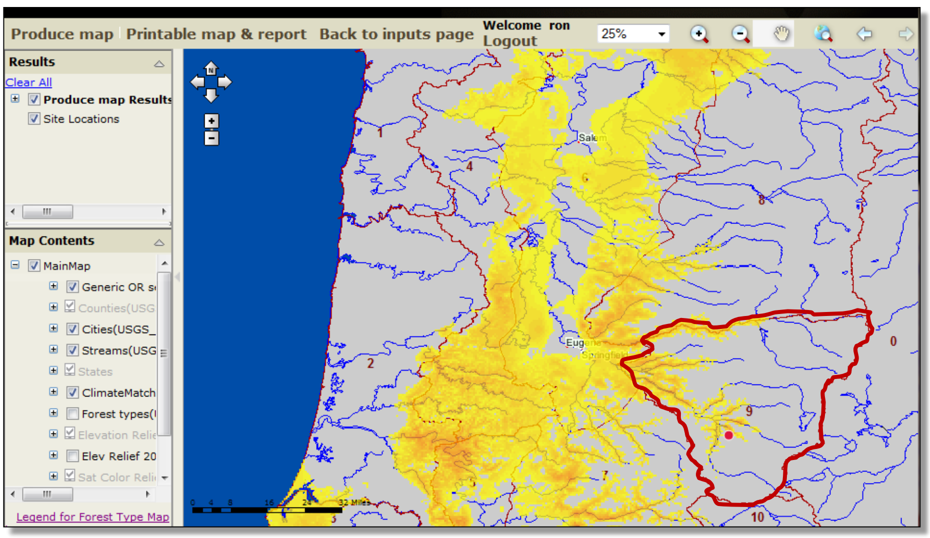
Data inputs: constraints



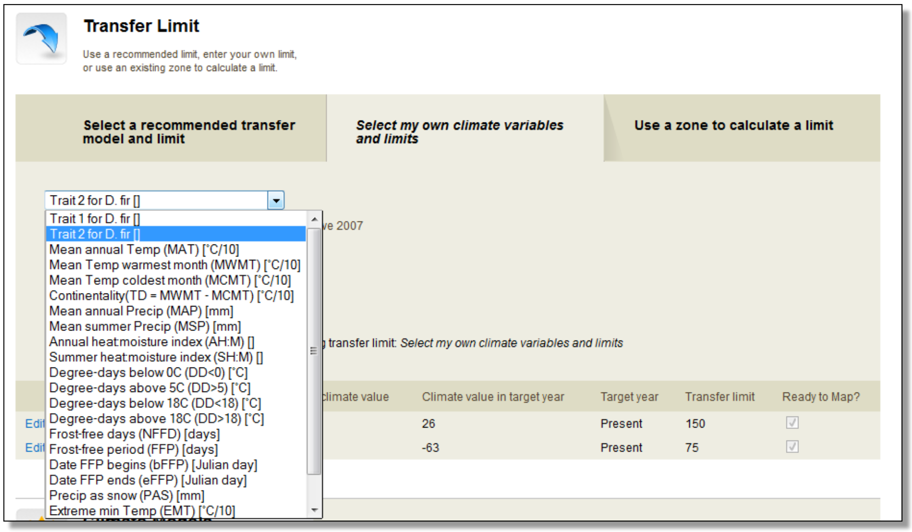
Map results



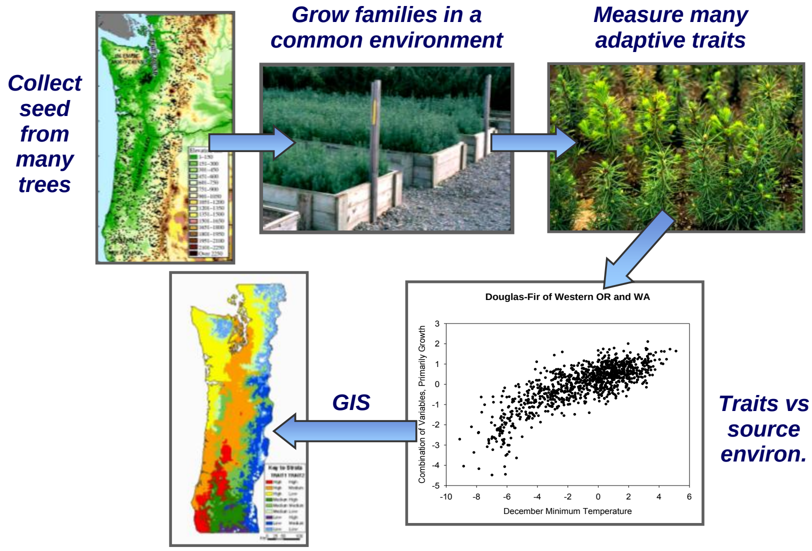
Map results



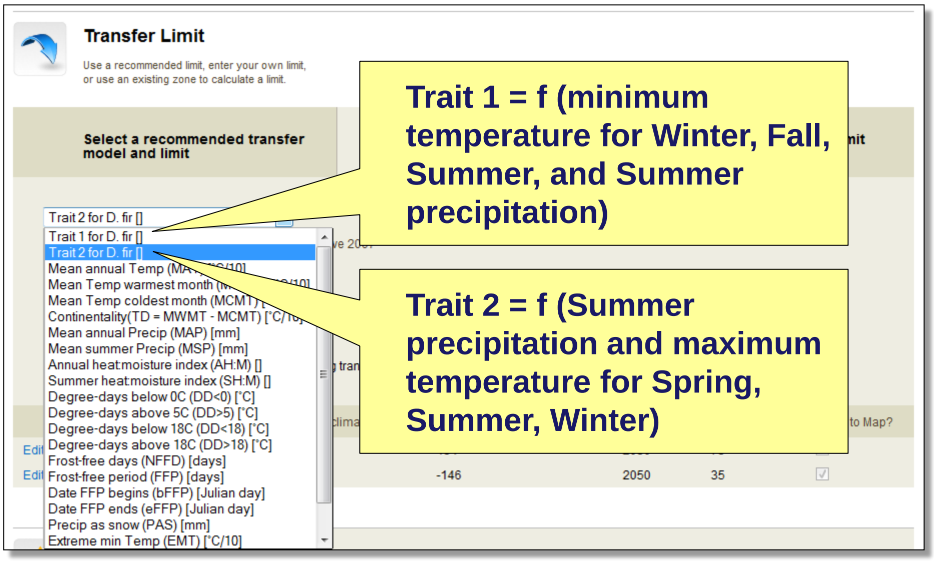
Data inputs: transfer limit



Transfer limits from seedling tests



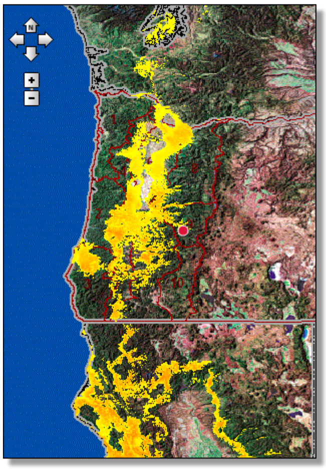
Data inputs: transfer limit



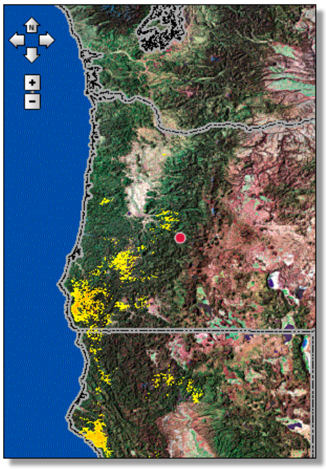
Data inputs: transfer limit

Find seedlots (2050)

Mean annual temperature &
mean annual precipitation



Trait 1 and Trait 2

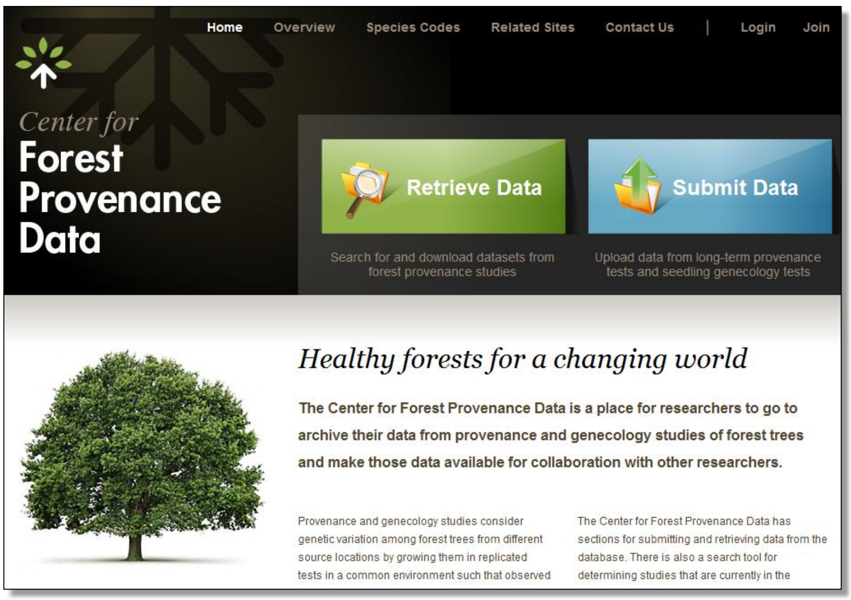


Next steps

- Add seed, breeding zones for other species
- Add more present and future climate models, especially regional models for the PNW
- Continue analyses needed to develop transfer limit recommendations
- Add multivariate models
- Develop analogous web tools for other regions
- Enhance map data layers

Acknowledgements

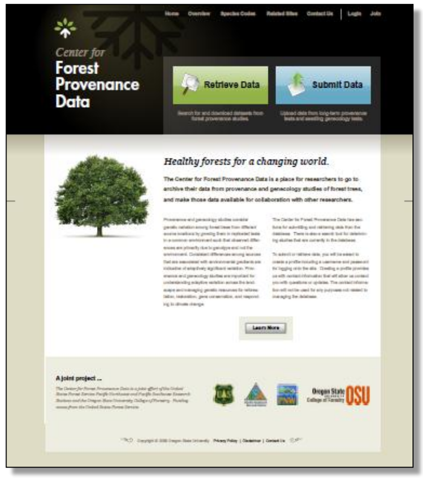
- Lauren Magalska - GIS assistance
- Tongli Wang - ClimateWNA climate data
- Nick Crookston – ANUSPLIN climate data
- Paul Berrang – Eastern regions tester
- Greg DeVeer - web designer



Center for Forest Provenance Data

Objectives

1. Archive data from long-term provenance tests and seedling genecology tests
2. Make datasets available to researchers through the web

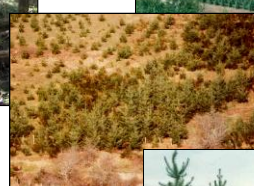


Web site: http://cenforgen.forestry.oregonstate.edu/index.php

Denise Cooper, Brad St.Clair, Glenn Howe, Jessica Wright, Greg DeVeer
Funded by USFS Climate Change Research Program

Current Status

- 19 studies in system
  - ✓ 11 Douglas-fir
  - ✓ 1 Whitebark Pine
  - ✓ 2 Sugar Pine
  - ✓ 3 Ponderosa Pine
  - ✓ 1 White Fir / California Red Fir
  - ✓ 1 Ponderosa Pine / Jeffery Pine



- 3 studies to process, add to database/web
- Some studies provide data for all categories; others require contacting PI for response data

Budget and Other Business

Glenn Howe

Pacific Northwest Tree Improvement Research Cooperative
Department of Forest Ecosystems and Society
Oregon State University

PACIFIC NORTHWEST TREE IMPROVEMENT
RESEARCH COOPERATIVE

PNWTIRC

Budget 2010-11

Main points

- 2010-11 income = $110K
- Rayonier = new member
- 2011-12 income = $110K
- Indirect = 13%
- Income exceeded expenses (see next slide)
- Have substantial carryover – this year only (see next slide)

Attachment #1

Financial Support Received in 2010-2011

Organization	Financial Support
Regular Members	
Cascade Timber Consulting	8,000
Bureau of Land Management	8,000
Forest Capital Partners	8,000
Green Diamond Resource Company	8,000
Longview Timber Company	8,000
Olympic Resource Management	8,000
Oregon Department of Forestry*	8,000
Plum Creek Timber Company	8,000
Port Blakely Tree Farms	8,000
Rayonier	8,000
Roseburg Forest Products*	8,000
Stimson Lumber Company	8,000
Washington State Dept. of Natural Resources	8,000
Associate Members	
Starker Forests	4,000
Contractual Members	
Lone Rock Timber Company	2,000
Total	110,000

Budget 2010-11

Main points

- Summarizes costs of personnel
- Personnel costs were covered by PNWTIRC members and OSU (Director)
- Expenses were less than income because CAFS and CTGN funds were used to pay some salaries
- Carryover increased
- Budget could change after we learn which CAFS proposals are funded – but probably not

Attachment #2

PNWTIRC Income and Expenditures by Source

FY 2010-2011

Income and Expenditures	OSU	Members	Total
Income			
OSU Forest Research Laboratory	121,367	0	121,367
Membership fees and contracts	0	110,000	110,000
Carryover from previous year	0	25,576	25,576
Total income	**121,367**	**135,576**	**256,943**
Expenditures			
Salaries and OPE*			
Director (0.5 FTE funded by OSU)	68,065	0	68,065
Program Manager (0.10 FTE)	0	7,420	7,420
Research Coordinator (0.19 FTE)	0	13,655	13,655
Graduate students (0.58 FTE)	0	29,168	29,168
Student employees	0	6,669	6,669
Contracts	0	0	0
Supplies and Services	0	4,995	4,995
Travel	0	3,925	3,925
Total direct costs (TDC)	**68,065**	**65,832**	**133,897**
Indirect costs**	**53,302**	**8,558**	**61,860**
Direct + Indirect Costs	**121,367**	**74,390**	**195,757**
Carryover to next year	**0**	**61,186**	**61,186**

*OPE = other personnel expenses
**OSU indirect costs = (46.2% of OSU TDC) + (33.2% of Co-op TDC)
**Co-op indirect costs = 13% of Co-op TDC

Budget 2010-11

Main points

- Summarizes costs by project
- Most project costs reflect allocation of personnel costs to different projects
- Overall, expenditures were less than projected because CAFS and CTGN funds were used to pay some salaries
- We did not undertake additional CTGN wood stiffness field work this year
- The CAFS DF provenance test proposal was not funded

Attachment #3

Proposed and Actual PNWTIRC Budgets for 2010-2011*

Income	Proposed (7/10)	Actual (7/11)
Members fees and contracts	102,000	110,000
Carryover from previous year	22,402	25,576
Total income	**124,402**	**135,576**
Expenses	**Proposed (7/10)**	**Actual (7/11)**
Miniaturized Seed Orchards	8,766	9,586
Site Characterization (CAFS)	26,250	24,817
Wood Quality (CTGN)	15,831	0
Wood Quality (CAFS)	30,180	17,065
DF provenance tests (CAFS)	10,954	0
Technology Transfer	4,983	0
Administration	11,643	14,365
Total direct costs (TDC)	**108,606**	**65,832**
Indirect costs**	**14,119**	**8,558**
Direct + Indirect costs	**122,725**	**74,390**
Carryover to next year	**1,677**	**61,186**

*Cooperator funds only
**Co-op indirect costs are 13% of TDC

Budget details for 2010-2011

Attachment #4
Expenditures of Cooperator Funds for Fiscal Year 2010-2011 by Project and Activity

Expense*	Mini Orchards	Site Char. (CAFS)	WQ (CTGN)	WQ (CAFS)	Technology Transfer	Admin.	Total
Director (funded by OSU) (approx. FTE)	0 0.10	0 0.15	0 0.00	0 0.15	0 0.00	0 0.10	0 0.50
Program Manager (approx. FTE)	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	7,420 0.10	7,420 0.10
Research Coordinator (approx. FTE)	4,096 0.06	0 0.00	0 0.00	8,193 0.11	0 0.00	1,365 0.02	13,655 0.19
Graduate students (approx. FTE)**	0 0.00	24,642 0.49	0 0.00	4,526 0.09	0 0.00	0 0.00	29,168 0.58
Student employees (proportion of expense)	5,089 0.76	0 0.00	0 0.00	991 0.15	0 0.00	588 0.09	6,669 1.00
Personnel sub-total	**9,186**	**24,642**	**0**	**13,710**	**0**	**9,374**	**56,912**
Contracts	0	0	0	0	0	0	0
Supplies & Services	61	0	0	867	0	4,067	4,995
Travel	339	175	0	2,487	0	924	3,925
Non-personnel sub-total	**400**	**175**	**0**	**3,355**	**0**	**4,991**	**8,920**
Total direct costs (TDC)	9,586	24,817	0	17,065	0	14,365	65,832
Indirect costs (13% of TDC)	1,246	3,226	0	2,218	0	1,867	8,558
Total costs	**10,832**	**28,043**	**0**	**19,283**	**0**	**16,232**	**74,390**

*Personnel expenses include salary plus other personnel expenses (OPE)
**Full (half-time) graduate student assistantship = 0.49 FTE

Budget 2011-12

Main points

- Summarizes proposed costs of <u>personnel</u> for 2011-2012
- Part-time Program Manager (shared with CAFS and Strauss)
- Change to full-time Research Coordinator this year
- Increase in expenditures
  - *No CTGN funds to augment*
- Partial support of graduate student (Oguz Urhan)
- Contracts = proposed SNP genotyping

Attachment #5

Proposed Expenditures of Cooperator Funds for Fiscal Year 2011-2012

Income and Expenditures	FY 2010-11	FY 2011-12
Income from Cooperators		
Membership fees and contracts	110,000	110,000
Carryover from previous year	25,576	61,186
Total income	**135,576**	**171,186**
Expenditures		
Salaries and OPE*		
Director (0.5 FTE funded by OSU)	0	0
Program Manager (0.10 FTE)	7,420	7,500
Research Coordinator	13,655	73,746
Graduate students (0.58 FTE)	29,168	7,500
Student employees	6,669	7,000
Contracts	0	15,000
Supplies and Services	4,995	6,500
Travel	3,925	4,800
Total direct costs (TDC)	**65,832**	**122,046**
Indirect costs**	**8,558**	**15,866**
Direct + Indirect Costs	**74,390**	**137,912**
Carryover to next year	**61,186**	**33,274**

*OPE = other personnel expenses
**Co-op indirect costs = 13% of Co-op TDC

Budget 2011-12

Main points

- Summarizes proposed costs by project
- We expect that site characterization research will be augmented by CAFS
- We expect that WQ research will be augmented by CAFS
- I propose to transition into a new PNWTIRC project on SNP-based marker-assisted selection

Attachment #6

Proposed Expenditures of Cooperator Funds for Fiscal Year 2011-2012

Income	FY 2010-11	FY 2011-12
Members fees and contracts	110,000	110,000
Carryover from previous year	25,576	61,186
Total income	**135,576**	**171,186**

Expenses	FY 2010-11	FY 2011-12
Miniaturized Seed Orchards	9,586	25,674
Site Characterization (CAFS)	24,817	15,375
SNP Marker-assisted Selection	0	26,125
Wood quality (CAFS?)	17,065	34,998
Technology Transfer	0	0
Administration	14,365	19,875
Total direct costs (TDC)	**65,832**	**122,046**
Indirect costs*	**8,558**	**15,866**
Direct + Indirect costs	**74,390**	**137,912**
Carryover to next year	**61,186**	**33,274**

*Co-op indirect costs = 13% of Co-op TDC

Budget details for 2011-2012

Attachment #7

Proposed Expenditures of Cooperator Funds for Fiscal Year 2011-2012

Expense*	Mini Orchards	Site Char. (CAFS)	SNP MAS	WQ (CAFS)	Tech Transfer	Admin.	Total
Director (funded by OSU) (approx. FTE)	0 0.05	0 0.10	0 0.15	0 0.10	0 0.00	0 0.10	0 0.50
Program manager (approx. FTE)	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	7,500 0.10	7,500 0.10
Research Coordinator (approx. FTE)	22,124 0.30	7,375 0.10	7,375 0.10	29,498 0.40	0 0.00	7,375 0.10	73,746 1.00
FRA/Graduate students (approx. FTE)**	0 0.00	7,500 0.13	0 0.00	0 0.00	0 0.00	0 0.00	7,500 0.13
Student employees (proportion of expense)	3,000 0.43	0 0.00	2,000 0.29	1,000 0.14	0 0.00	1,000 0.14	7,000 1.00
Personnel sub-total	**25,124**	**14,875**	**9,375**	**30,498**	**0**	**15,875**	**95,746**
Contracts	0	0	15,000	0	0	0	15,000
Supplies & Services	250	250	1,500	1,500	0	3,000	6,500
Travel	300	250	250	3,000	0	1,000	4,800
Non-personnel sub-total	**550**	**500**	**16,750**	**4,500**	**0**	**4,000**	**26,300**
Total direct costs (TDC)	25,674	15,375	26,125	34,998	0	19,875	122,046
Indirect costs (13% of TDC)	3,338	1,999	3,396	4,550	0	2,584	15,866
Total costs	**29,011**	**17,373**	**29,521**	**39,548**	**0**	**22,458**	**137,912**

*Personnel expenses include salary plus other personnel expenses (OPE)
**Full (half-time) graduate student assistantship = 0.49 FTE

Conifer Translational Genomics Network
Coordinated Agricultural Project

CATTAGCTCTGN CAP CAAGTCATCCATGATTAGCT

Douglas-fir SNP chip

Future of Douglas-fir genomics research and application

Glenn Howe, Jianbin Yu, and Scott Kolpak

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CTGN CAP

The Conifer Translational Genomics Network Coordinated Agricultural Project is a multi-state, multi-institution project, funded by USDA/CSREES/NRI and the USDA Forest Service. CTGN will deliver genomic assisted breeding by linking laboratory and field research with education and extension. Assertive and comprehensive education and extension programs will provide widespread training for post-doctoral researchers, graduate and undergraduate students, tree breeders, managers, stakeholders, and the general public.

What is CTGN CAP?

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CTGN CAP

Our Team

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CTGN CAP

Overview

- What are SNPs? How do we find them?
- Transcriptome sequencing
- SNP discovery
- Marker-assisted selection – Genomic selection
- A Douglas-fir SNP chip is coming!
- Conclusions and future

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What are SNPs?
How do we find them?

Single nucleotide polymorphism (SNP)

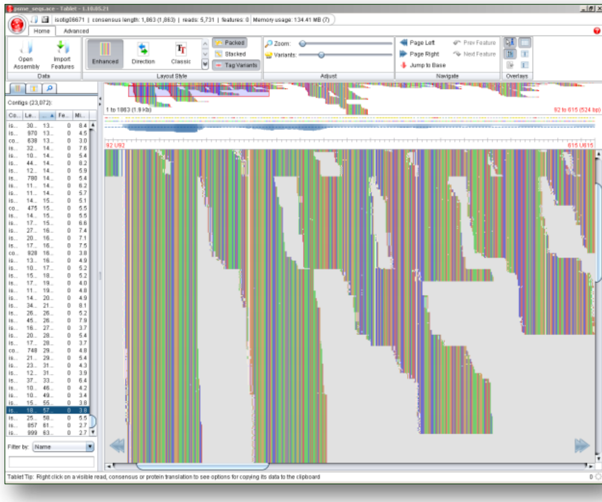
SNP ↓

Tree 1	A C G T G T C **G** G T C T T A	Maternal chrom.
	A C G T G T C **A** G T C T T A	Paternal chrom.
Tree 2	A C G T G T C **G** G T C T T A	Maternal chrom.
	A C G T G T C **G** G T C T T A	Paternal chrom.
Tree 3	A C G T G T C **A** G T C T T A	Maternal chrom.
	A C G T G T C **A** G T C T T A	Paternal chrom.

Tree 1 is ***heterozygous*** Trees 2 and 3 are ***homozygous***

A genome from many short sequences

Next-generation sequencing



Find SNP markers

Focus of Douglas-fir CTGN program

Need more SNP markers for Douglas-fir

- Available resources at the start of the CTGN project
  - *18,000 ESTs (Sanger) and 384 SNP chip (121 genes)*

We added next-generation transcriptome sequencing for SNP discovery

- DOE Joint Genome Institute 454 sequencing project (Dean et al)
- New CTGN sequencing (454 and Illumina)
- Collaboration with Rich Cronn, USFS (Illumina sequencing)

Use of CTGN information and resources

- Incorporate phenotypes from the NWTIC program (relevant to breeders)
- A valuable goal would be to genotype all second-cycle parents
- Measure new phenotypes where possible

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Transcriptome sequencing

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Transcriptome sequencing and SNP discovery

mRNA isolation from diverse tissues

↓

cDNA Library preparation

↓

454 and Illumina sequencing

↓

Sequence assembly and annotation

↓

SNP detection and SNP chip design

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Transcriptome sequencing strategy

Sanger sequences have lower error rates

- 18K previous Sanger sequences from Dana Howe project
- Used with 454 sequences for transcriptome reference

Roche 454 GS-FLX Titanium provides longer reads

- DOE JGI collaboration (single-genotype sample)
- Univ Illinois Carver Biotechnology Center (multi-genotype sample)
  - *Transcriptome reference and SNP discovery*
  - *Diverse tissues from trees of 79 seed sources throughout the year*

Illumina Genome Analyzer IIx provides greater depth

- Greater sequence depth than 454 sequencing
- Multi-genotype samples for SNP discovery

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Douglas-fir cDNA libraries

Table 1. Characteristics of Douglas-fir cDNA libraries and numbers of sequences (reads) filtered using the snoWhite pipeline.

Plant materials (dataset ID) Collection information	Sequencing method*	Total reads in dataset (%)	Number of reads filtered from the input dataset (% of library total)					
			Short or low quality	Adapter or vector	Chloro-plast	Mitochon-drial	rRNA	Retro-transposon
Multi-genotype #1 (MG1_S) Cold season Greenhouse	Sanger Normalized Non-normalized	12157 (100)	57 (0.47)	0 (0.00)	2 (0.02)	2 (0.02)	0 (0.00)	1 (0.01)
Multi-genotype #2 (MG2_R) Cold and warm seasons	GS-FLX Titanium Normalized	1709211 (100)	6649 (0.39)	1893 (0.11)	8570 (0.50)	5519 (0.32)	7264 (0.42)	11114 (0.65)
Single-genotype (SG_R) July 8, 2008	GS-FLX Titanium Non-normalized	1241260 (100)	6582 (0.53)	1826 (0.15)	11070 (0.89)	10463 (0.84)	86828 (7.00)	21849 (1.76)
All libraries		2962628 (100)	13288 (0.45)	3719 (0.13)	19642 (0.66)	15984 (0.54)	94092 (3.18)	32964 (1.11)

*GS-FLX Titanium is the Roche 454 sequencing platform.

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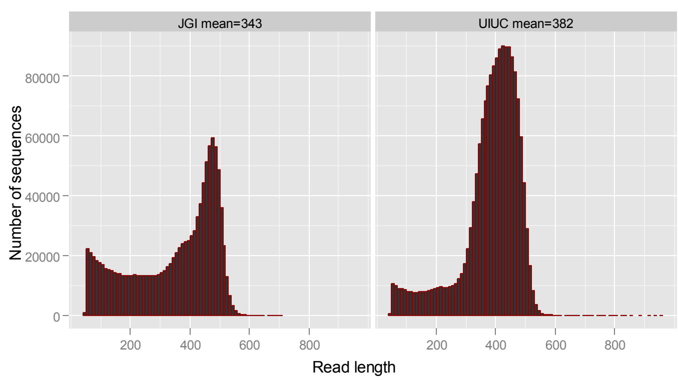
New 454 sequences (reads) after cleaning

Source	No. reads	Min length	Max length	Mean length	Bases
SG-JGI	1100843	50	706	343	378020744
MG-UIUC	1657805	50	955	382	632655354



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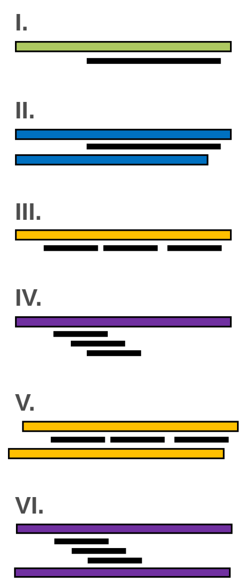
DF transcriptome assembly

Statistic	Number
Total reads	2764549
Assembled reads	2544087
Total assembled	2741911
Singletons	102623
Isogroups (genes)	25002
Isotigs	38589
One isotig/isogroup	18774
Mean length of isotig	1390
N50	1883
Total consensus nucleotides	72302278

DF isotigs vs WS unigenes

Type	No. of WS hits	Diff DF hits same WS?	Do other DF overlap?	Isotig Confid.	Number of isotigs: 1 isotig/ Isogroup (18774)	Number of isotigs: 2+ isotigs/ isogroup (19815)
I	1	No	–	Highest	5140	261
II	2+	No	–	Higher	894	86
III	1	Yes	No	Higher	1767	577
IV	1	Yes	Yes	Medium	1736	6974
V	2+	Yes	No	Medium	587	161
VI	2+	Yes	Yes	Lower	3406	7040
	Total hits	–	–	–	**13530**	**15099**
VII	**No hits**	–	–	Lower	**5244**	**4716**



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We can infer the functions of many genes

Table 2. Numbers and percents of Douglas-fir cDNA sequences with matches to sequences in three protein databases (BlastX e-value < 10^{-5}).

	Unigenes (25002)*				Singletons (102623)†	
	1 isotig/isogroup (18774)		>1 isotig/isogroup (6228)		Singletons (102623)	
Database	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Uniref50	15054	80.2	3446	55.3	25757	25.1
TAIR9	13747	73.2	3254	52.3	15917	15.5
Annot8r	11733	62.5	2862	46.0	14836	14.5

* Unigenes are Newbler v2.3 isogroups. For the isogroups with more than 1 isotig, a hit was counted only if all isotigs matched the same protein in the database.

† Singletons are 454 reads that did not assemble with any other reads.

Table 3. Numbers of Douglas-fir cDNA sequences with matches to sequences in the Uniref50 protein database. Matches are grouped by taxonomic affiliation and percentages are relative to the total number of matches (BlastX e-value < 10^{-5}). Numbers of input Douglas-fir sequences are in parentheses.

	Unigenes (25002)				Singletons (102623)	
	1 isotig/isogroups (18744)		> 1 isotig/isogroups (6228)		Singletons (102623)	
Taxonomic category	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Conifers	4088	27.16	1073	31.14	6486	25.18
Other plants	9713	64.52	2047	59.40	16061	62.36
Fungi	6	0.04	4	0.12	66	0.26
Invertebrates	487	3.24	120	3.48	1087	4.22
Vertebrates	17	0.11	6	0.17	92	0.36
Other Eukaryotes	582	3.87	182	5.28	658	2.55
Bacteria	123	0.82	8	0.23	830	3.22
Viruses	4	0.03	0	0.00	19	0.07
Environmental samples	21	0.14	6	0.17	37	0.14
Unassigned	13	0.09	0	0.00	421	1.63
Total matches	**15054**	**100**	**3446**	**100**	**25757**	**100**

We can infer the functions of many genes

Annotation	Accession	Species	Bit-score	E-value						
Enhanced disease susceptibility 1	Q9SU72	Arabidopsis thalia	209	2.00E-53					Disease	
Putative uncharacterized protein	Q8BQW4	Mus musculus	55.5	2.00E-08						
Disease resistance protein RPS5	O64973	Arabidopsis thalia	116	2.00E-39					Disease	
Non-specific lipid-transfer protein 3	Q9LLR7	Arabidopsis thalia	70.5	3.00E-12						
Cytochrome P450 84A1	Q42600	Arabidopsis thalia	232	5.00E-90						
Probable disease resistance protein At4g33300	Q9SZA7	Arabidopsis thalia	467	e-131					Disease	
Putative adenylosuccinate lyase	Q8RY94	Arabidopsis thalia	636	0						
Cell cycle-related protein	Q9ZPE7	Arabidopsis thalia	214	2.00E-55						
Laccase-5	Q9SIY8	Arabidopsis thalia	148	3.00E-36						Laccase
Aquaporin NIP1-2	Q8LFP7	Arabidopsis thalia	211	2.00E-54			Aquaporin			
Leucine-rich repeat receptor-like protein kinase (Frag	C0LGM1	Arabidopsis thalia	317	e-115						
Leucine-rich repeat receptor-like protein kinase (Frag	C0LGM1	Arabidopsis thalia	320	e-116						
Cytokinin-O-glucosyltransferase 2	Q9SK82	Arabidopsis thalia	288	3.00E-77				Growth		
Putative lipid phosphate phosphatase 3, chloroplasti	Q8LFD1	Arabidopsis thalia	375	e-103						
Mannan endo-1,4-beta-mannosidase C	Q5AZ53	Emericella nidula	150	6.00E-36						
17.9 kDa class I heat shock protein	Q84Q77	Oryza sativa subsp	157	3.00E-38	Temp					
Disease resistance protein RPS2	Q42484	Arabidopsis thalia	127	2.00E-44					Disease	
Xanthoxin dehydrogenase	Q9C826	Arabidopsis thalia	216	9.00E-56						
Dehydration-responsive element-binding protein 2A	O82132	Arabidopsis thalia	117	2.00E-25		Water				
Argonaute (AGO1)-like protein	Q9ZVD5	Arabidopsis thalia	897	0						
Argonaute (AGO1)-like protein	Q9ZVD5	Arabidopsis thalia	897	0						
Gamma-secretase subunit Aph-1	Q9VQG2	Drosophila melan	68.2	5.00E-11						
Peroxidase 54	Q9FG34	Arabidopsis thalia	319	8.00E-87						
Disease resistance protein-like	Q9LXN9	Arabidopsis thalia	228	8.00E-59					Disease	
Lipoxygenase 5, chloroplastic	Q9LUW0	Arabidopsis thalia	808	0						

SNP discovery

Illumina short-read sequencing
Multi-genotype sample

Goal was to increase sequence depth and confidence of SNP calls

- Genome Analyzer IIx
- Illumina paired-end sequencing
  - *100-bp reads*
  - *64.0 million reads (32.0 million pairs)*
- Same multi-genotype sample as 454 sequencing
- Accomplishments
  - *We mapped the reads to our reference transcriptome and detected* ***206,026 potential SNPs (all isotigs)***

Illumina short-read sequencing
Gene expression samples

Primary goal is to compare gene expression among provenances, sites, and seasons (Cronn, Knaus, Dolan)

- Collaboration with ongoing USDA AFRI project
- Illumina single-read sequencing
  - *80 bp single-end reads*
  - *We used 22.4 million reads*
  - *Will generate ~20 Gbp of transcriptome sequence*
- Coos Bay (coastal DF) and Yakima (interior?) seed sources
- Accomplishments
  - *We mapped the reads to our reference transcriptome and detected a total of* ***170,629 SNPs summed over two seed sources (all isotigs)***

Extension to interior Douglas-fir

Goal was to develop SNP markers for interior Douglas-fir (var. glauca)

- Collaboration with Sam Cushman, USFS Rocky Mountain Station
- Include 'interior' SNPs on the SNP chip
- Multi-genotype sample = 80.4 million reads (40.2 million pairs)
  - *Trees in BCMoF provenance test and N. Idaho*
  - *Marc Rust, Director, Inland Empire Tree Improvement Cooperative*
  - *Needles, stems, and buds*
- Accomplishments
  - *We mapped the reads to our reference transcriptome and detected* ***203,714 potentially unique and shared SNPs with coastal Douglas-fir (all isotigs)***

Potential SNP markers in Douglas-fir

SNPS detected in our most confident genes

(1 isotig/isogroup)

Douglas-fir variety	No. of SNPs	No. of genes with SNPs
Coastal	238,760	17,556
Interior	151,918	16,580
Both (in common)	71,376	13,759

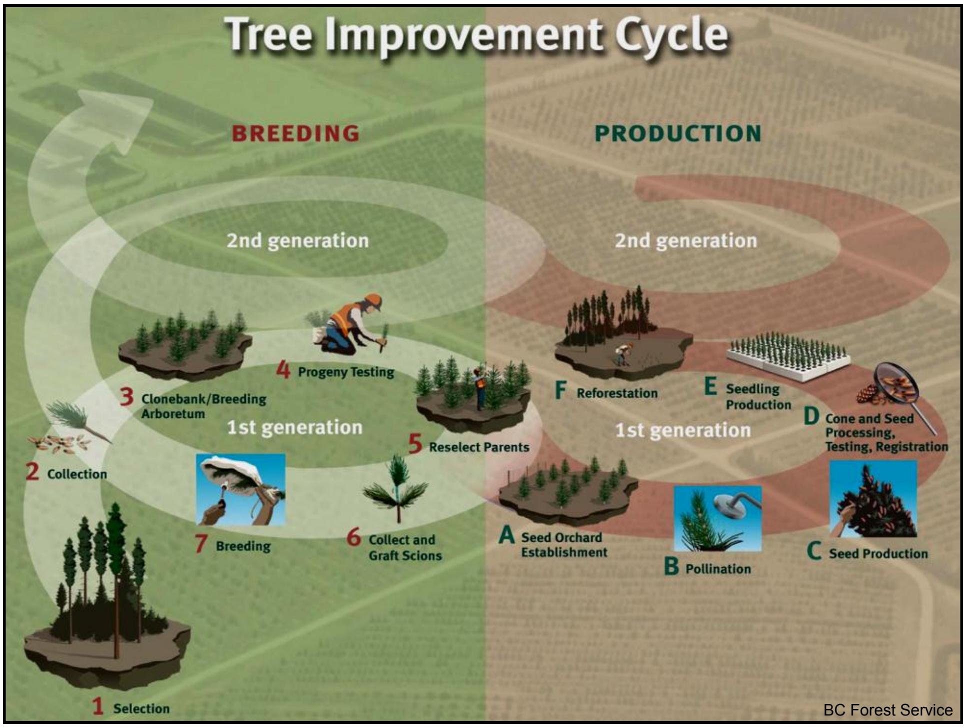
Conclusion = lots of SNP markers to choose from!

Marker-assisted selection
Genomic selection

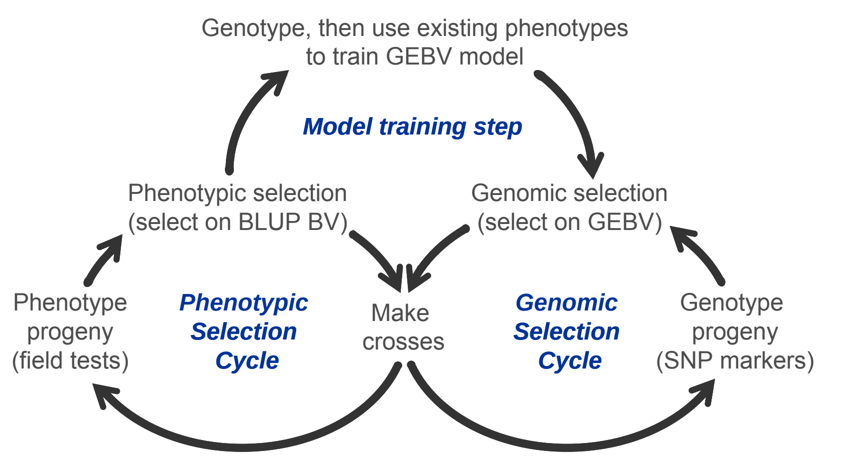
The promise of genomic selection

Paradigm shift in perspective

- Forget about finding individual markers associated with desirable traits
- Explain desirable traits by using many, many markers at the same time
- Now possible because we can genotype many SNP markers at modest cost
  - *SNP, single nucleotide polymorphism, = changes between A, G, C, T*
- Why might it be useful?



The promise of genomic selection



GEBV = genomic estimated breeding value

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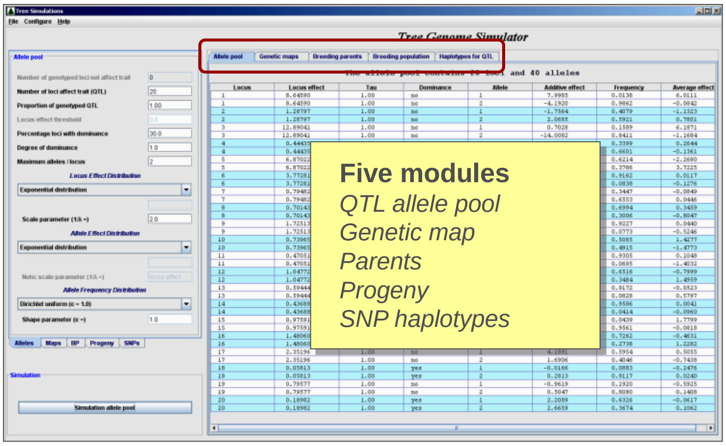
Tree Genome Simulator



A Douglas-fir SNP chip is coming!

SNP chip

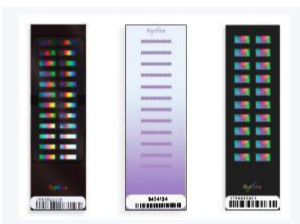
SNP choices are based on…

- Confidence in the assembled gene
  - *1 isotig/isogroup versus 2+ isotig/isogroup*
  - *White spruce comparisons (highest, higher, medium, lower confidences)*
- Inferred functions (annotations)
  - *Growth, wood properties, adaptation to environmental stresses*
  - *Genes targeted by lobolly pine SNP chip*
- SNP quality based on SAMTools statistics
  - *Primarily consensus quality, SNP quality, number of covering reads*
- SNPs detected in multiple datasets (including interior Douglas-fir)
- Illumina Infinium SNP design scores

Douglas-fir SNP chip (Illumina Infinium)

Douglas-fir SNP chip from will soon become available

- Recently ordered - now working with Illumina to finalize SNP choices
- Up to 9000 SNPs (9000 ‘attempted bead types’)
- Cost of the chip is covered by CTGN
- Additional cost of genotyping ~10$/sample



Proposed PNWTIRC research

Use SNP chip to genotype NWTIC second cycle parents

- Test the SNP chip on coastal and interior Douglas-fir
- Genotype NWTIC second-cycle parents
- Leverage CTGN information and investment in SNP chip
- Total cost for PNWTIRC genotyping may be $15K
- Develop a longer-term proposal for PNWTIRC research on genomic selection
  - *New PNWTIRC graduate student?*
- Use as a foundation for other competitive grant proposals

Conclusions and future

Future

SNP verification is the highest priority for Douglas-fir

- Goal is to maximize the number of SNPs assayed (versus genotypes) to be able to test genomic selection
- Our CTGN goal was to construct the largest SNP chip possible
  - *1536 SNP chip was originally proposed*
  - *We recently ordered an Infinium SNP chip for Douglas-fir*
  - *Potentially 9000 SNPs with CTGN funds*
- Test the SNP chip on the highest priority genotypes
- Make the SNP chip available to tree breeders so that in-kind support can expand the number of genotypes analyzed

Douglas-fir CTGN accomplishments

New phenotypes and breeding values

- BVs for wood stiffness, fall cold hardiness, vegetative phenology, or reproductive phenology were estimated for about 1300 genotypes
- BVs for growth and stem form are already available for these same genotypes

Reference transcriptome for Douglas-fir

- A reference transcriptome based on 2.8M Roche 454 and12K Sanger sequences has 25,002 isogroups (gene models) and 102,623 singletons

SNP chip for coastal and interior Douglas-fir

- As many as 9000 SNPs (ABTs) and 1152 samples
- Costs of the SNP chip (but not genotyping) are covered by CTGN

Tree Genome Simulator

- Software can be used to design and evaluate marker-assisted selection schemes

Acknowledgements

Genomic resources from CTGN can be used by Douglas-fir breeders

- Pacific Northwest Tree Improvement Research Cooperative (PNWTIRC)
- Northwest Tree Improvement Cooperative (NWTIC)
- Inland Empire Tree Improvement Cooperative (IETIC)

Collaborators are…

- PNWTIRC, NWTIC (Keith Jayawickrama), and IETIC (Marc Rust)
- USFS Pacific Northwest Research Station (Cronn)
- University of GA and Joint Genome Institute (Dean)
- USFS Rocky Mountain Research Station (Cushman)

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Thank You.

Conifer Translational Genomics Network
Coordinated Agricultural Project

PNWTIRC
Miniaturized Seed Orchard Study

Scott Kolpak[1], Jim Smith[2], Glenn Howe[1]

Pacific Northwest Tree Improvement Research Cooperative
Department of Forest Ecosystems and Society
Oregon State University

Background

*Miniaturized Seed Orchards (MSO) **

- Increased per hectare seed yields through higher stocking of orchards and crown management (e.g., fruit trees, *Pinus radiata*)
- Shift to earlier production of operational quantities of seed
- Increased genetic gains by facilitating pollination techniques (CMP, SMP) and reducing pollen contamination (bloom delay)
- Reduced costs of CMP, SMP, and cone harvest

Orchards were mostly grafted in 2003 and 2004

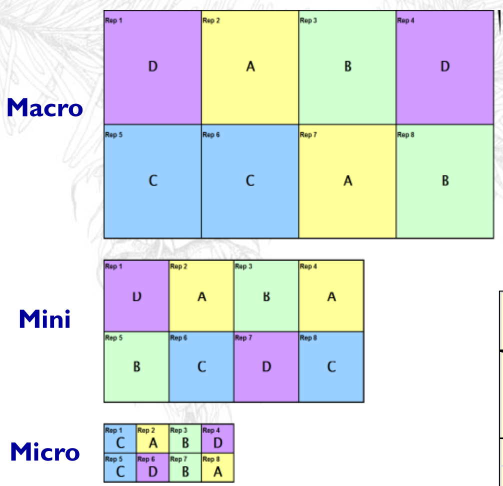
Flower stimulation began in 2009

***** Seed Orchard Research in Coastal Douglas-fir: Comparison of Macro, Micro, and Mini Orchards, July 1999, T.S. Anekonda and W.T. Adams.***

Background

Table 1: MSO research goals and progress (Anekonda and Adams 1999)		
Original objectives	**Location**	**Status**
1) Compare three orchard types for seed production and management efficiency	Plum Creek MSO	Ongoing
2) Define the best age to begin floral stimulation in MSOs	Roseburg Resources Vaughn & PNWCTA orchards	Completed - Cherry et al. 2007
3) Evaluate crown control techniques	Roseburg Resources Vaughn orchard	Completed - Pruning study
4) Compare pollination methods (CP, SMP)		Drop objective
5) Evaluate the clonal response to MSO management regimes	Plum Creek MSO	Ongoing

MSO design and layout



3 orchard spacings

- 4x6 m, 2x4 m, 1x3 m

4 block-pairs / spacing

- 8 total replications

5-tree to 6-tree row-plots

Table 2: MSO spacing, no. of trees, and crown height.			
Spacing (m)	**No. of trees**	**Stems / ha**	**Crown height (m)**
4x6	640	416	4
2x4	640	1,250	3
1x3	768	3,333	2

MSO design and layout

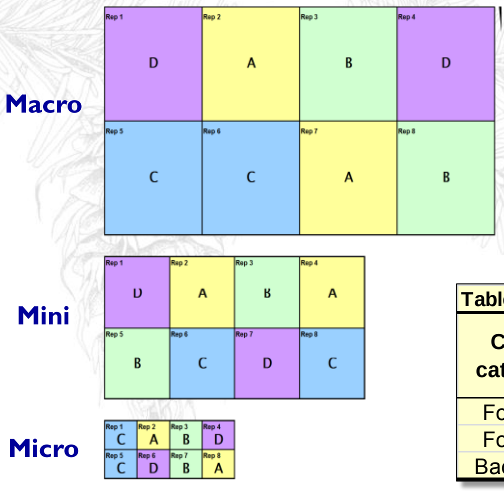


Table 3: Clone composition		
Clone category	**Age of ortet at grafting**	**No. clones**
Forward	10	12
Forward	30	4
Backward	60-100	8

Orchard activities 2010 - 2011

Flower stimulation

- Half the blocks in the 2x4 and 4x6 m orchards, all of the 1x3 m orchard block were stimulated in the spring of 2010 (girdling and calcium nitrate)

Data collected

- **2010 crop** – crown size, cone counts, seed counts
- **2011 crop** – cone counts

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Talk outline

Talk goal: ***Discuss cone production differences among orchard spacings and age of ortets***

- ***What factors influenced cone production in 2010 and 2011?***

Talk outline

- ***Crown volume*** – 2010 crop, background and results
- ***Cone production*** – 2010 and 2011 crops by spacing, ortet age, and crown volume
- ***Flower production*** – 2010, background, comparisons with cone production
- ***Future directions***

Crown measurements

Observations

- Crown shapes are different between clone ages

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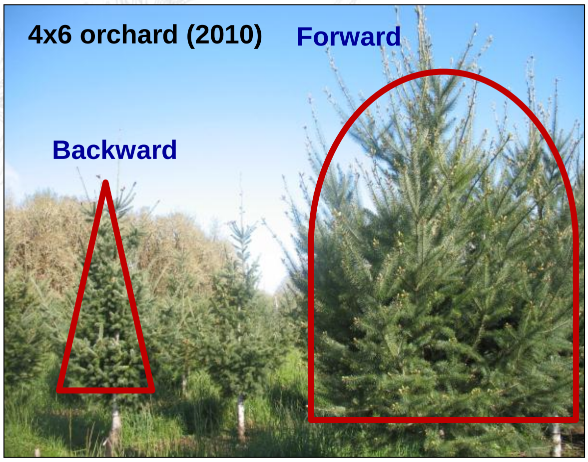
Crown volume measurements

Observations

- Crown shapes are different between clone ages



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Crown volume measurements

Observations

- Pruning altered crown shape, but effects on crown volume are less known

1x3 orchard (2010)

Backward

Forward

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RESEARCH COOPERATIVE

Crown volume goals

1x3 orchard (2010)

Learn how orchard differences in crown volume affect cone production

Backward

Forward

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Crown volume measurements

Direct measurements

- Crown height = total tree height - live crown height
- Crown shape
- Maximum crown radius (west side)

Indirect measurements

- Basal diameter – stem diameter at the middle of the first internode above the graft union

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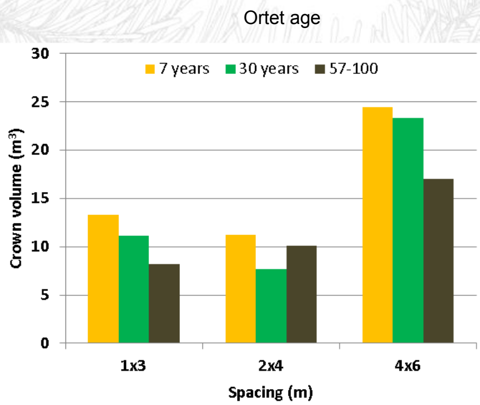
Crown volume by spacing and ortet age



Crowns larger in 4x6 orchard

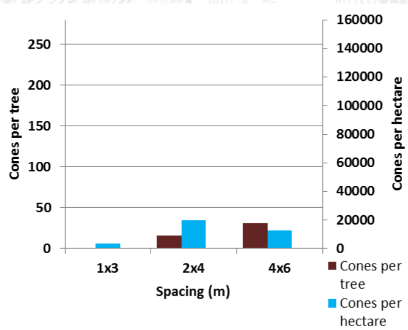
- Never pruned
- Wider spacing

Crowns larger in forward clones

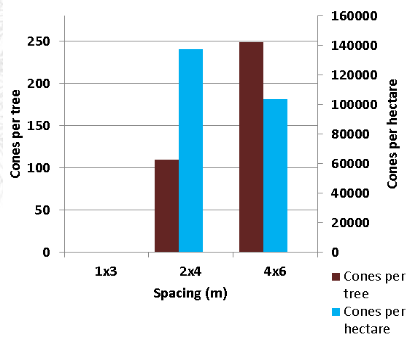
- Particularly in the 4x6 orchard
- Developmentally younger scions
- Management levels-the-playing-field (e.g., 1x3 & 2x4 orchards)

Cone production by spacing: 2011 crop

Unstimulated



Stimulated



- Stimulation increases cone production
- Cones / tree = 4x6 m orchard is best
- Cones / hectare = 2x4 m orchard is best

PACIFIC NORTHWEST TREE IMPROVEMENT
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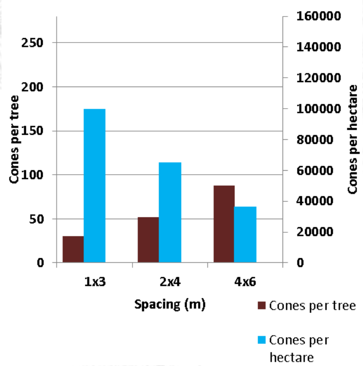
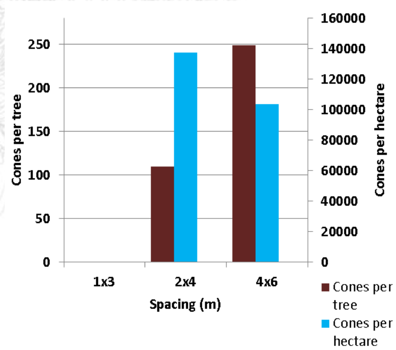
Cone production by spacing 2010 vs. 2011 cone crops

2010 cone crop



2011 cone crop



- Tradeoff between managing for more cones/tree vs cones/hectare
- Consider smaller trees at higher planting densities

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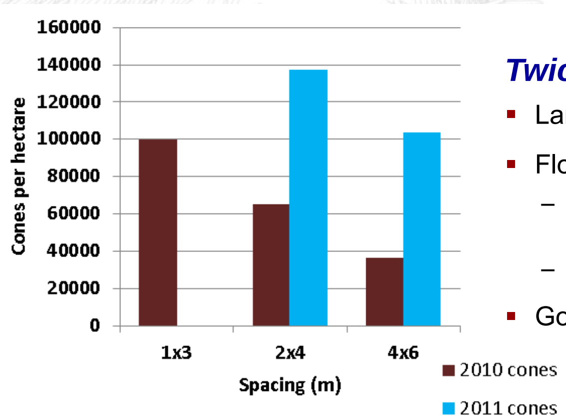
Cone production per hectare by spacing



Twice the cones in 2011

- Larger and older trees
- Flower stimulation differed
  - *2010 = girdling + calcium nitrate + GA*
  - *2011 = girdling + GA*
- Good cone year in 2011

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Miniaturized seed orchards

2x4 orchard

4x6 orchard

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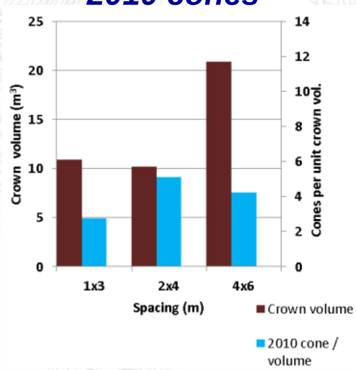
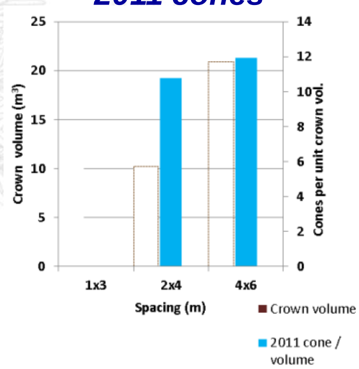
Crown volume & cone production by spacing

2010 cones



2011 cones



- **2010 cone crop** – 4x6 orchard trees are twice as large, but still support the same number of cones per unit crown volume
- **2011 cone crop** – measure this fall

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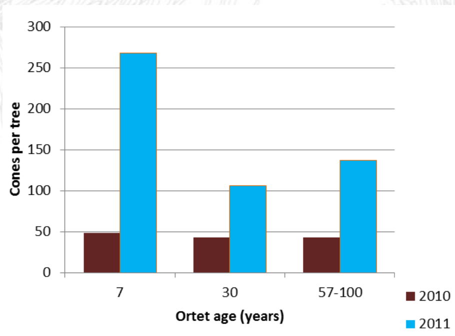
Cone production by ortet age



- Higher cone production in young clones

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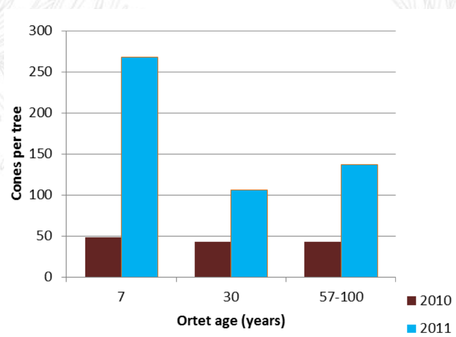
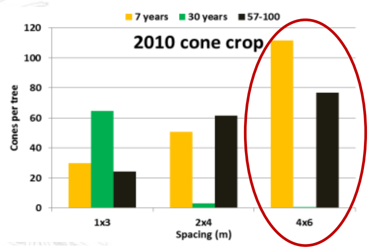
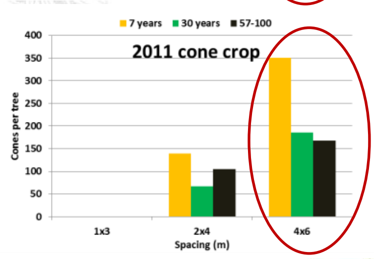
Cone production by ortet age







- Higher cone production in young clones
- Mostly influenced by trees in the 4x6 orchard

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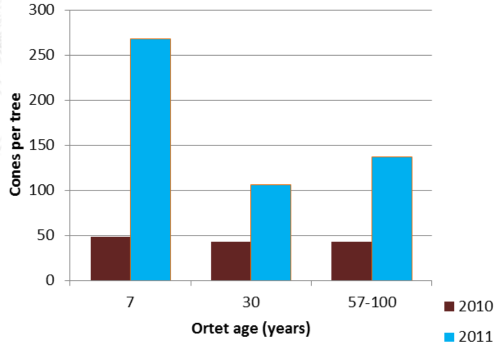
Cone production by ortet age



- Higher cone production in young clones
- Mostly influenced by trees in the 4x6 orchard
- Likely a consequence of the larger crowns on the forward selections

2010 cone crop: Data collection

Flower data

- Flower counts
  - *Female flowers were counted (to the nearest 10 flowers)*
  - *Numbers of male flowers were estimated and placed into 5 classes*
- Floral developmental stages
  - *Rated using a 5-point scale*

Vegetative bud development ("bud burst")

- Rated using a 5-point scale

Frost flower damage survey

- Damaged female flowers: Yes or no
- Percent damaged female flowers
- Floral developmental stage when damage occurred

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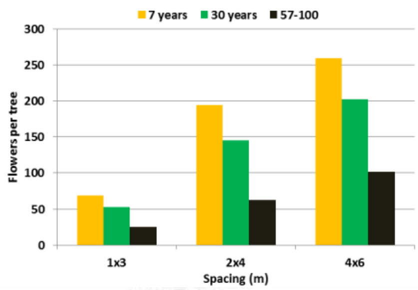
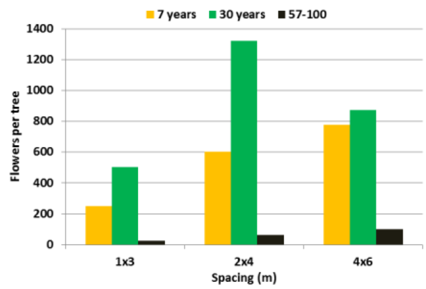
2010 cone crop
Flowering by spacing and ortet age

Female flowers



Male flowers



More male and female flowers from developmentally younger trees

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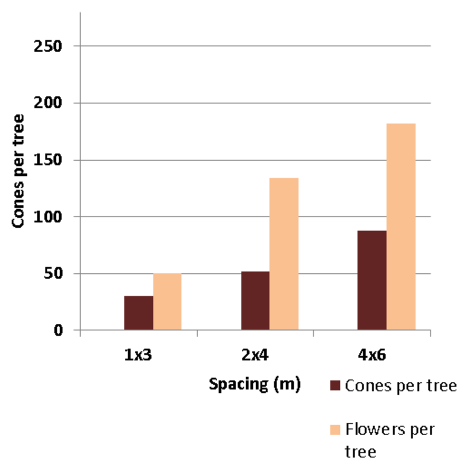
2010 cone crop: Flowers and cones



Moderate flower to cone relationship because of frost damage, liberal scoring

Acknowledgements

Field work help

Annie Simmonds

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Future measurement activities 2011-2012

Activity	*Scope*	*Date*
Crown measurements	*2011 crop - cones / crown volume*	*October*
Flower counts	*2012 crop – flwr. to cone relationship*	*April*
Flower & bud phenology	*2012 crop – diff. between orchards*	*April*
Flower stimulation	*2013 crop – stim. method or methods*	*March*
Cone counts	*2012 crop – cones by orchard spacing*	*August*
Seed measurements	*2012 cone – filled seed consequences*	*November*

2011 Cone crop = half of the 2x4 and 4x6 m orchards replications
2012 Cone crop = half of the 2x4 and 4x6 m orchards, all 1x3 replications
2013 Cone crop = same replications as 2011

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Future management activities 2011-2012

Flower stimulation

- ***Plan is to stimulate half of the 2x4 and 4x6 orchards in the spring of 2012***
- ***Plan is to use calcium nitrate fertilizer and girdling***
- ***Discuss the value of testing GA x N treatments***
  - Results will only be available after the PNWTIRC report is completed
  - Advantage – may shed light on alternative methods
  - Disadvantage – may compromise future comparisons of orchards

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Future management activities 2011-2012

Bloom delay

- ***Plan is not to use bloom delay***
- ***Discuss the value of testing bloom delay treatments***
  - Results will only be available after the PNWTIRC report is completed
  - Advantage – learn something?
  - Disadvantage – published results on bloom delay are already available, this research does not seem to be MSO-specific, and treatments may compromise future comparisons of orchards

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Future management activities 2011-2012

Pruning

- ***Plum Creek's long-term recommendation is to leave the trees unpruned, so no pruning is planned for this year***
- ***Our plan is to complete MSO research over the next year, so lack of pruning will not impact these plans***

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Future management activities 2011-2012

Thinning

- ***Plum Creek's recommendation is to thin the 1x3 and 2x4 orchards after the 2012 cone harvest***
- ***Our plan is to complete MSO research over the next year, so thinning will not impact our plans***
- ***Discuss thinning strategies***
  - 1x3 spacing has formed a closed canopy, mechanized management not possible now, cone collection will be difficult, remove alternate rows
  - 2x4 spacing – crowns are starting to compete, mechanized management becoming difficult, maximal cone production might start declining

PNWTIRC

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