Growing Confidence in Forestry's Future

24-25 March 2015, Christchurch, NZ

Advances in productivity research in the Pacific Northwest

Doug Maguire

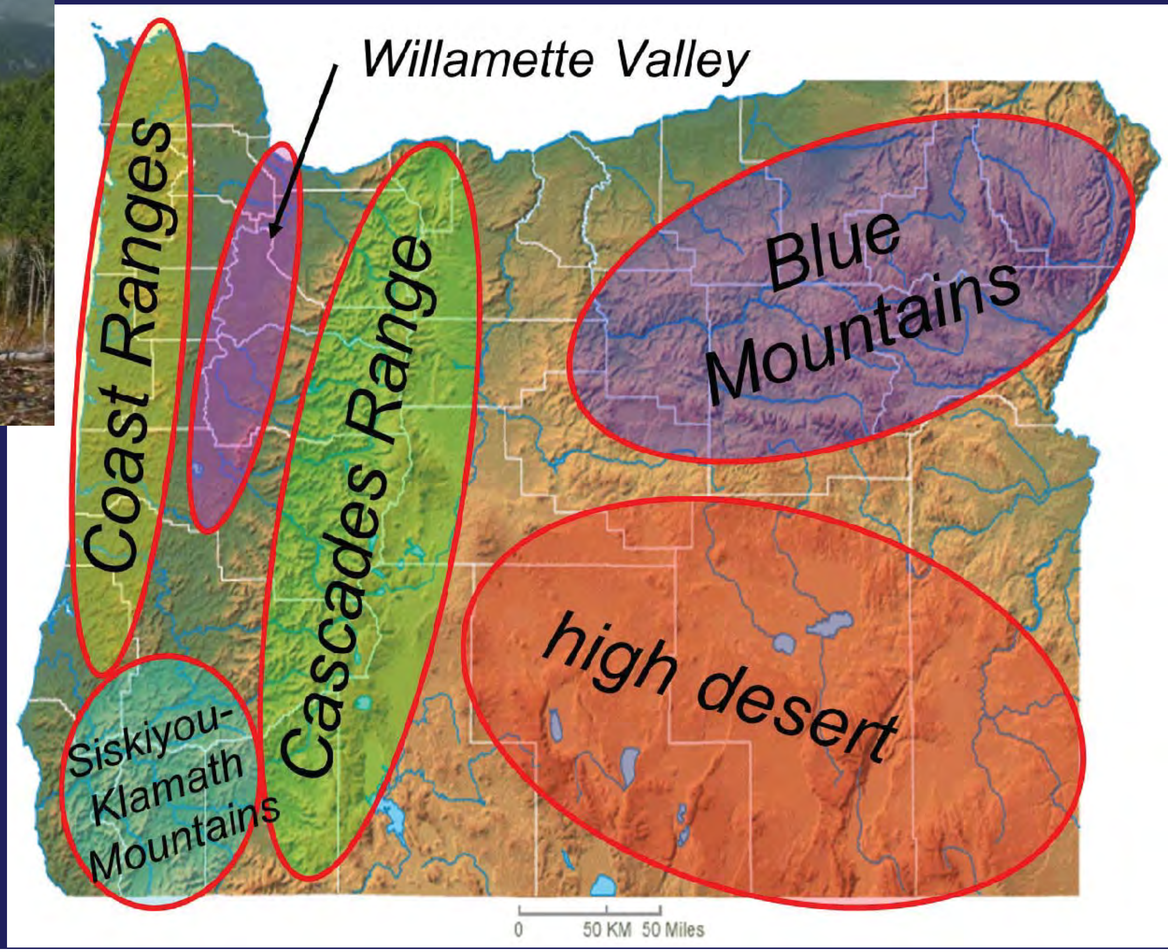
College of Forestry

Oregon State University

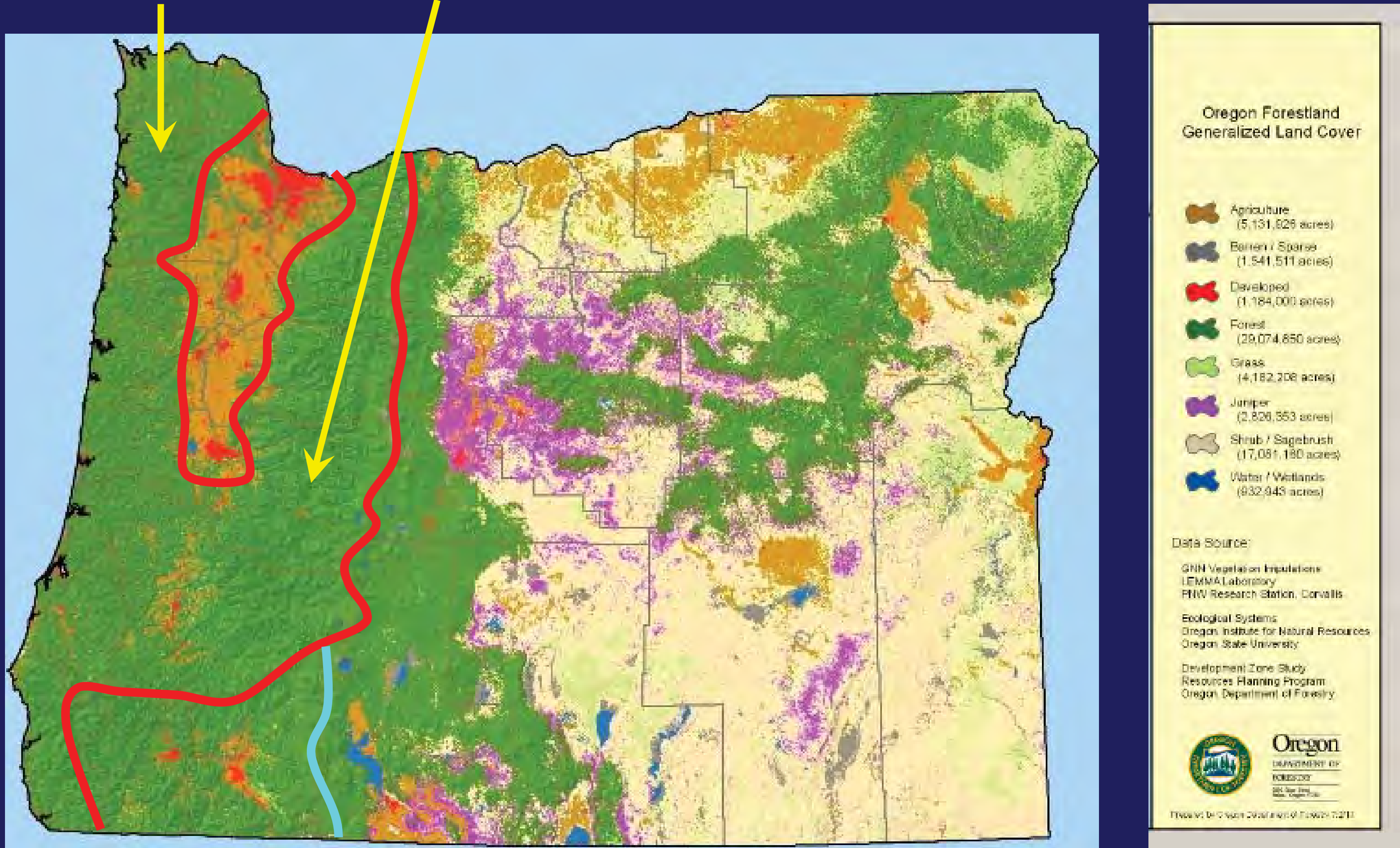
Topics:

- Biophysical setting and limits on net primary production
- Current research questions addressing productivity
- Current silvicultural research activities addressing productivity
- Synthesis of forest productivity research

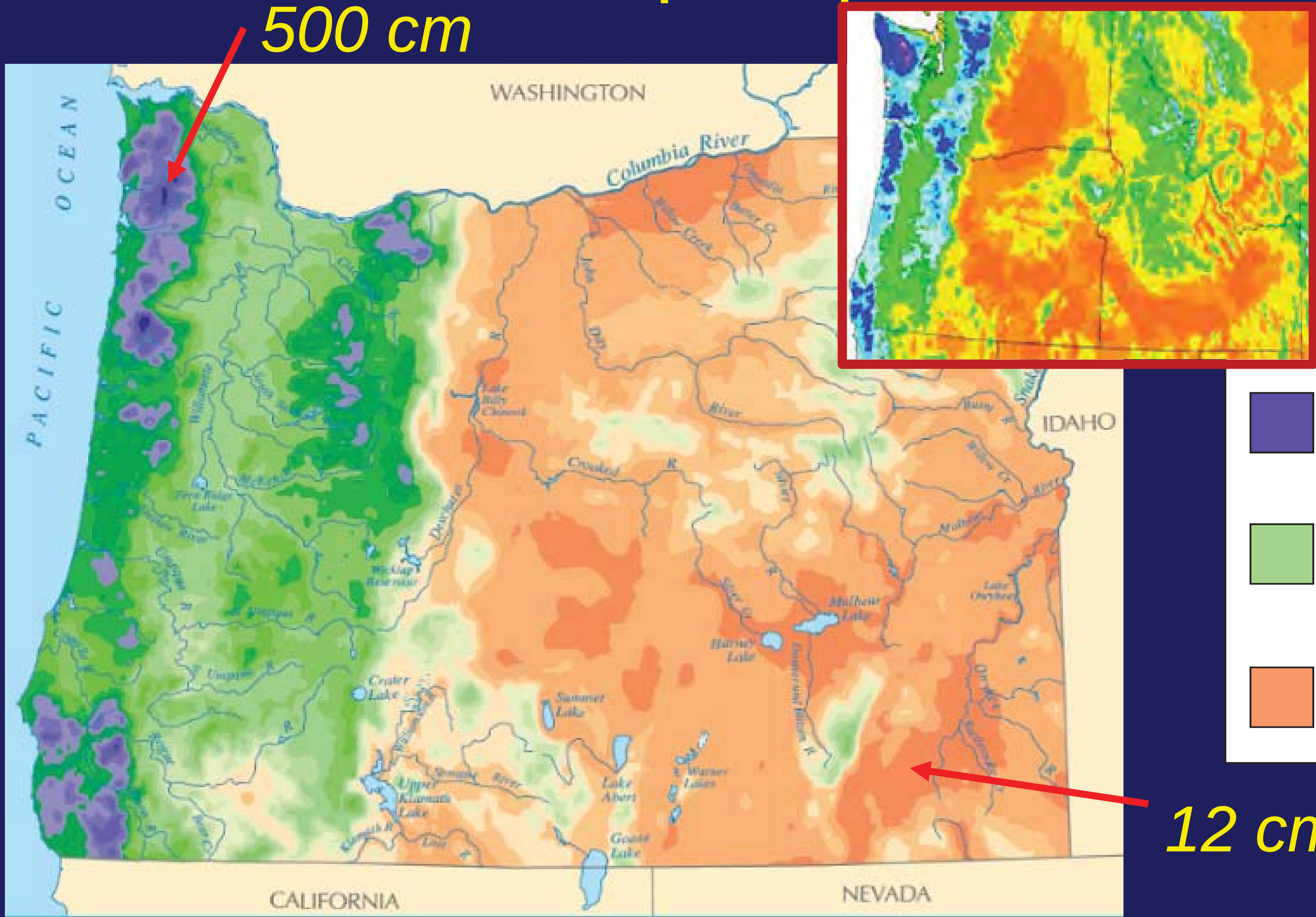
Biophysical setting



High productivity Douglas-fir & western hemlock



Annual precipitation



cm	
250-500	
65-250	
12- 65	

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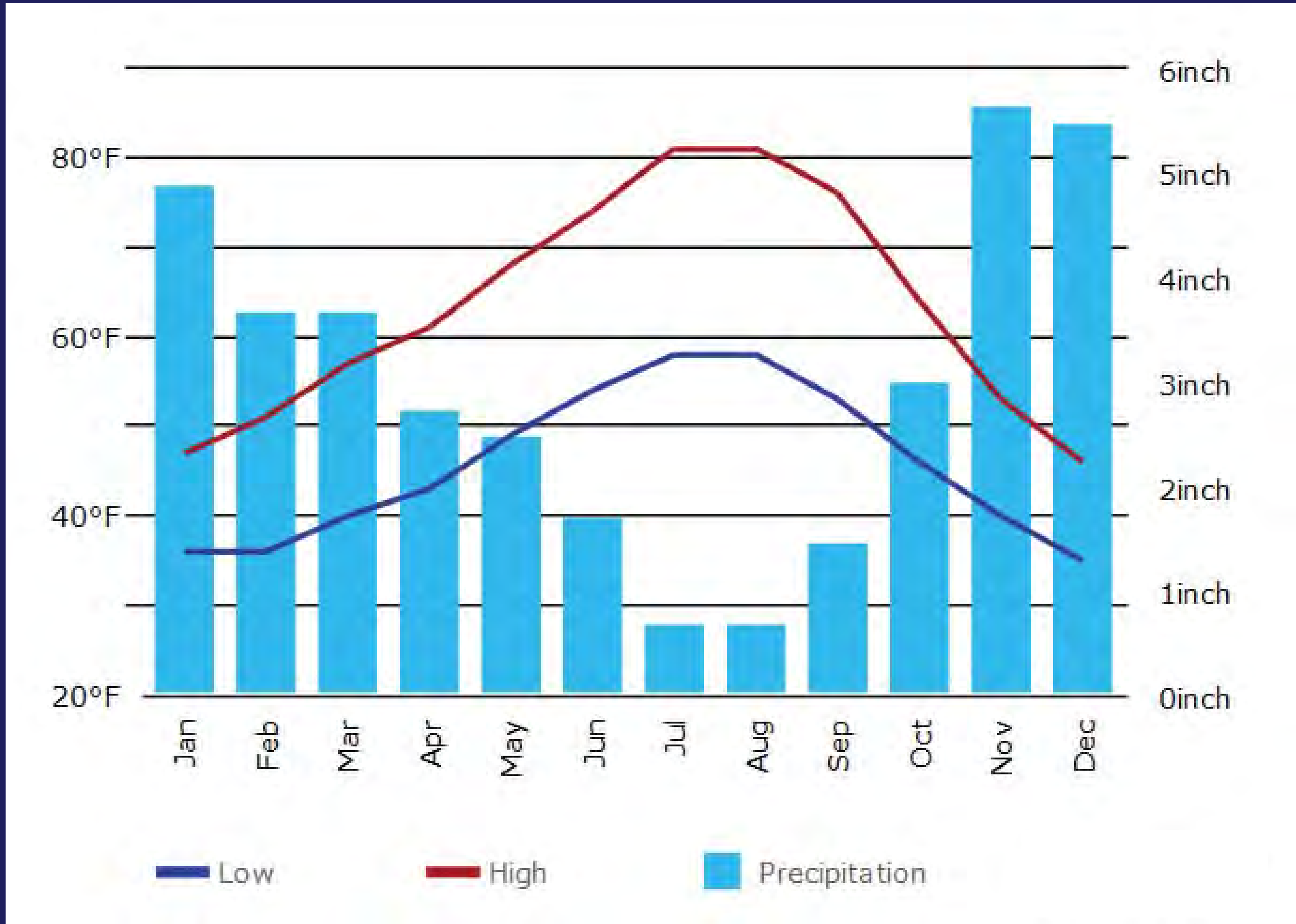
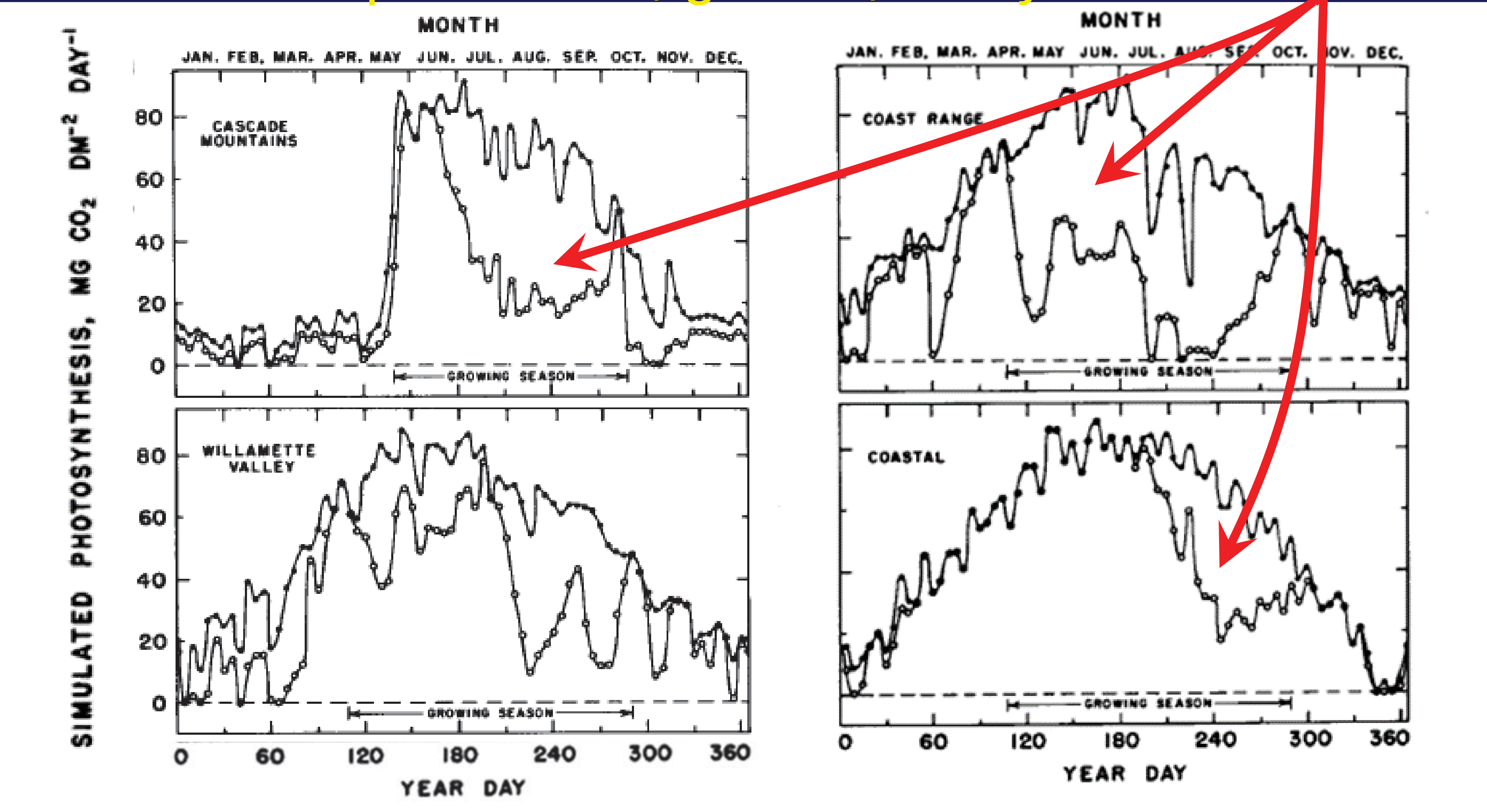
Western Oregon/Washington monthly precipitation and temperature (~vapor pressure deficit)



Water limitations to Douglas-fir net primary production, growth, and yield



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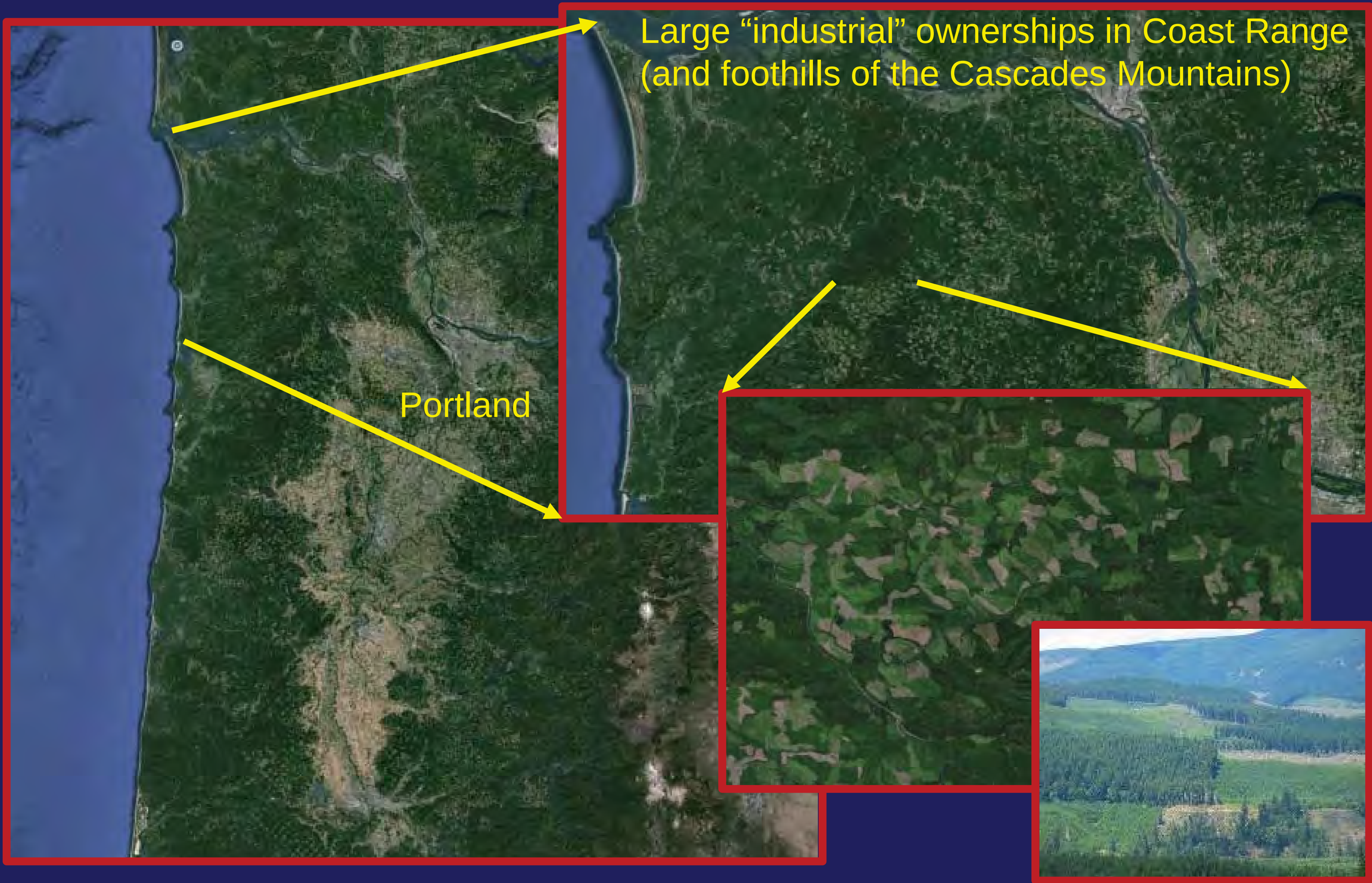

Clearcut:

Regeneration cut in clearcutting silvicultural system

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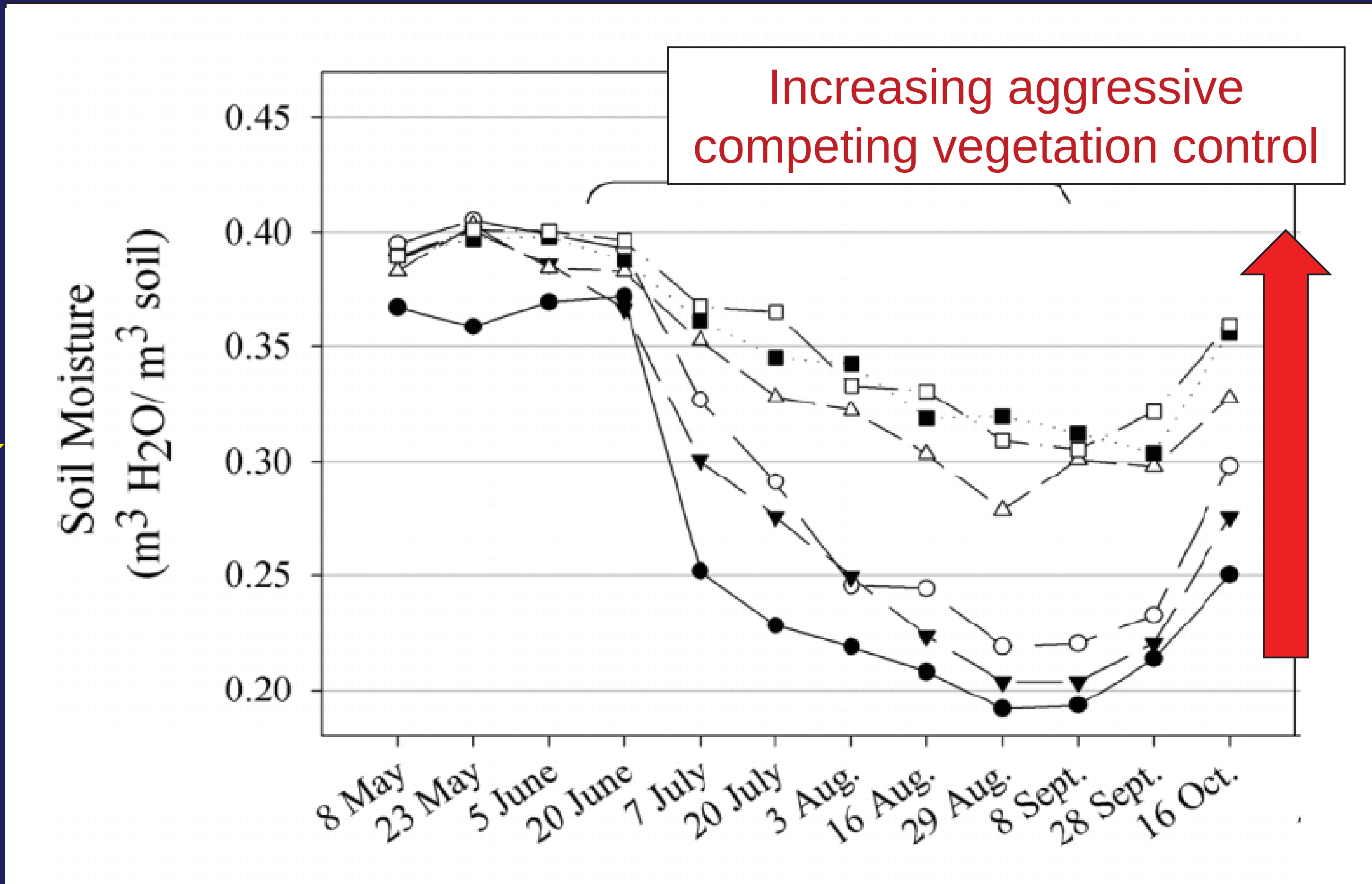
Planting as soon as soil temperature starts to warm up in mid- to late-winter

Key decisions on competing vegetation control for growth (survival)

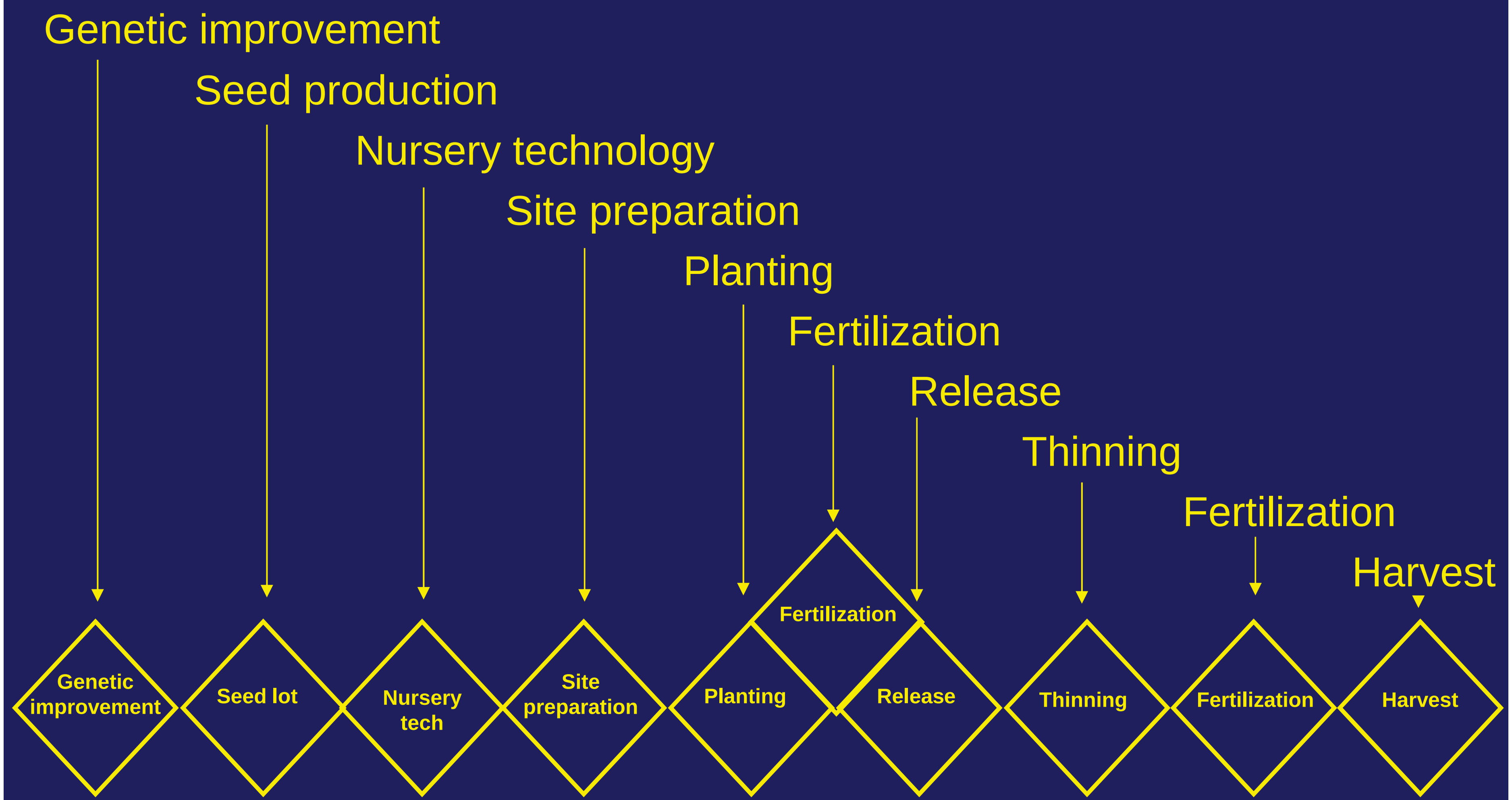
Vegetation Management Research Cooperative

Concurrent monitoring of soil moisture, seedling water stress, and growth over six alternative regimes for controlling competing vegetation

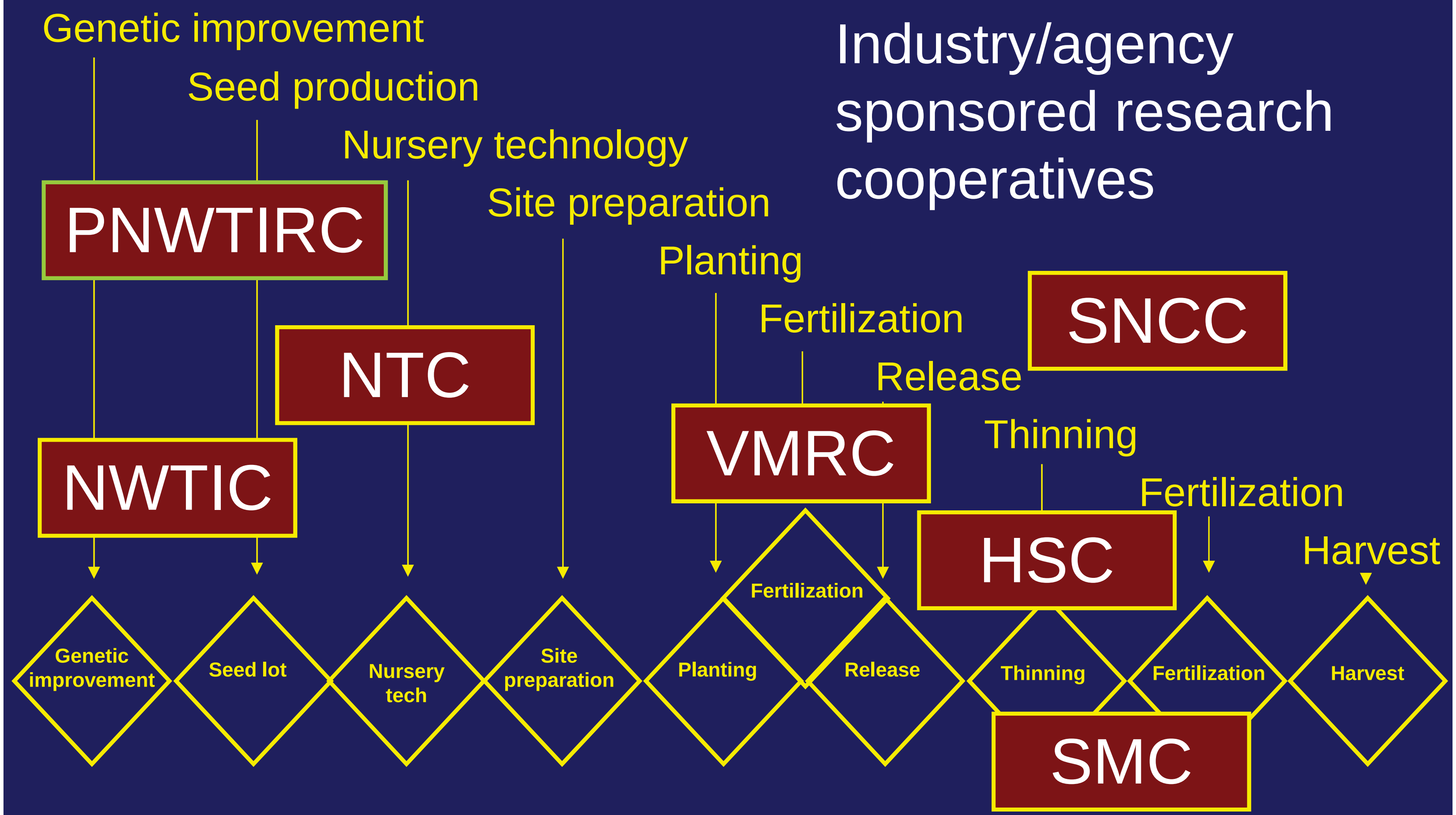


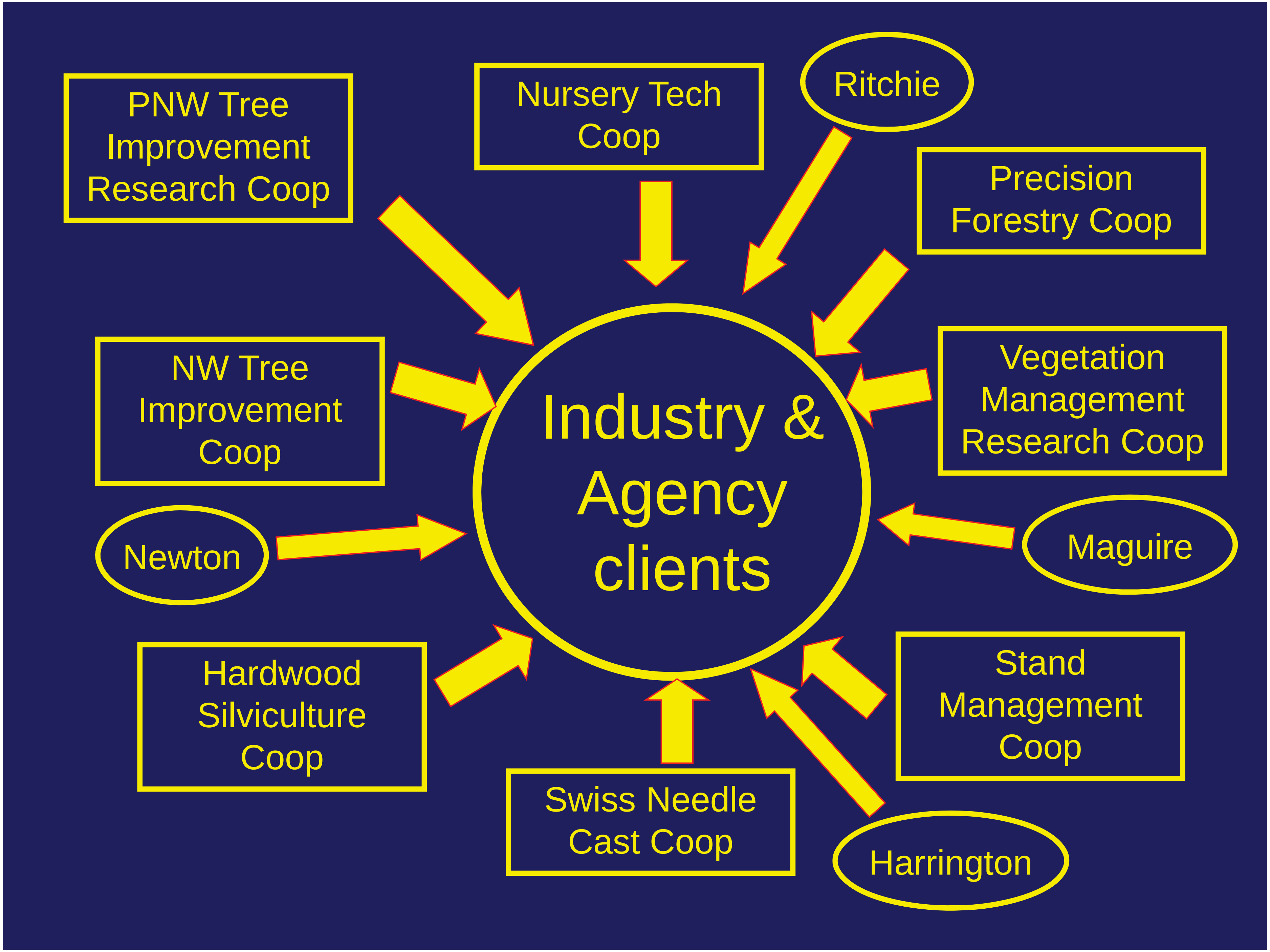
Dinger and Rose 2009

Silvicultural technology



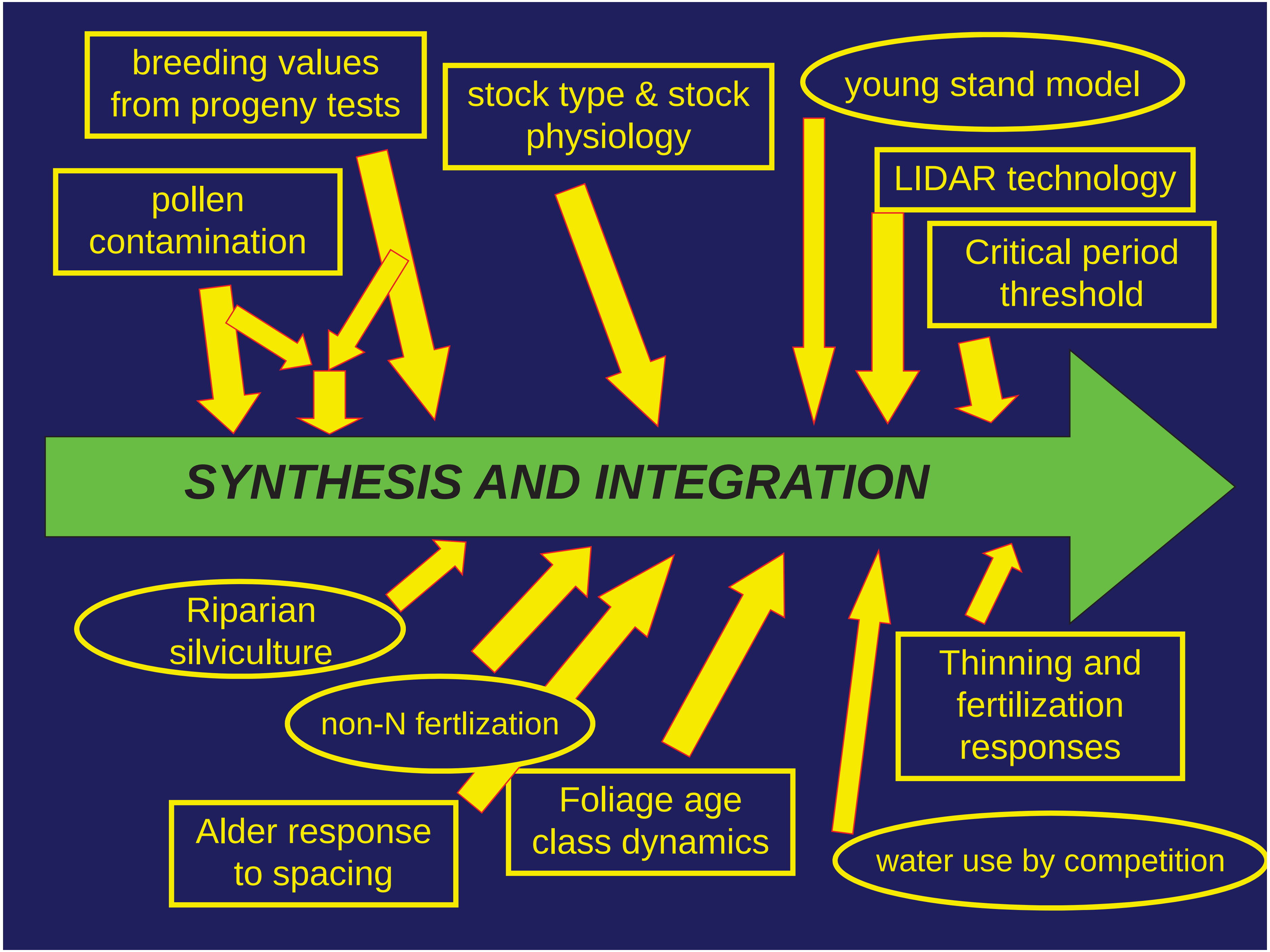
PNW silvicultural technology




PNW Tree Improvement Research Coop
Nursery Tech Coop
Ritchie
Precision Forestry Coop
NW Tree Improvement Coop
Industry & Agency clients
Vegetation Management Research Coop
Newton
Maguire
Hardwood Silviculture Coop
Stand Management Coop
Swiss Needle Cast Coop
Harrington

Increasing amount of increasingly fragmented information!

AND diminished capacity for interpreting and synthesizing this information.


breeding values from progeny tests
stock type & stock physiology
young stand model
pollen contamination
LIDAR technology
Critical period threshold
SYNTHESIS AND INTEGRATION
Riparian silviculture
non-N fertlization
Thinning and fertilization responses
Alder response to spacing
Foliage age class dynamics
water use by competition

OSU College of Forestry

Center for Intensive Planted-forest Silviculture

Fragmented mass of data on intensive silviculture of Douglas-fir

↓

Synthesis of existing data and information

Project initiation 2009

CIPS Vision

To develop , maintain, and validate comprehensive, science-based models and other tools for managing planted forests under intensive silvicultural practices in the Pacific Northwest.

CIPS Mission

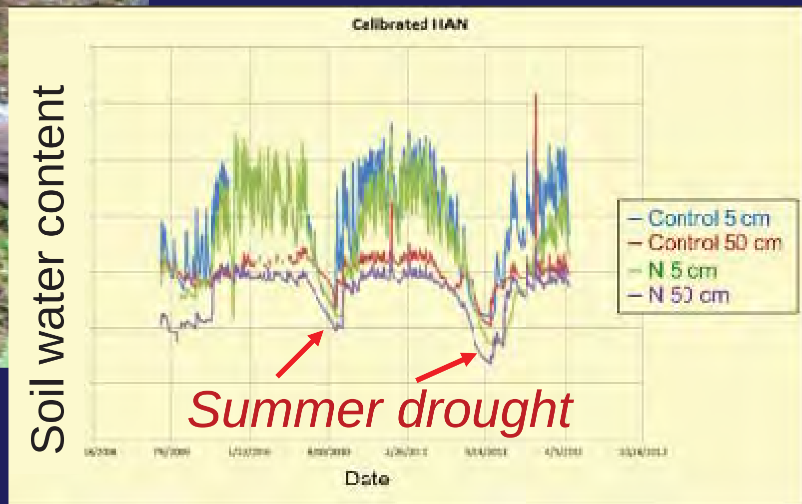
To understand and quantify the interactive effects of silvicultural activities and site conditions on maintaining and improving the productivity, health, and sustainability of intensively-managed, planted forests in the Pacific Northwest.

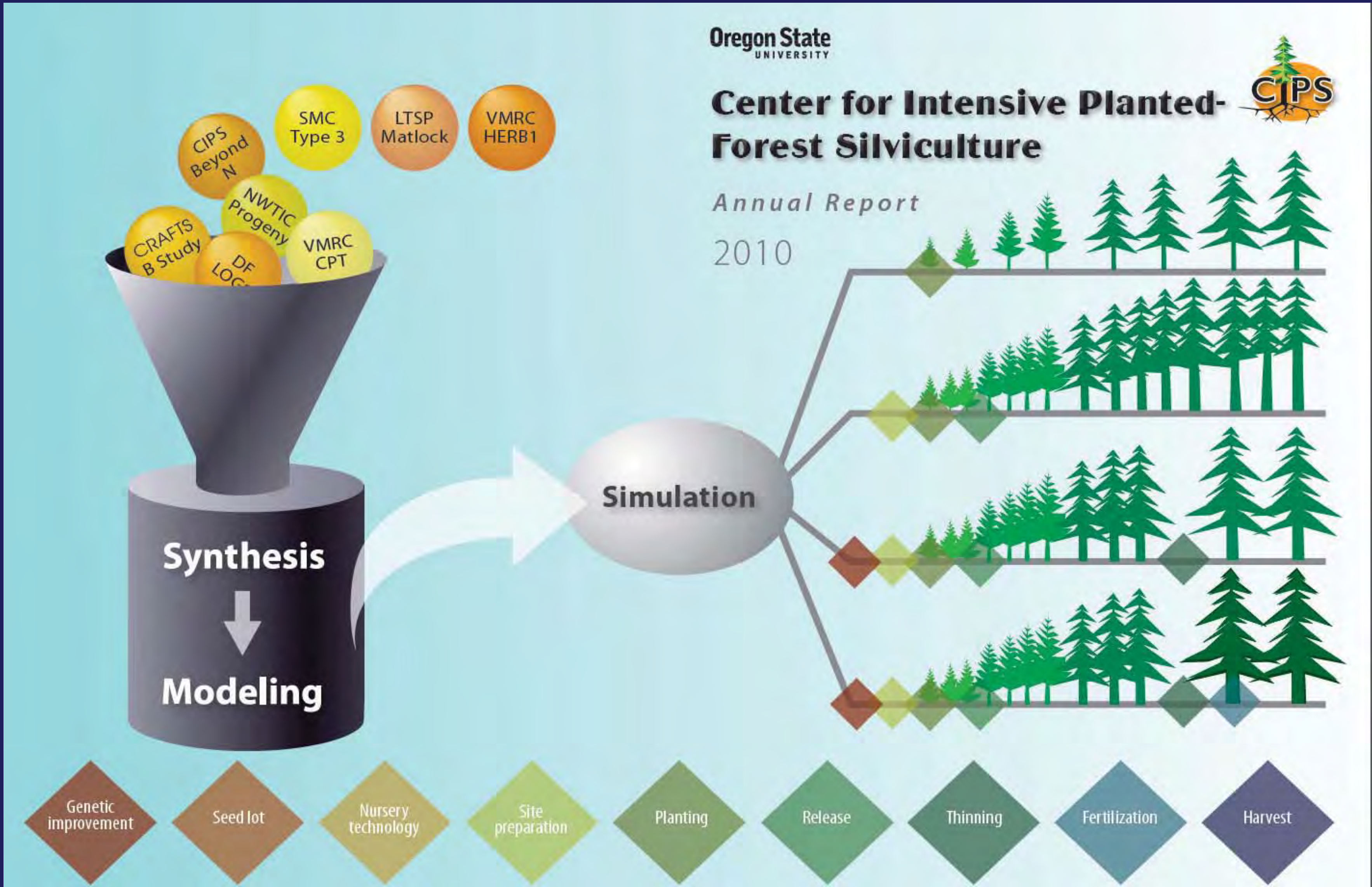
CIPS Mission

Silvicultural activities include genetic tree improvement, stock type production and selection, site preparation, planting technology, control of competing vegetation, stand density management, pruning, nutritional amendment, and protection from insects, disease, and animal damage.

CIPS Mission

Site conditions include the many biotic and abiotic facets of forest soils and climatic drivers of forest productivity.




Oregon State UNIVERSITY
Center for Intensive Planted-Forest Silviculture
Annual Report
2010
CIPS
SMC Type 3
LTSP Matlock
VMRC HERB1
CIPS Beyond N
NWTIC Progeny
CRAFTS B Study
VMRC CPT
Synthesis
Modeling
Simulation
Genetic improvement
Seed lot
Nursery technology
Site preparation
Planting
Release
Thinning
Fertilization
Harvest

CIPS projects INCORPORATE advances in productivity research:

Collaborations with existing research cooperatives and projects.

CIPS projects REPRESENT advances in productivity research:

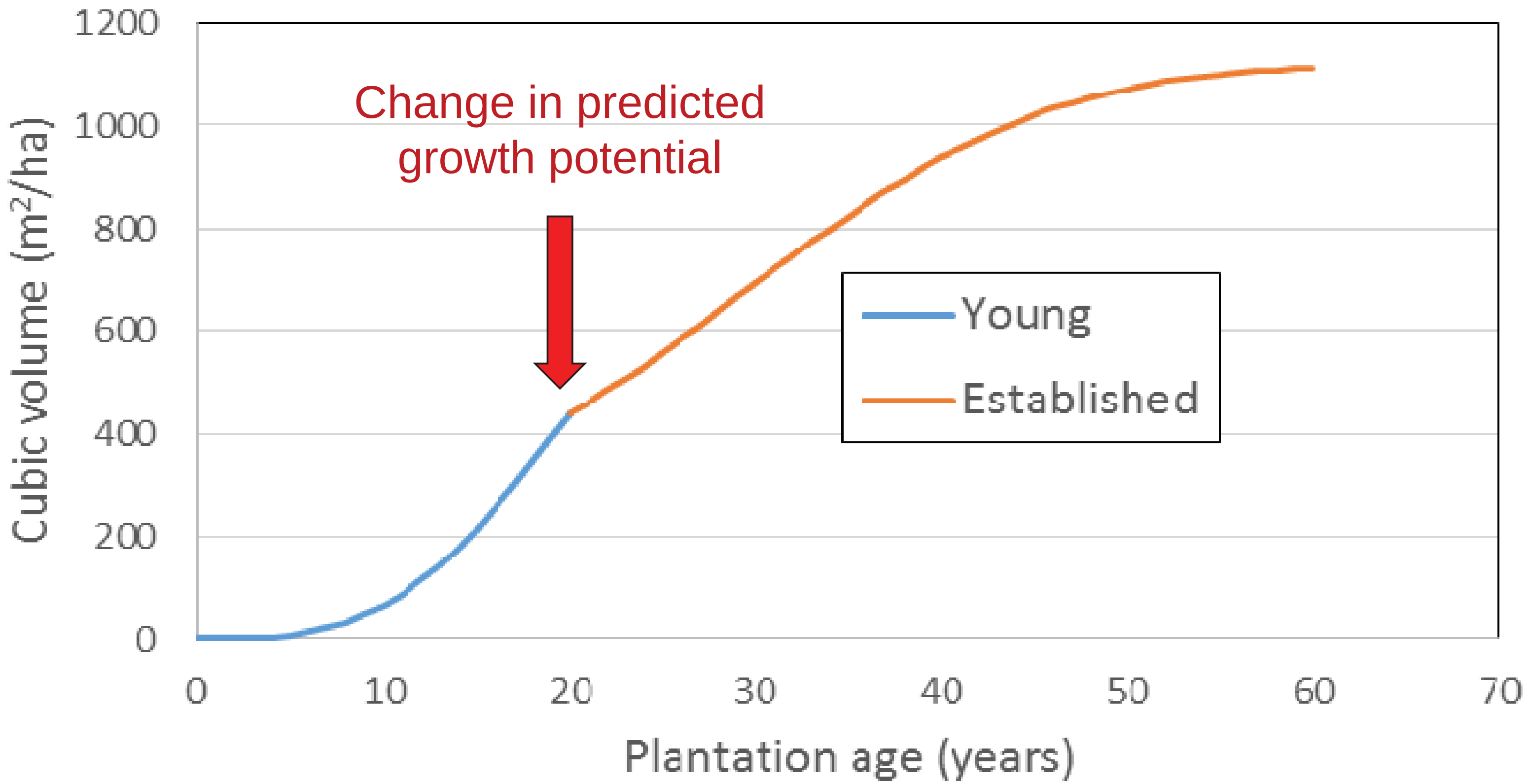
Synthesis of existing data, information, and principles into a more coherent picture of rotation-length silvicultural strategies.

Sample of CIPS projects:

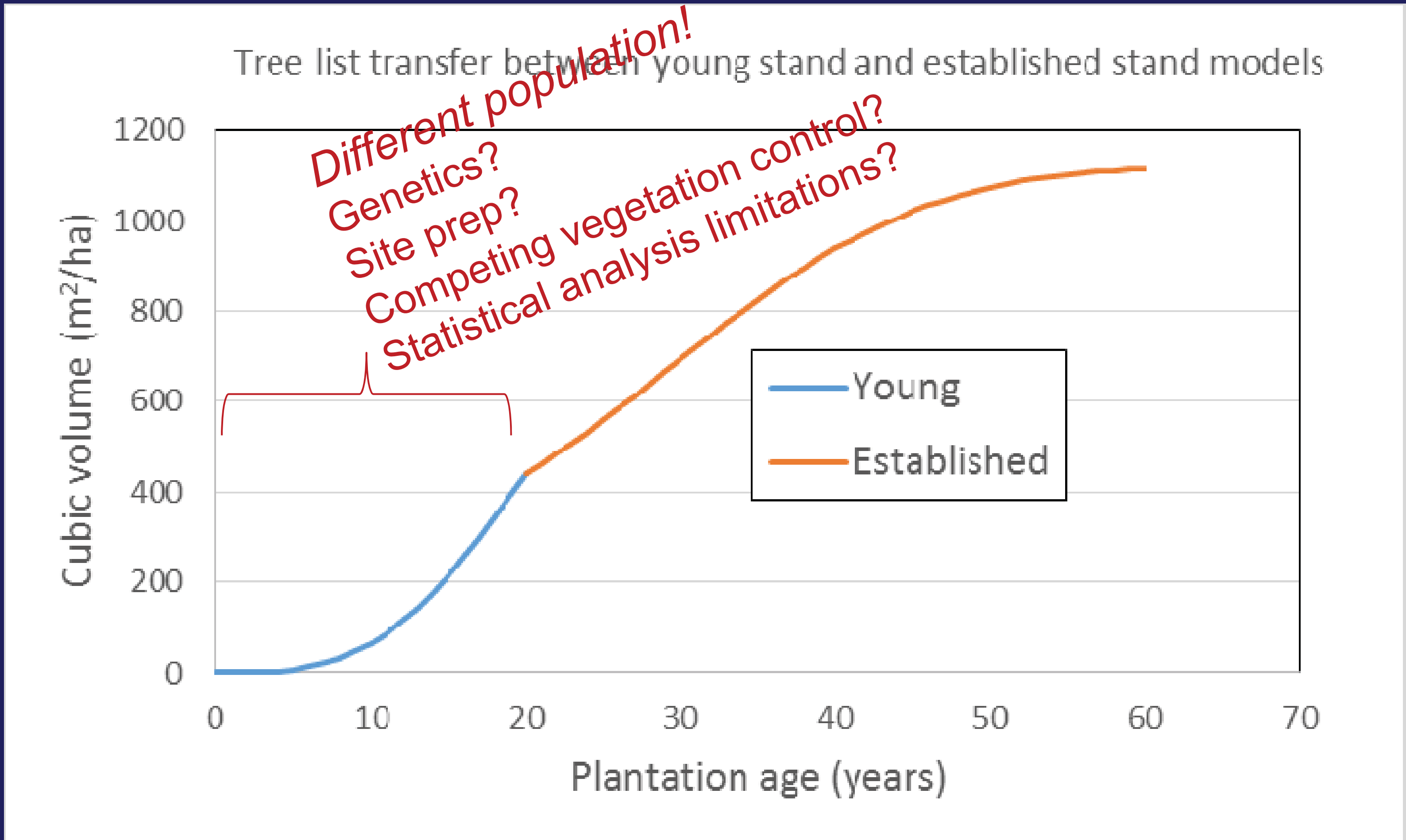
- Refinement of young stand models
- Better site characterization (soil, climate)
- Mechanisms driving productivity and response to silviculture (based on better site characterization)
- Modelling direct and indirect responses to thinning and fertilization
- Morphological representation of genetic tree improvement in growth models
- Individual-tree growth multipliers for Swiss needle cast growth impact
- Estimation of biomass productivity, carbon pools and fluxes, and nutrient pools and fluxes
- Simulation of wood quality attributes
- Suites of tools (XORG, CIPSR ← ORGANON)

Refinement of young stand models for Douglas-fir plantations

"Hand-off" of tree list from young stand model to established stand model



Refinement of young stand models for Douglas-fir plantations



Refinement of young stand models for Douglas-fir plantations

The role of vegetation management for enhancing productivity of the world's forests

ROBERT G. WAGNER[1]*, KEITH M. LITTLE[2], BRIAN RICHARDSON[3] AND KEN McNABB[4]

[1] University of Maine, 5755 Nutting Hall, Orono, ME 04469, USA
[2] Institute for Commercial Forestry Research, PO Box 100281, Scottsville 3209, South Africa
[3] Forest Research, Private Bag, Rotorua, New Zealand
[4] Auburn University, 122 M.W. Smith Hall, Auburn, AL 36849, USA
* Corresponding author. E-mail: bob_wagner@umenfa.maine.edu

2006. Forestry 79:57-79

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24-25 March 2015, Christchurch, NZ

Refinement of young stand models for Douglas-fir plantations

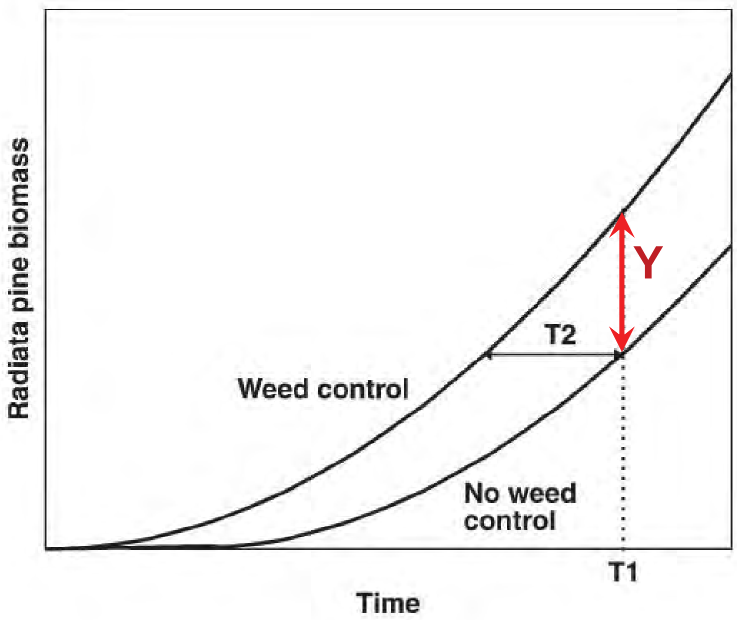


Figure 1. Growth benefit to radiata pine from vegetation control. At time T1, T2 represents the effective age difference with and without initial vegetation control.

T2 = time gain to given yield
Y = yield gain at given time

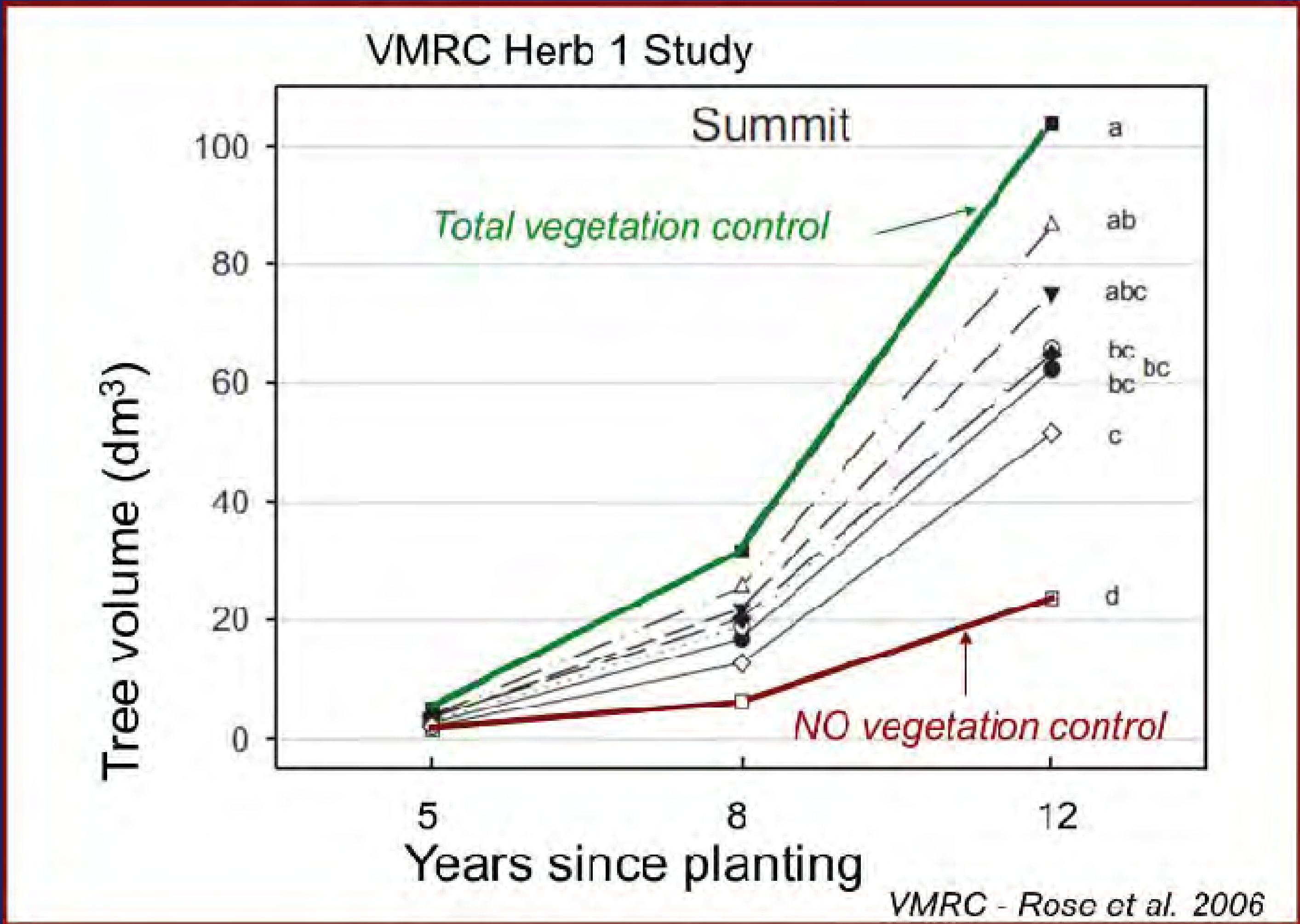
Refinement of young stand models for Douglas-fir plantations

Challenge: rotation age = ~ (35-) 40-50 (-70) yrs

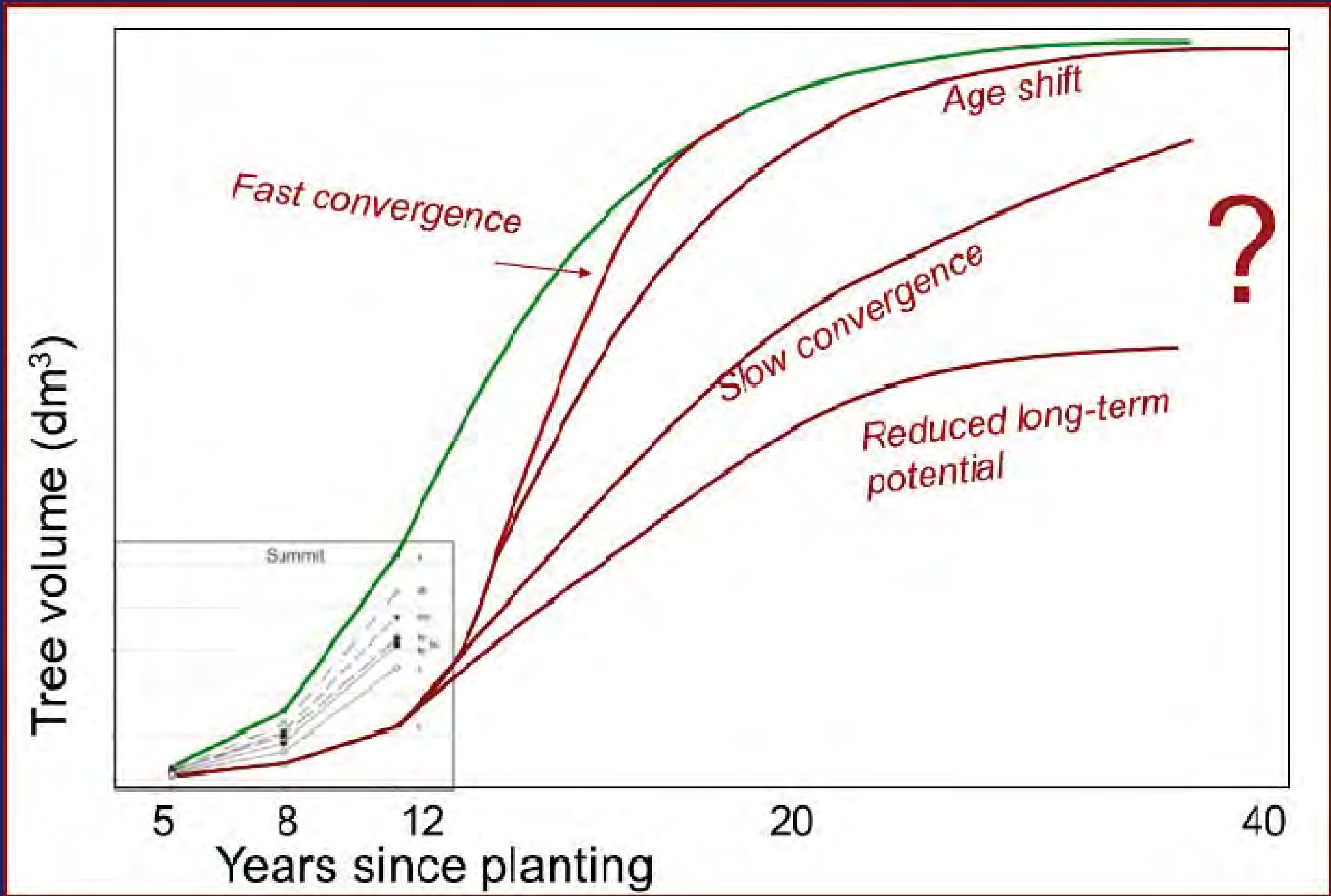
Yield increase at rotation age?

Tree species	Length of measurement after treatment (years)	Mean stem volume from untreated plots	Mean stem volume from most effective vegetation control treatment	Volume gain from treatment	Units	Wood volume yield increase (%)	No. of study sites/locations*
Pseudotsuga menziesii	14	0.010	0.035	0.025	m^3 $tree^{-1}$	245	1 site, OR
Pseudotsuga menziesii	12	0.008	0.023	0.015	m^3 $tree^{-1}$	200	1 site, OR
Pinus ponderosa	14	0.013	0.071	0.058	m^3 $tree^{-1}$	464	1 site, OR
Tsuga heterophylla	12	0.050	0.150	0.100	m^3 $tree^{-1}$	200	3 sites, OR
Pseudotsuga menziesii	10	39.0	89.0	50.0	m^3 ha^{-1}	128	6 sites, OR & WA
Pseudotsuga menziesii	10	7.8	28.9	21.1	m^3 ha^{-1}	272	4 sites, OR
Pseudotsuga menziesii	10	0.0270	0.0590	0.032	m^3 $tree^{-1}$	119	1 site, OR

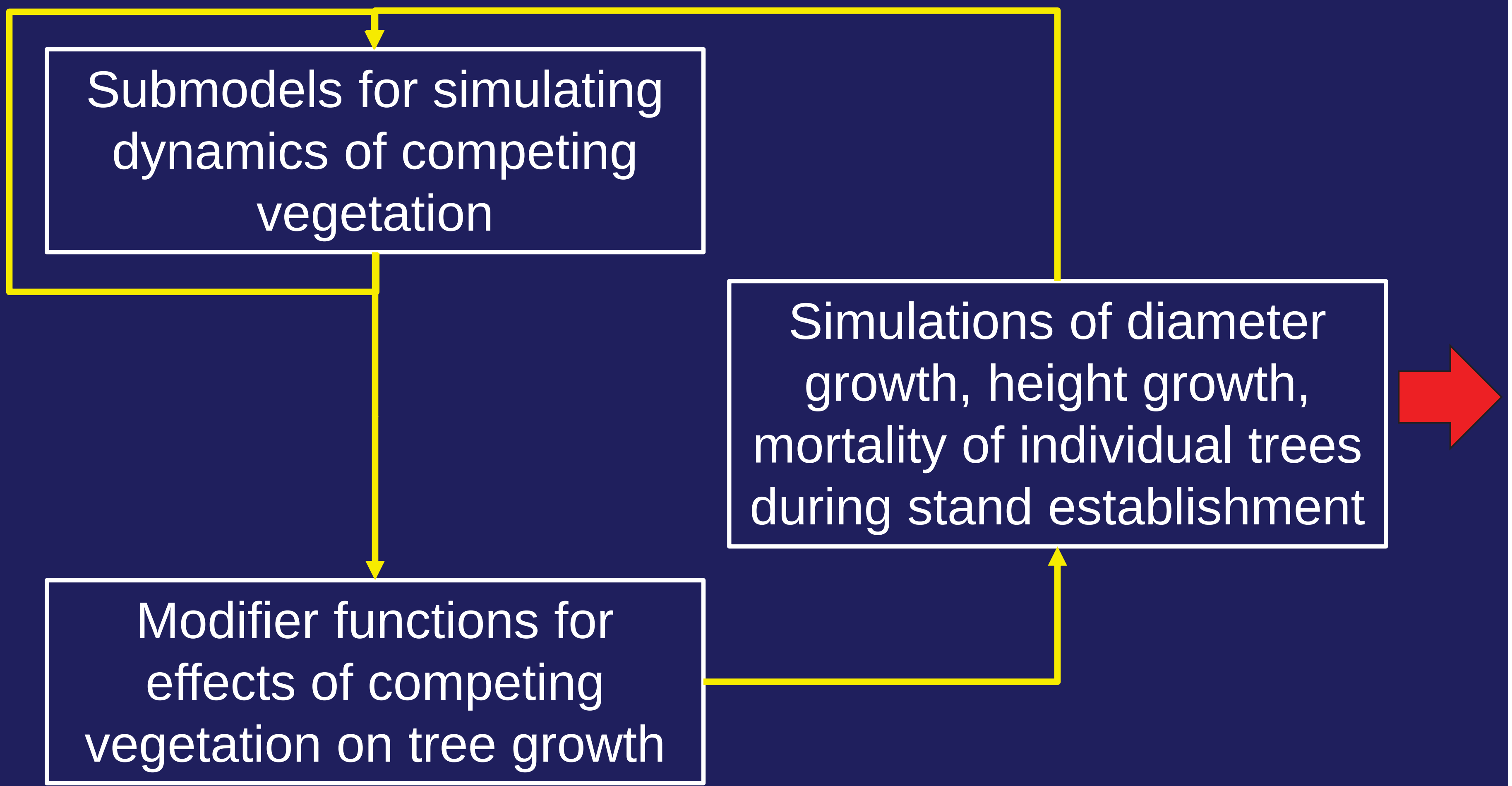
Refinement of young stand models for Douglas-fir plantations



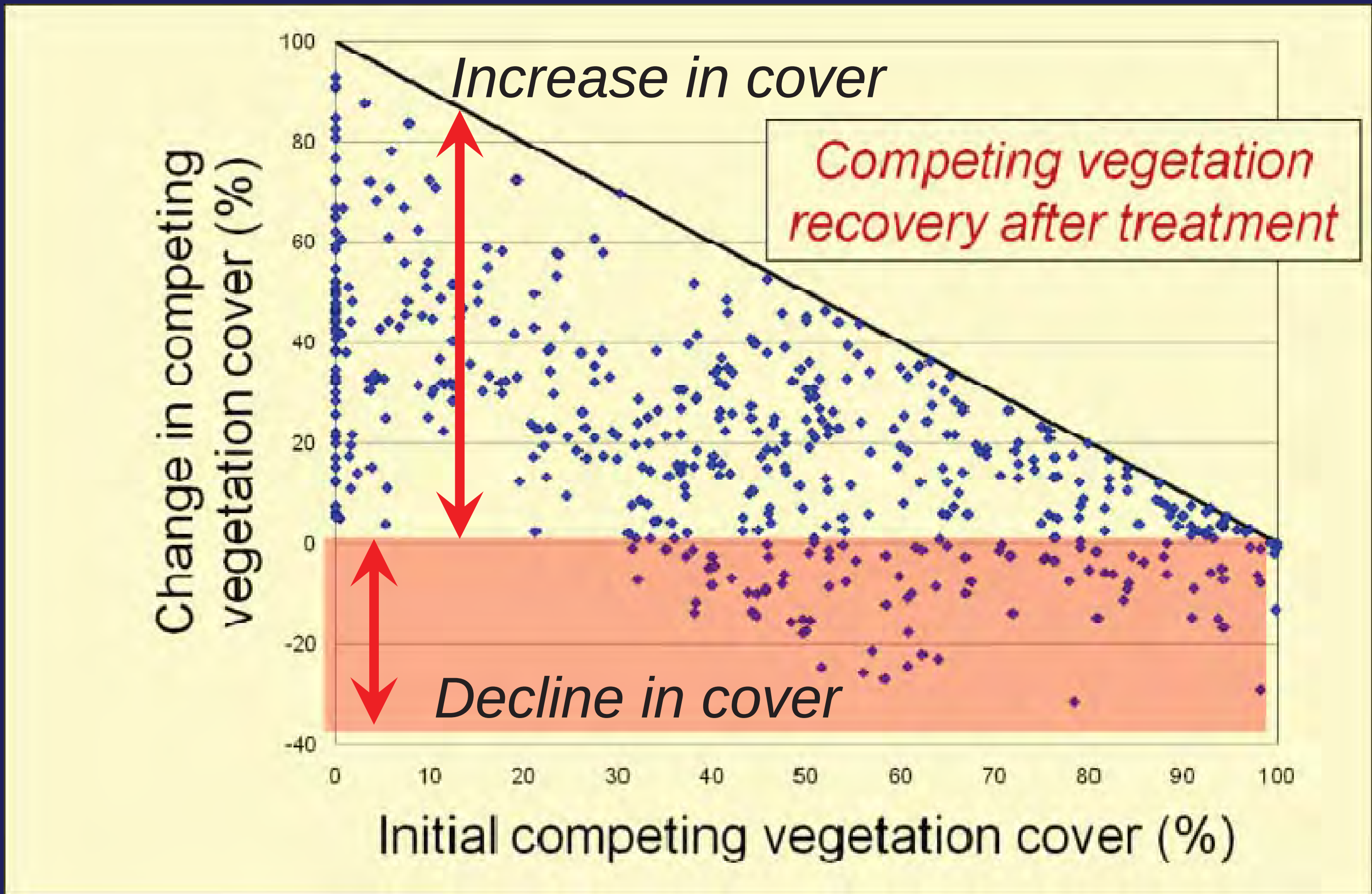
For now, rely on well-conditioned and objective models for projecting rotation-age benefits to Douglas-fir plantations



Current approach to finding a better answer



What to the data look like?
(What is best approach to modeling these data?)



Approach:

- Simplify to 4 life forms
  - Herbs (forb+fern+graminoid)
  - Shrubs
  - Hardwood trees
  - Other conifer trees
- Predict probability of an increase in cover vs. decrease
- Predict conditional increase and conditional decrease in competing vegetation cover

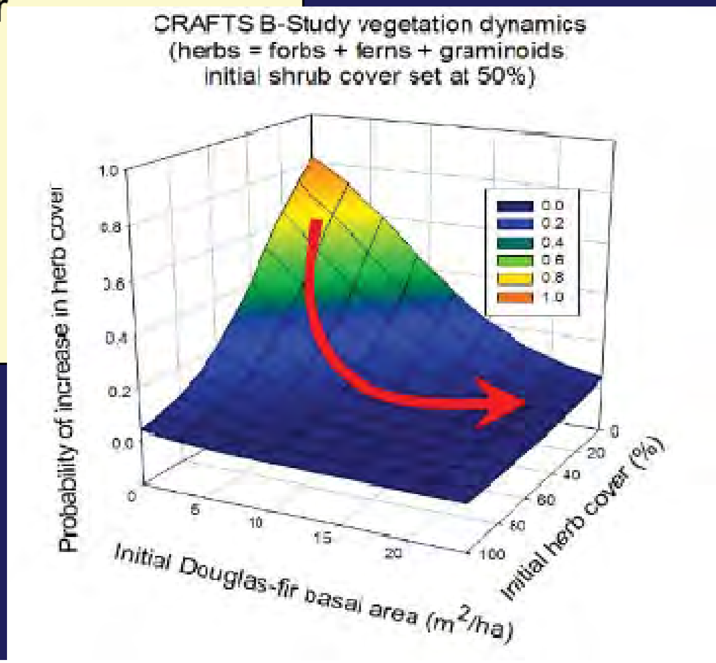
Probability of increase in herb cover

$$\ln\left(\frac{p_I}{1-p_I}\right) = \beta_0 + \beta_1 \cdot HERB + \beta_2 \cdot SHRUB + \beta_3 \cdot DFBA$$
$$= X\beta$$

where P_I = probability of increase in herb cover

$1 - P_I$ = probability of decrease in herb cover

$$\Rightarrow \qquad p_I = \frac{\exp(X\beta)}{1+\exp(X\beta)}$$



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24-25 March 2015, Christchurch, NZ

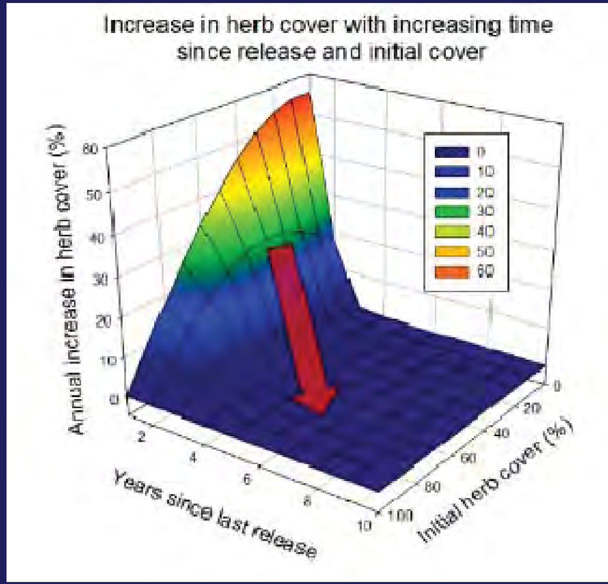
Conditional increase and decrease in herb cover

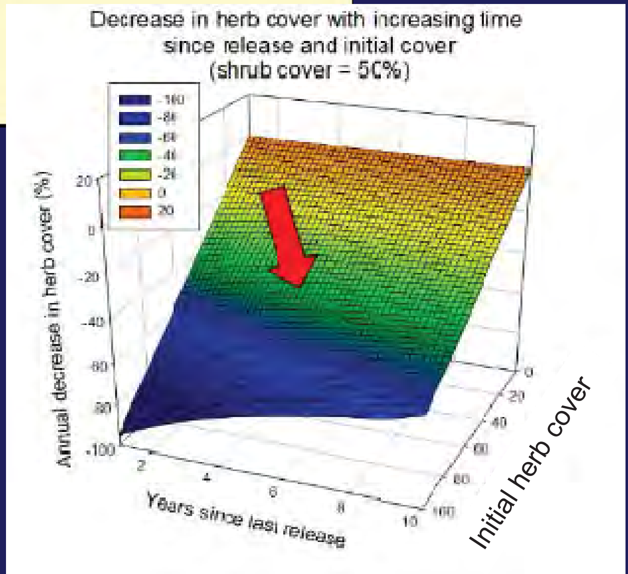
$$+\Delta HERB = (100 - herb_i)\cdot \exp[-\exp(\beta_0 + \beta_1 \cdot herb_i + \beta_2 \cdot yrst)]$$

$$-\Delta HERB = herb_i \cdot \{1 - \exp[-\exp(\beta_0 + (\beta_1 + \beta_2 \cdot shrub_i)\cdot yrst)]\}$$

where $+\Delta HERB$ = conditional increase in herb cover
$-\Delta HERB$ = conditional decrease in herb cover

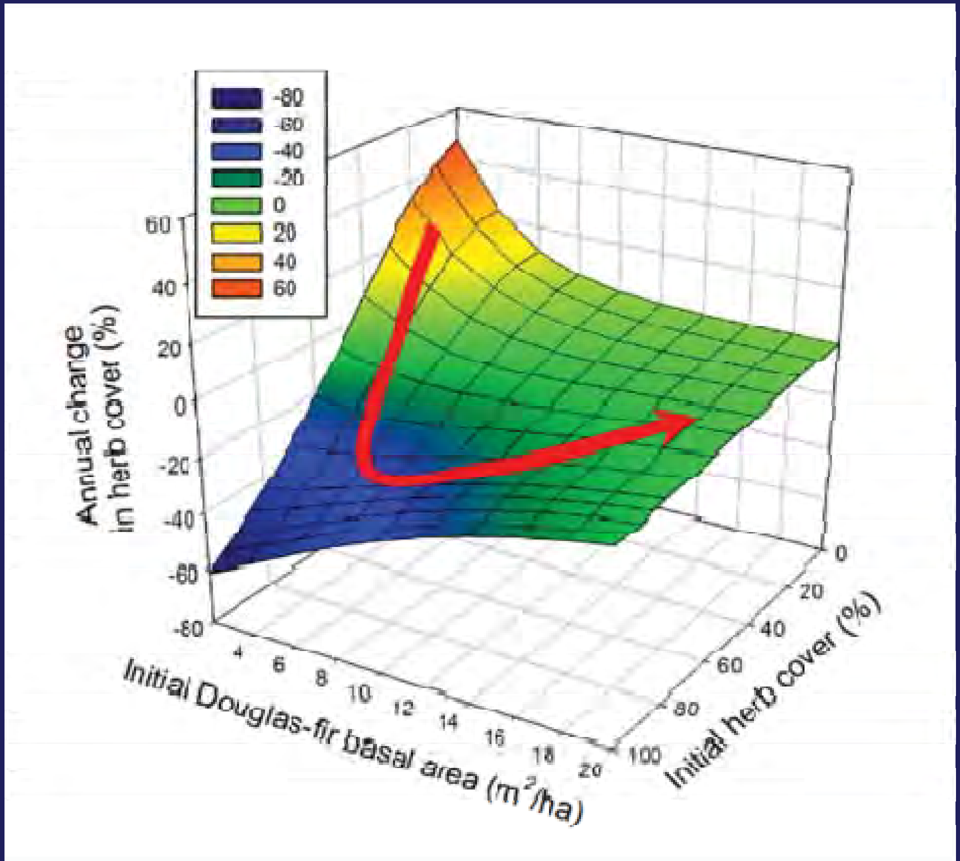
$herb_i$ = initial herb cover
$shrub_i$ = initial shrub cover
$yrst$ = years since last release





Average expected annual change in cover:

$E(\Delta cov) = p_i \cdot (\Delta cov | increase) + (1-p_i) \cdot (\Delta cov | decrease)$

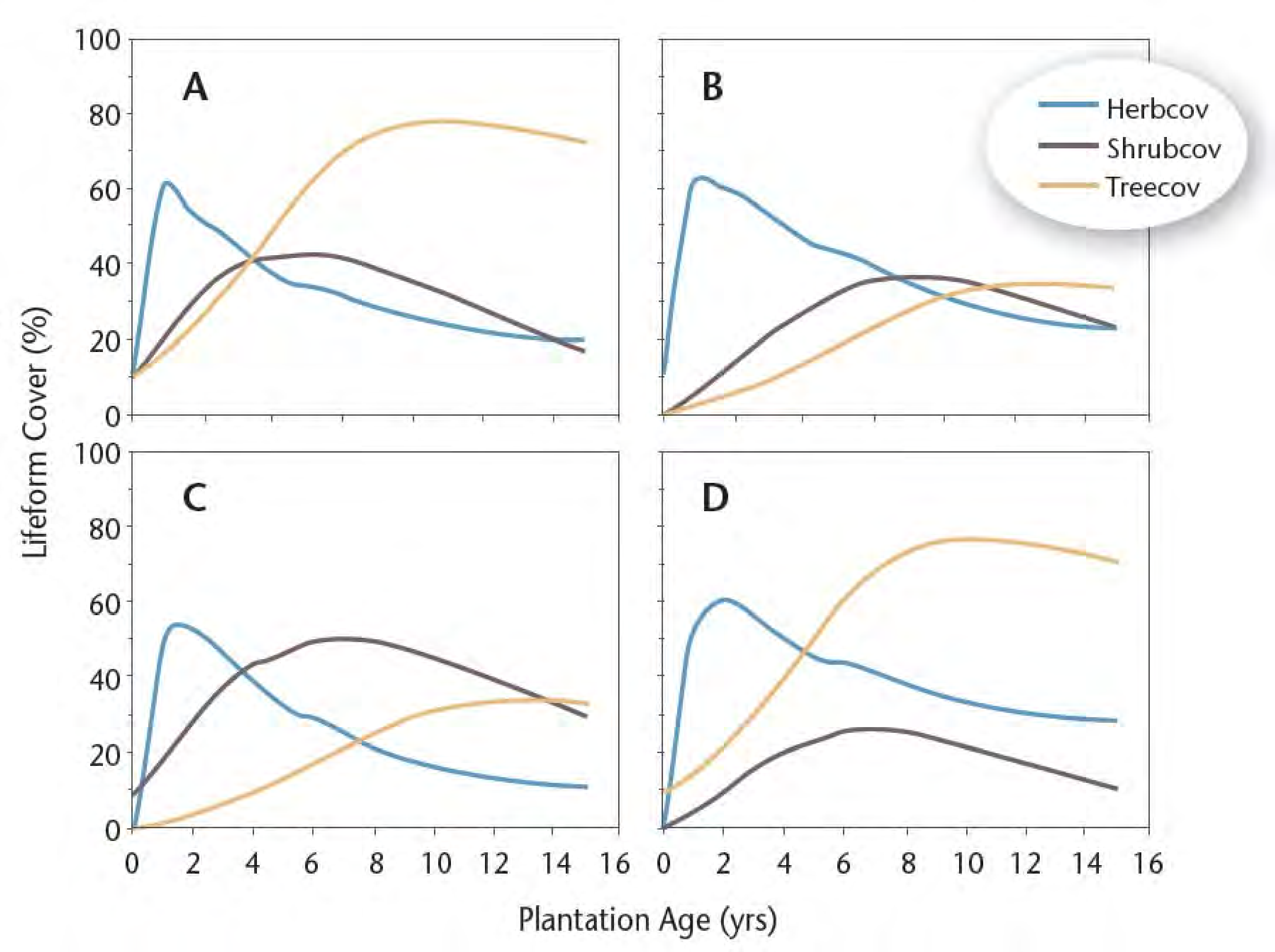


Initial rapid increase in herb cover early in plantation.

Followed by rapid decline as Douglas-fir closes.

Convergence on low cover with little additional change

Results from simulating competing vegetation dynamics – For differing initial conditions in cover by lifeform



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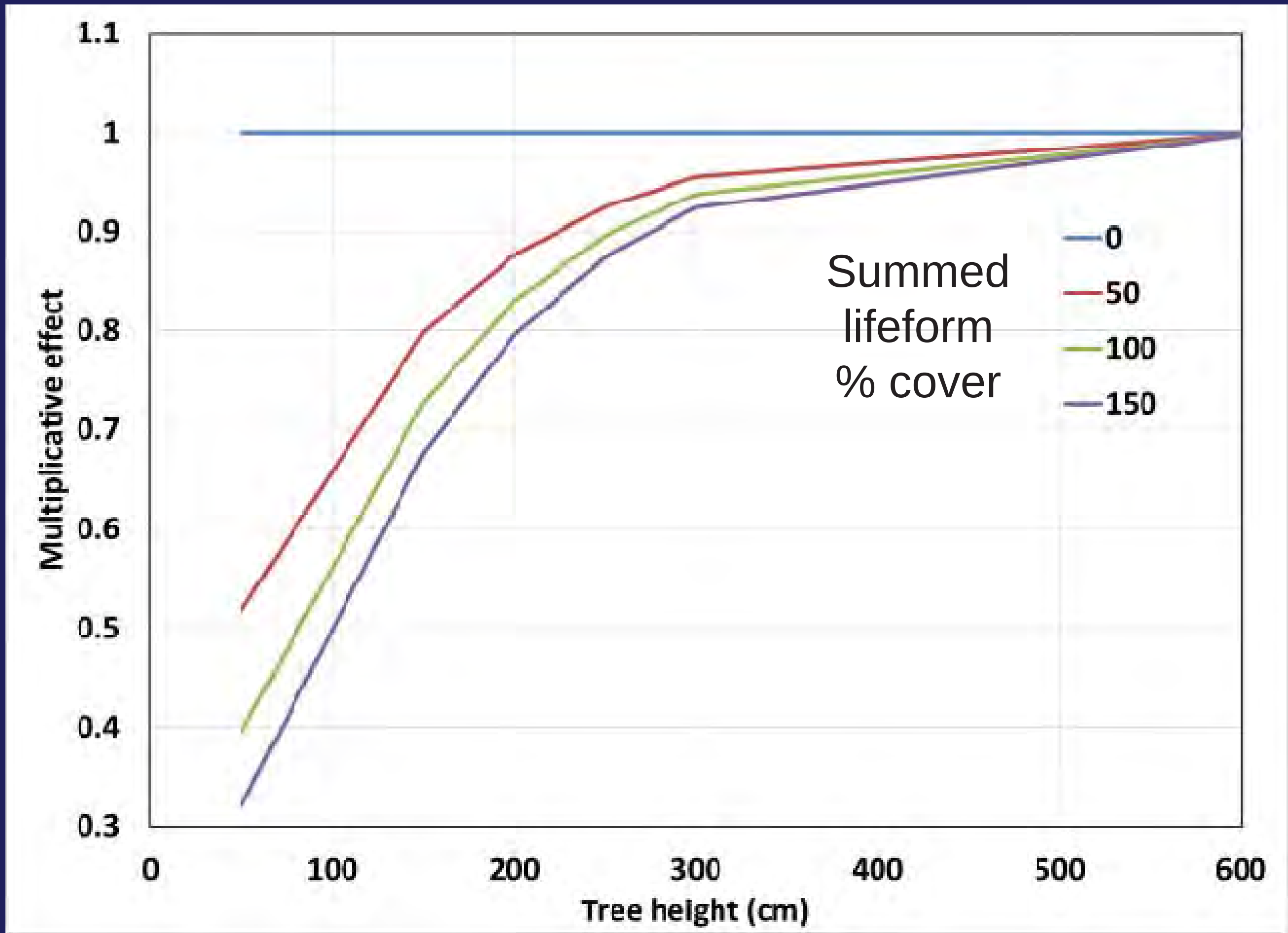
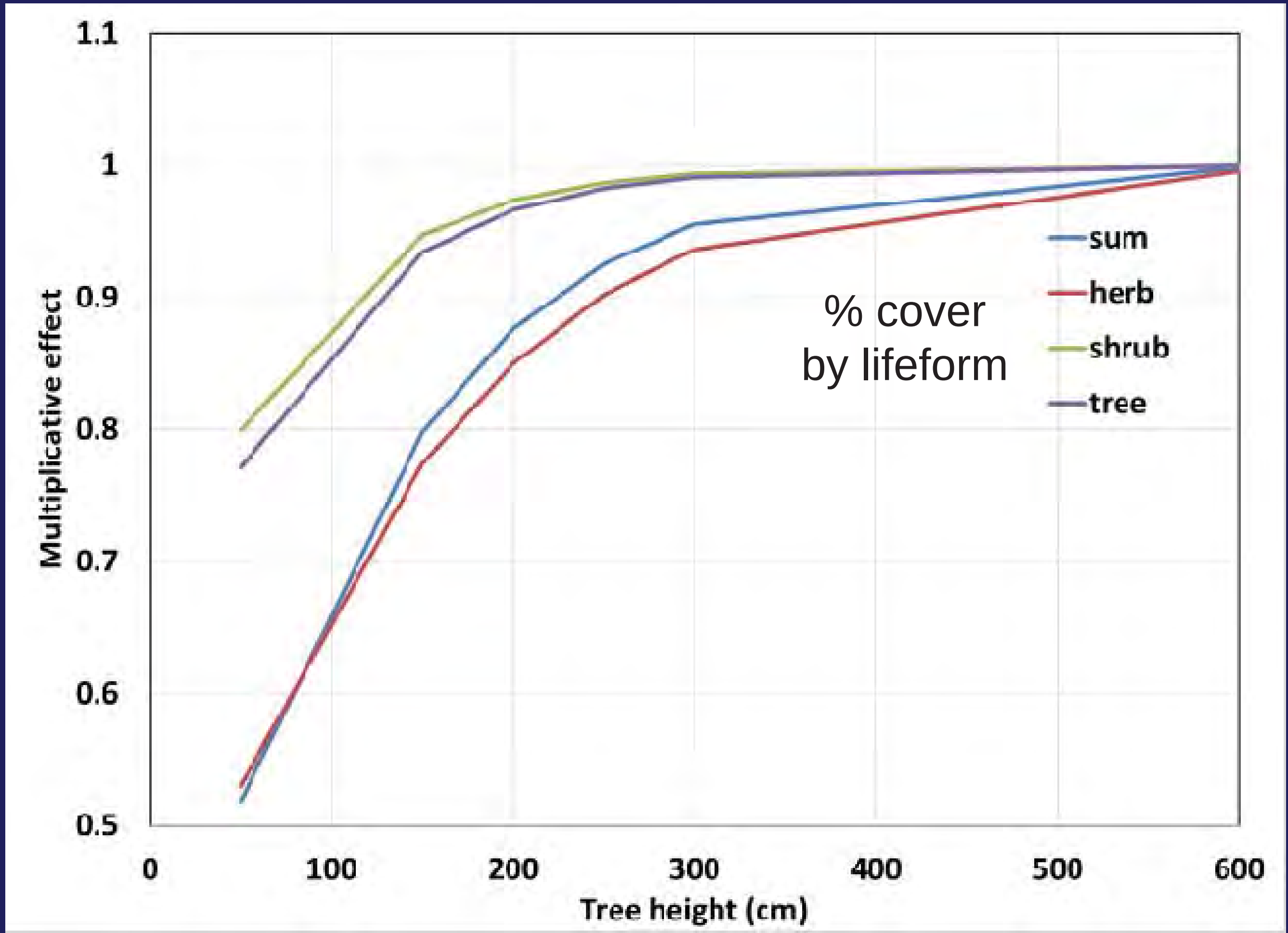
24-25 March 2015, Christchurch, NZ

Height growth multiplier by differing levels of summed lifeform cover (%)



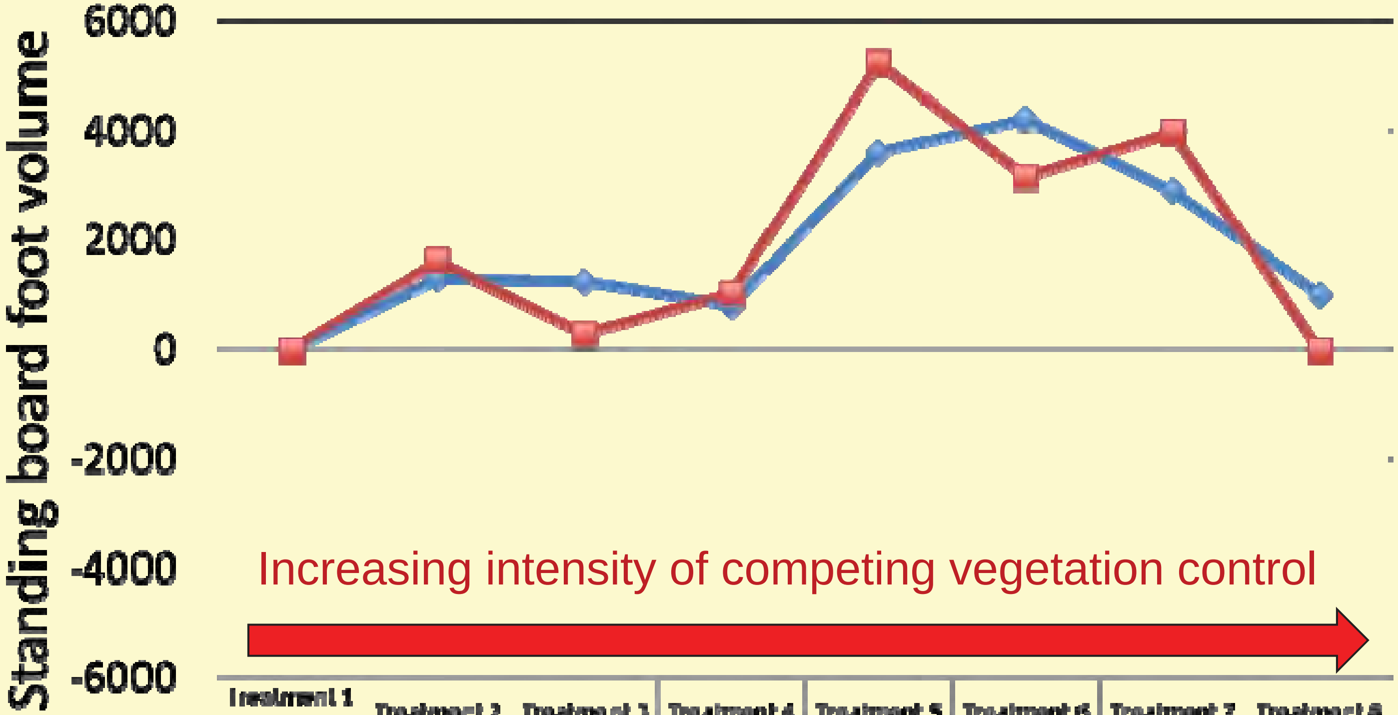
Height growth multiplier implied by 50% cover of three lifeforms of competing vegetation



Results from simulating Douglas-fir growth– Differing years of transfer between models and differing conversions of site index

20 year transfer

Flewelling site index 100 in CONIFERS and Bruce site index 159 in ORGANON



	Treatment 1 (Control)	Treatment 2	Treatment 3	Treatment 4	Treatment 5	Treatment 6	Treatment 7	Treatment 8
40	0	1312	1252	815	3618	4225	2905	1013
80	0	1618	283	1040	5233	3152	3976	-7

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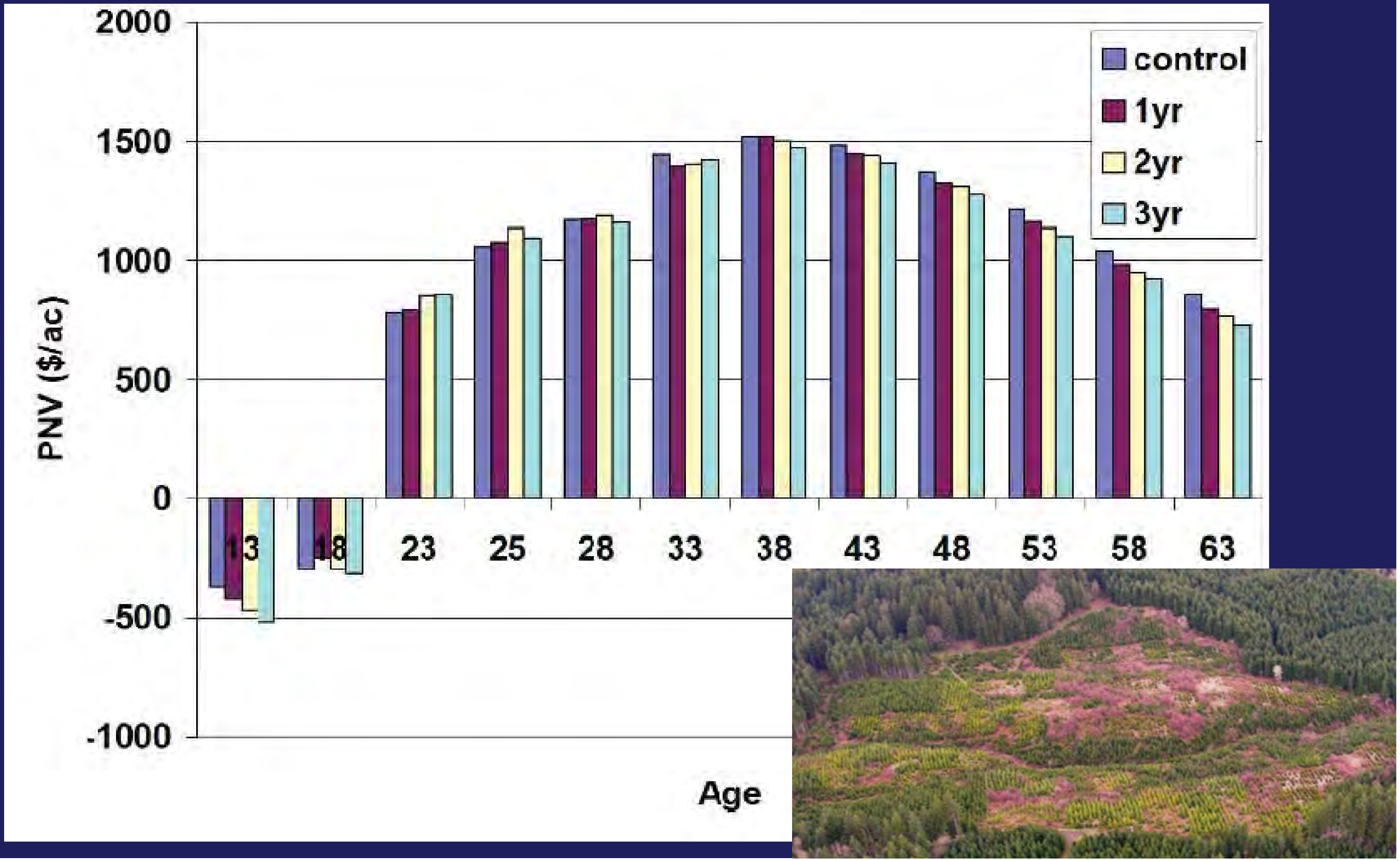
Implied PNV by age, with reduction to 10% competing vegetation cover and subsequent thinning



More work to do on refinement of young stand models for Douglas-fir plantations!

Mechanisms driving productivity and response to silviculture (based on better site characterization)

Forest Ecology and Management 255 (2008) 4040–4046

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

ELSEVIER

Why is the productivity of Douglas-fir higher in New Zealand than in its native range in the Pacific Northwest, USA?

Richard Waring [a,*], Alan Nordmeyer [b], David Whitehead [c], John Hunt [c], Michael Newton [a], Christoph Thomas [a], James Irvine [a]

[a] *Department of Forest Science, Oregon State University, Corvallis, OR 97331, USA*

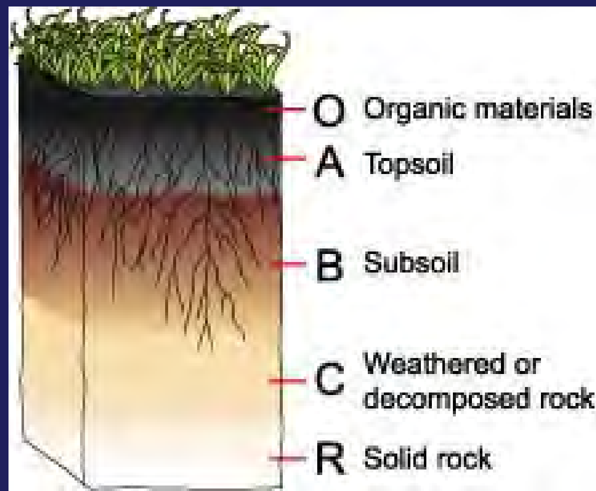
[b] *PO Box 63, Woodend 7641, New Zealand*

[c] *Landcare Research PO Box 40, Lincoln 7640, New Zealand*

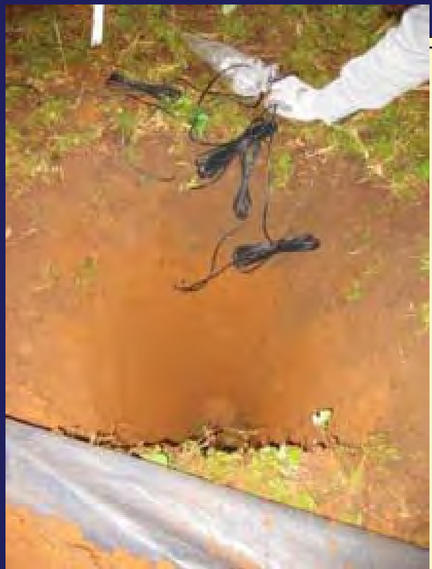
It's the water,
of course!

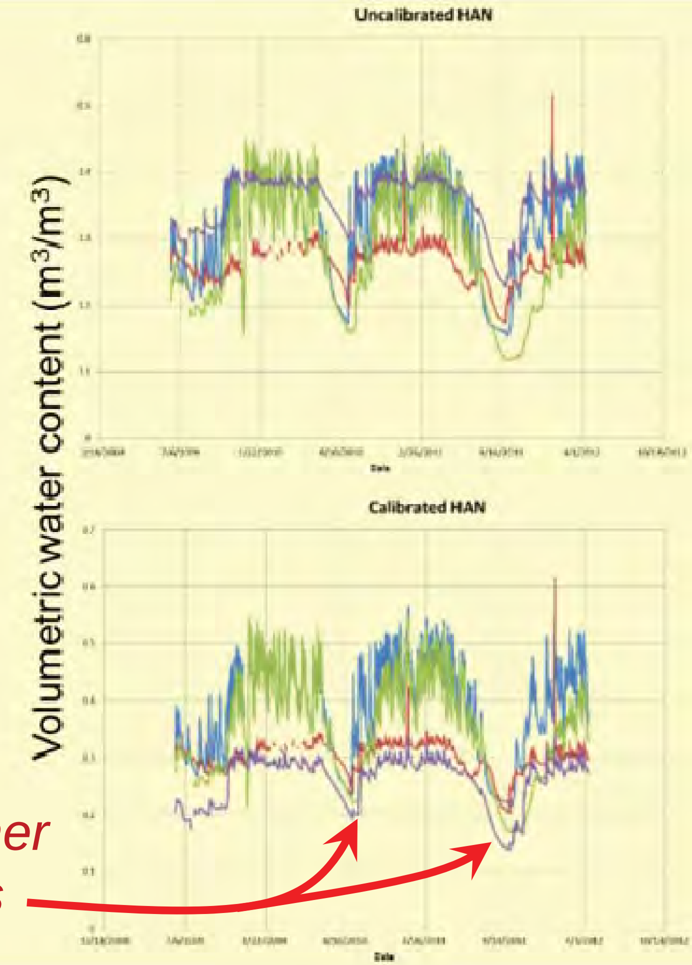
Growing season
precipitation

AWHC
(field capacity at
start of growing
season)



Monitoring soil water availability and use under varying silvicultural regimes





— Control 5 cm
— Control 50 cm
— N 5 cm
— N 50 cm

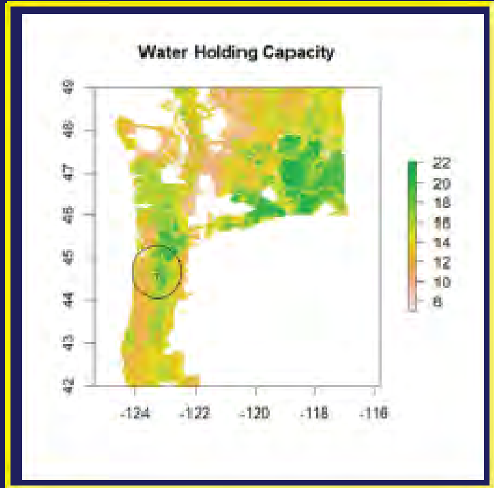
Fertilization with 224 kg N/ha as urea

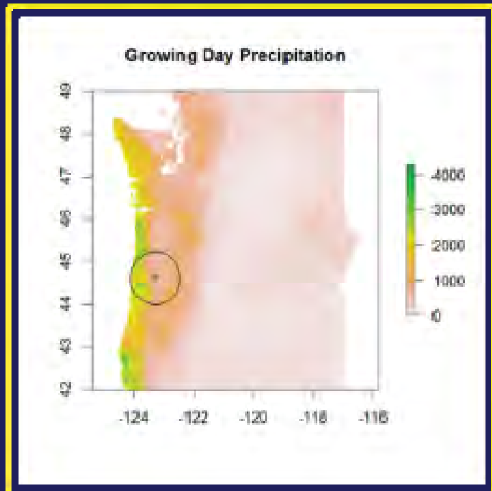
Mid- to late-summer water limitations

CIPSANON

- SWO – Southwest Oregon
  - Statistical/site index
  - Mechanistic/soils & climate
- CIPS – Douglas-fir plantations
  - Statistical/site index

Annualized growth predictions
Growth driven by soil & weather





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24-25 March 2015, Christchurch, NZ

Natural Resources Conservation Service

Soils maps

Data for soil pits by series

Pedotransfer functions

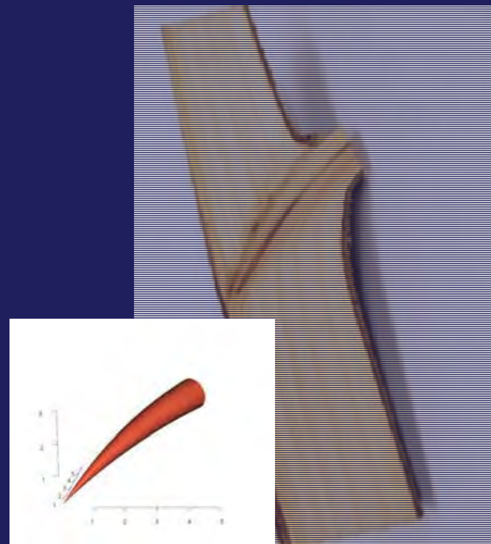
Available water holding capacity

Raster files accessible to CIPSR for given latitude and longitude

Practical on-site field assessment for index or calibration?

Simulation of wood quality attributes

- Juvenile wood core → wood density profiles
- Branch size and distribution
- Internal knot geometry
- Heartwood / sapwood delineation
- Environmental controls on earlywood / latewood ratios

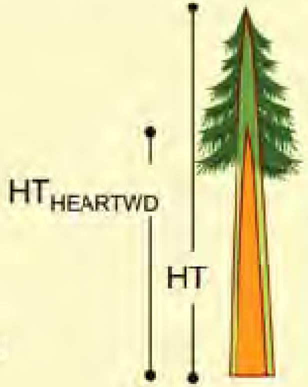


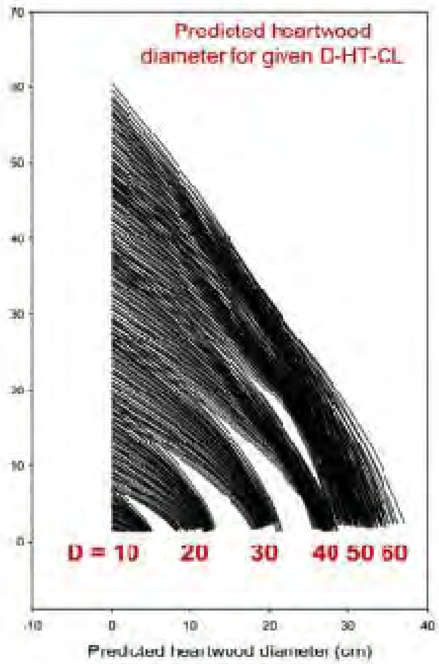
Heartwood model: height of heartwood core; taper of heartwood core

$$HT_{HEARTWD} = \frac{HT}{1 + \exp\left[-\beta_0 + \beta_1 \ln(CR) - \beta_2 \ln(CL) + \beta_3\left(\frac{HT}{D}\right)\right]}$$

where

$HT_{HEARTWD}$	=	Height of heartwood core
HT	=	Total tree height
CR	=	Crown ratio
CL	=	Crown length
D	=	Tree diameter at breast height





Based upon heartwood at breast height and height of heartwood core

Segmented polynomial taper equation

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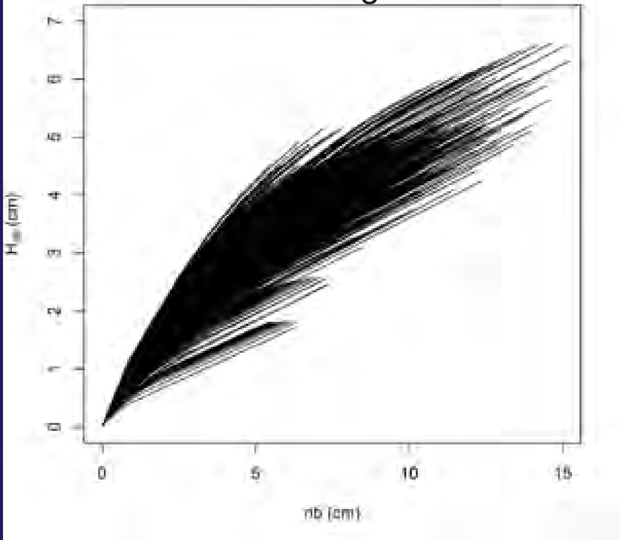
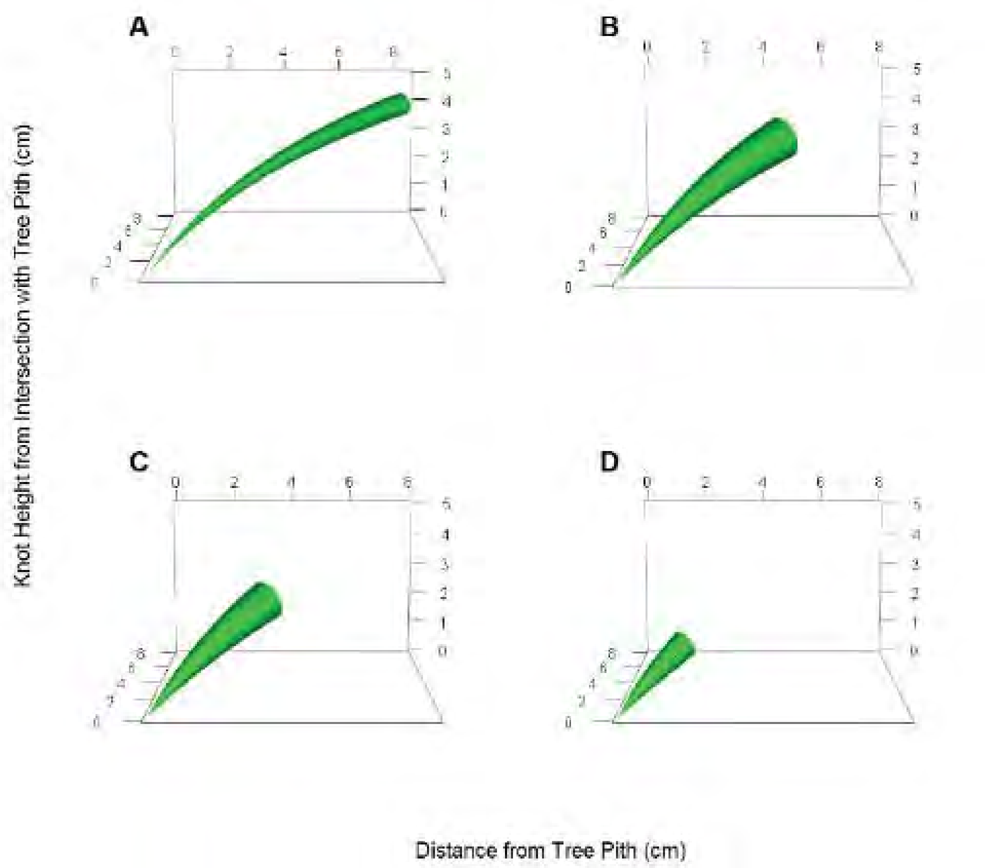
24-25 March 2015, Christchurch, NZ

Nate Osborne, Ph.D. candidate

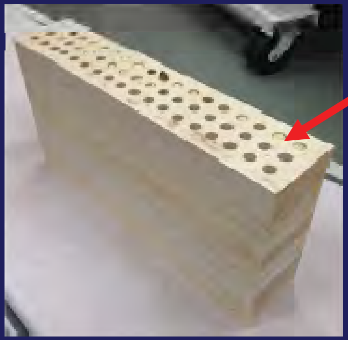
Chronosequence of branch angles



Internal knot geometry



Aligning the object for scanning



1-cm increment cores

Best Settings

Filter	Lung
kVp	135
mA	300

Set the filter, kVp and mA

Jason Wiest (OSU VETMED)

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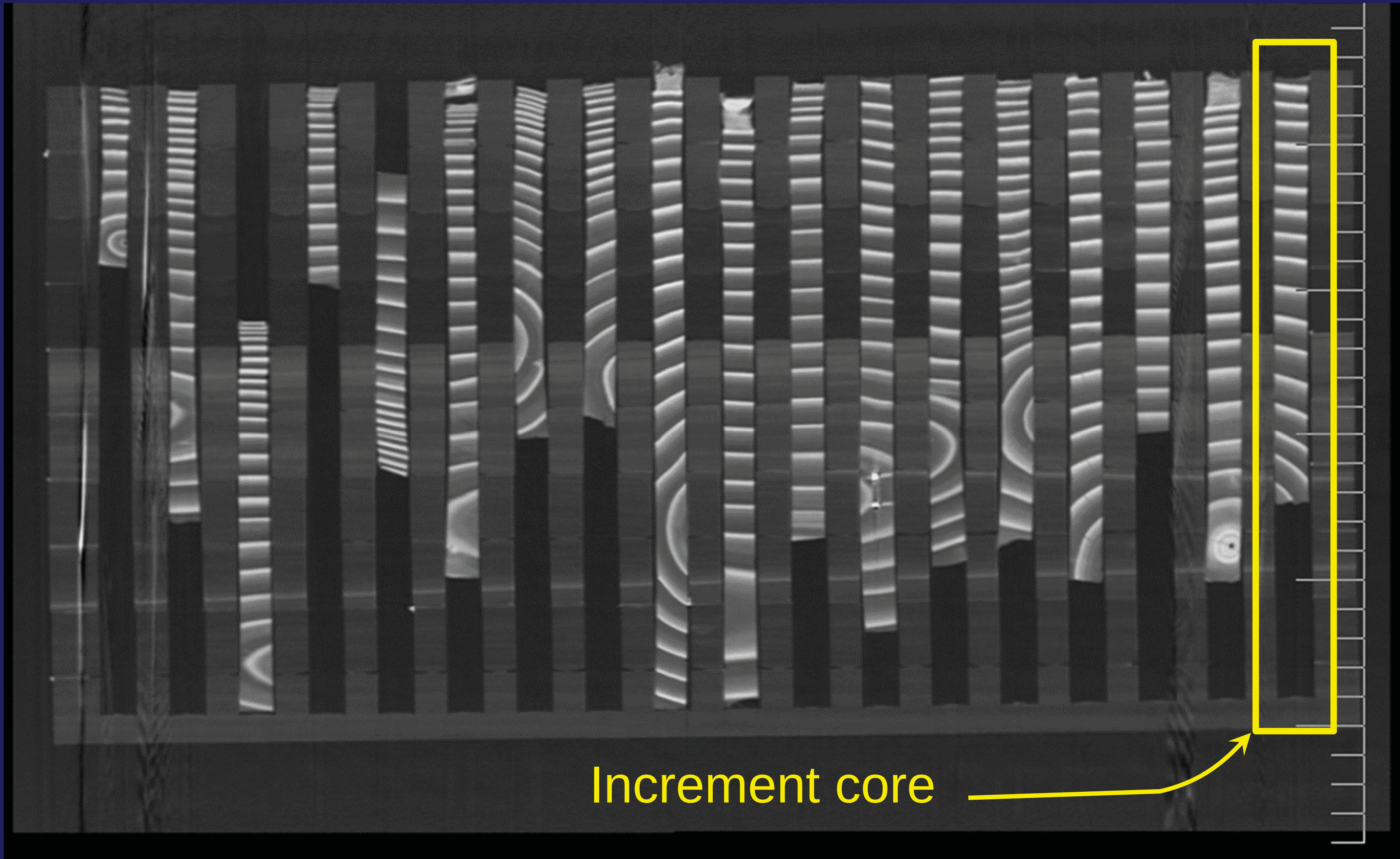
Developing calibration model to convert the Hounsfield units (x-ray attenuation units) to wood density at various moisture contents



Growing Confidence in Forestry's Future
24-25 March 2015, Christchurch, NZ

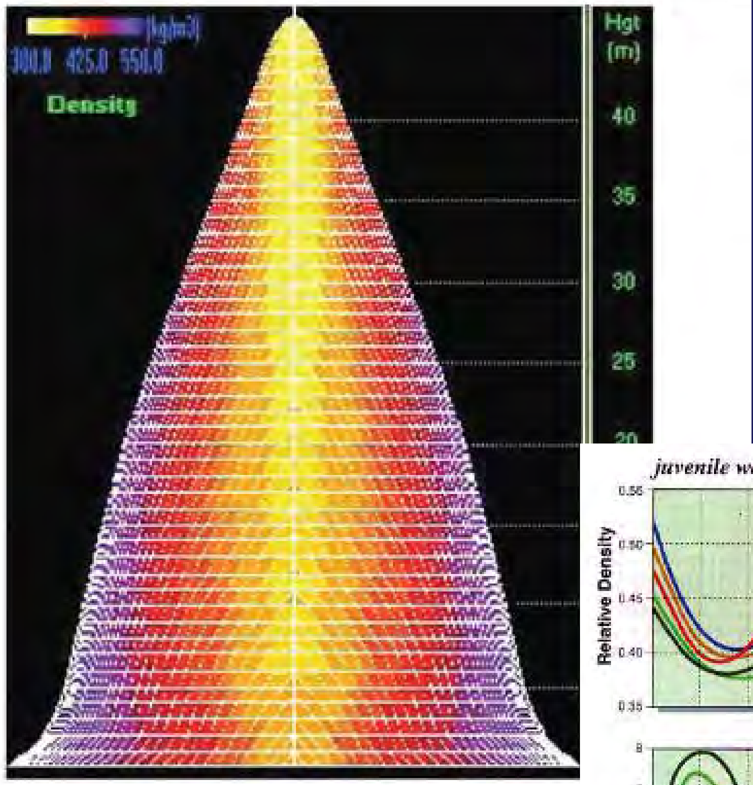
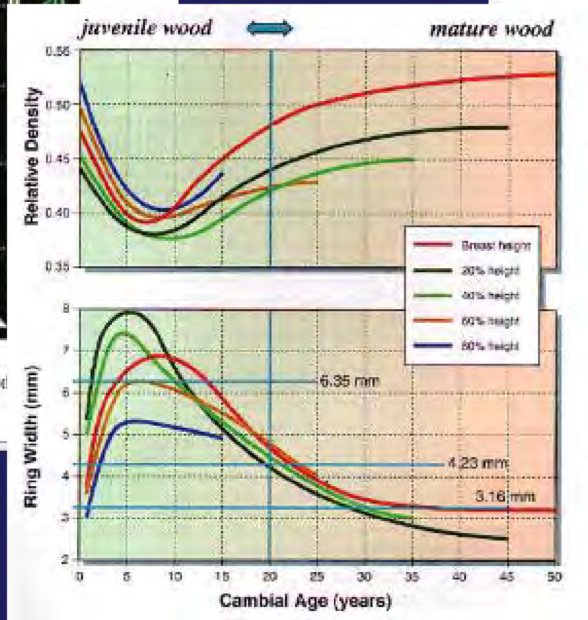
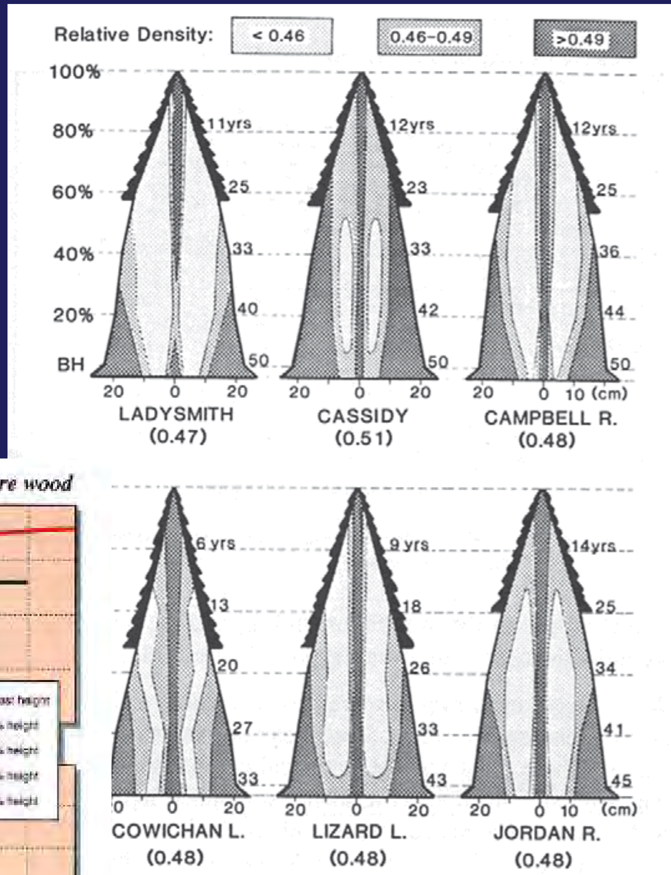


Fig. 1 Pattern of within-tree wood density variation for a 30-year-old ... North Island of New Zealand

RPBC 2003



Josza and Middleton 1994



Goal: Wood density profiles in response to site and silviculture

Modelling direct and indirect responses to thinning and fertilization

Until very recently, many if not most, corporate landowners fertilized Douglas-fir with 220 kg N / ha.

On average, growth was increased by about 3 m^3/ha/yr for 5-8 years.

About 40% of Douglas-fir stands do not respond, but we have poor predictability for what stands and sites will respond.

But also, as repeated rotations are harvested, are other nutrients important?

"Beyond N" fertilization trials

Soil moisture and temperature monitoring

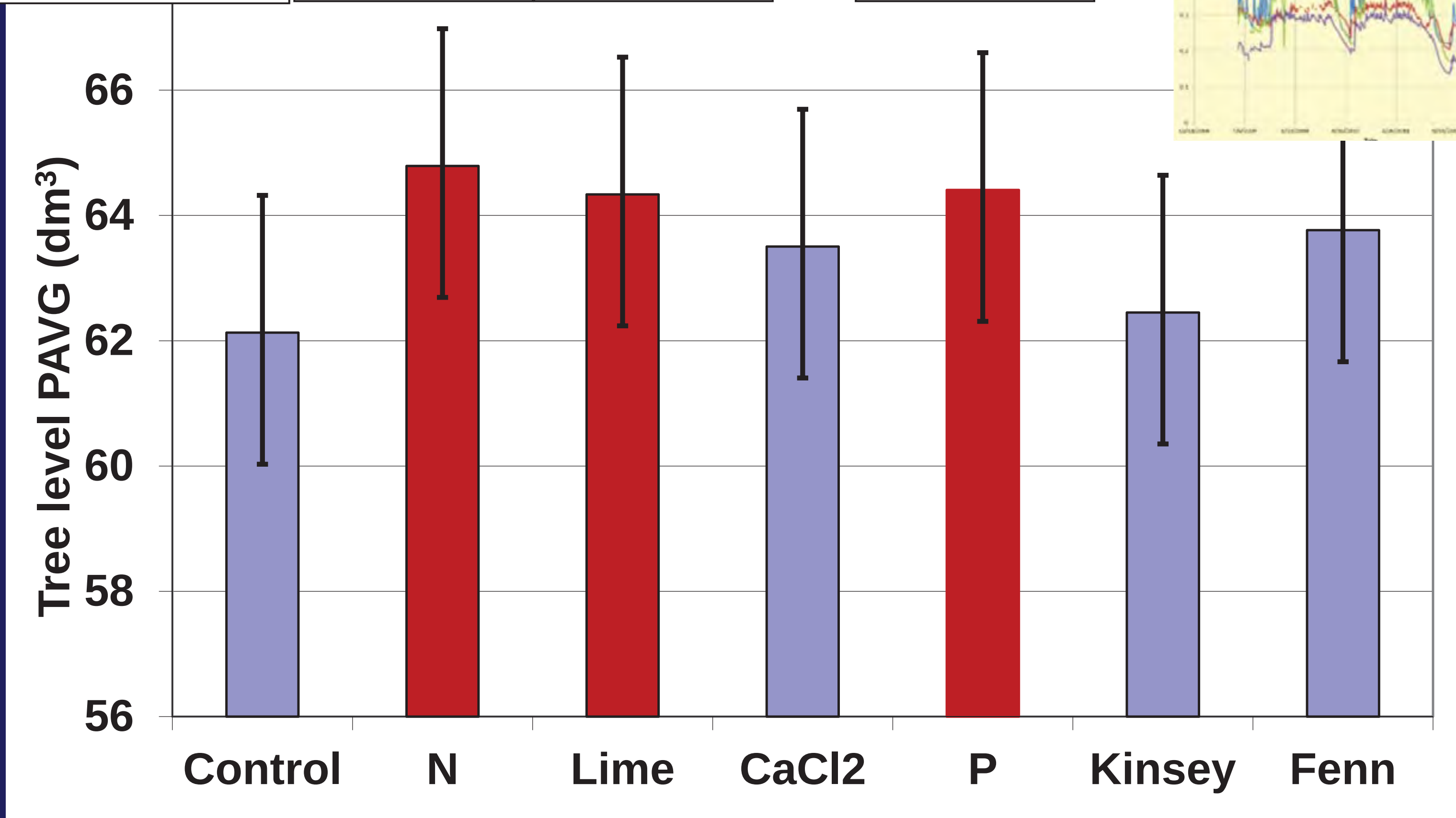
1/40-ac tree-centered circular plot

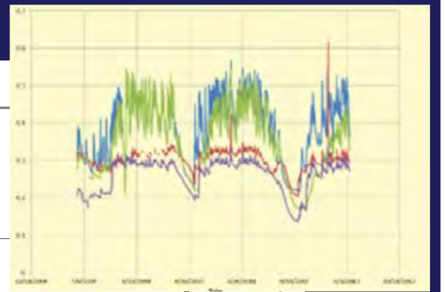
"Beyond N" fertilization trials

Treatment	Form	Amount	Reason for inclusion
Control	- -	- -	Statistical reference for treatments
N	Urea	224 kg N/ha	Industry standard
Lime	$CaCO_3$	1000 kg Ca/ha	Elevates pH, reduces Al, adds Ca
Ca	$CaCl_2$	100 kg Ca/ha	Add Ca without change in pH
P	Na_3PO_4	500 kg P/ha	P-fixing soils in Coast Range
Kinsey	Blend	Site specific	Agricultural regime to "feed" soil
Fenn	Blend	Site specific	Optimal ratios of foliar nutrients

Three-year volume growth response

P-values	N	Lime	P
without covariates:	*0.007*	*0.017*	*0.033*
with covariates:	*0.089*	*0.098*	*0.139*





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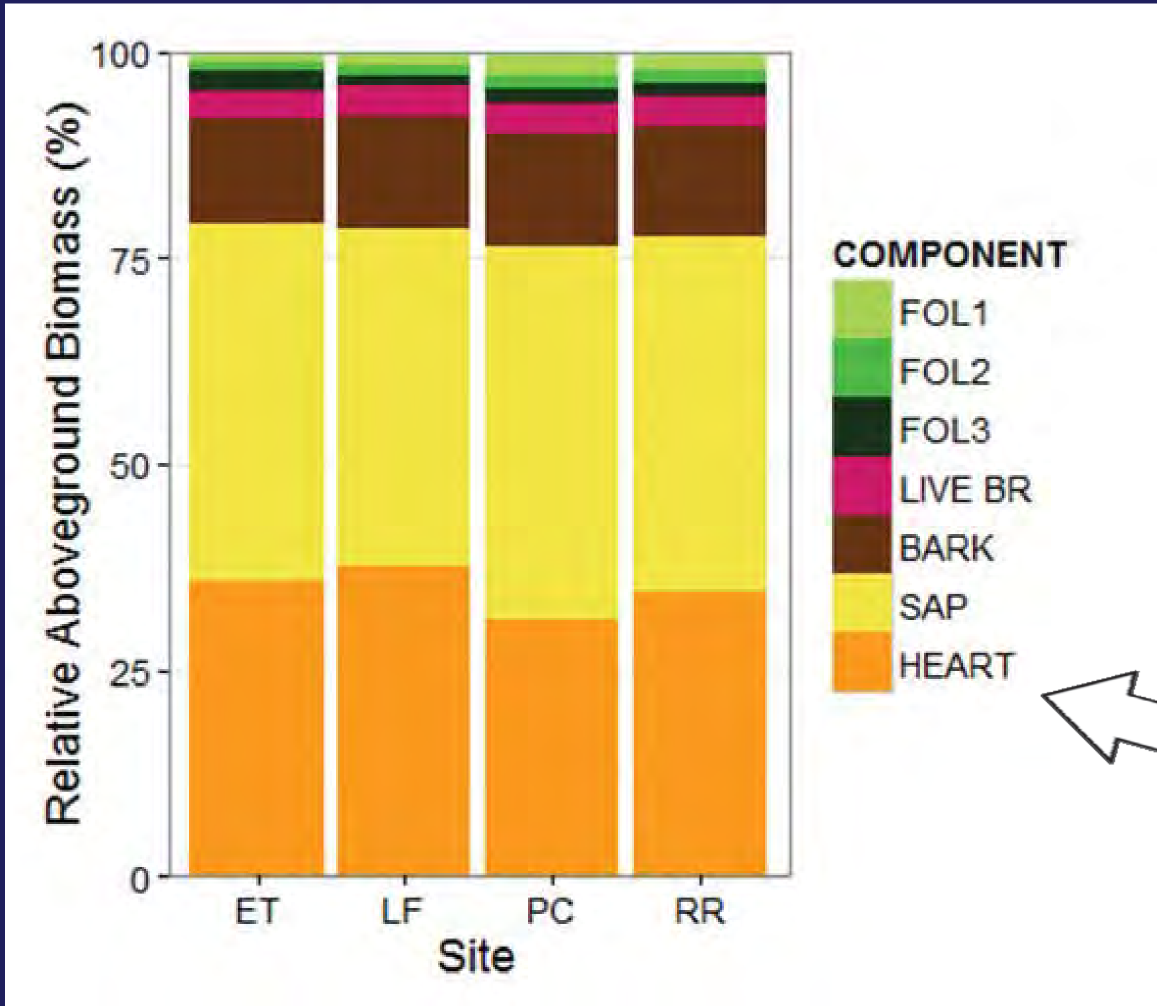
Estimation of biomass productivity, carbon pools and fluxes, and nutrient pools and fluxes

Sustainability of utilizing logging residuals as feedstock for liquid biofuels production



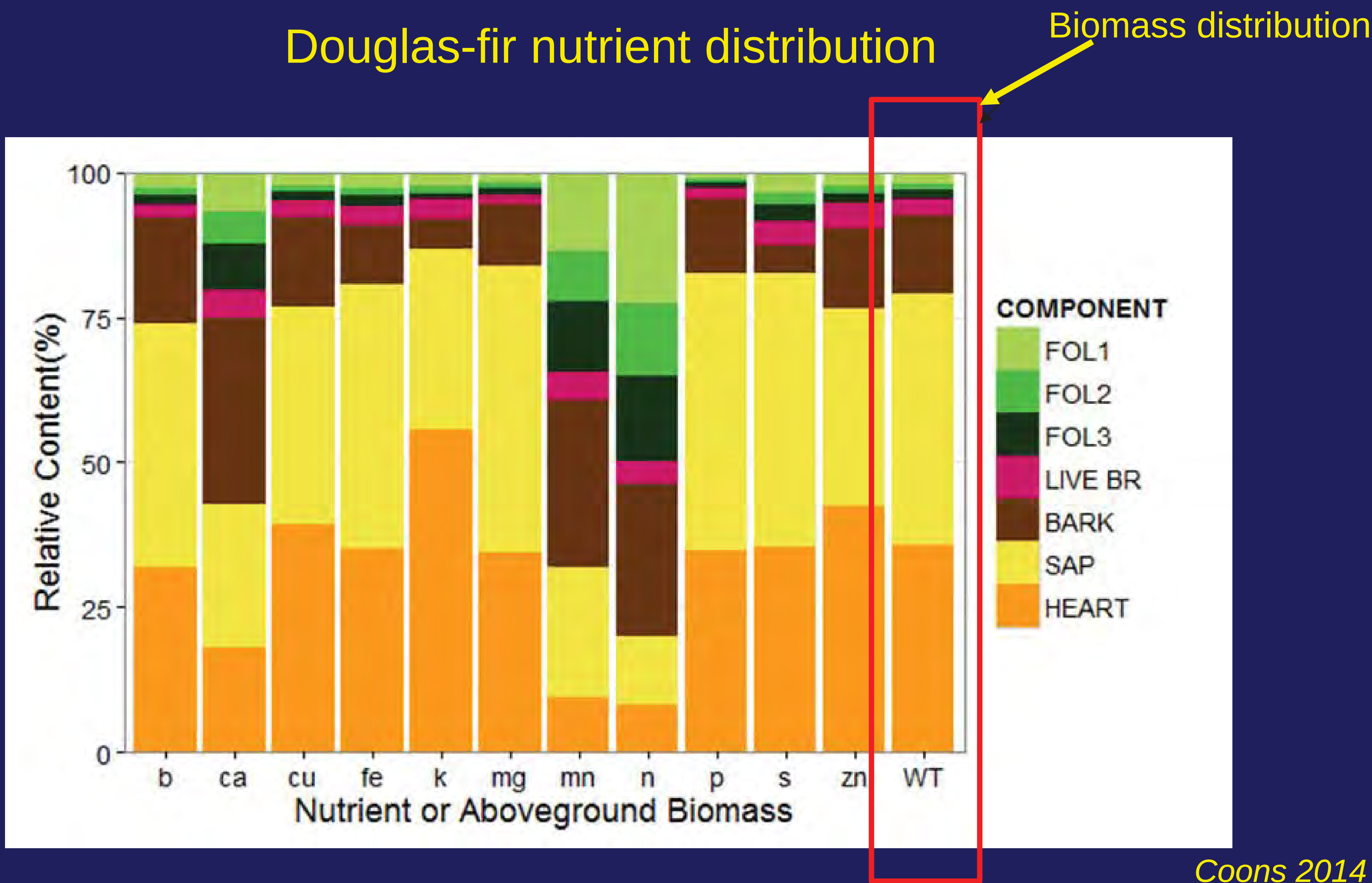
New biomass equations for intensively managed Douglas-fir plantations

↓

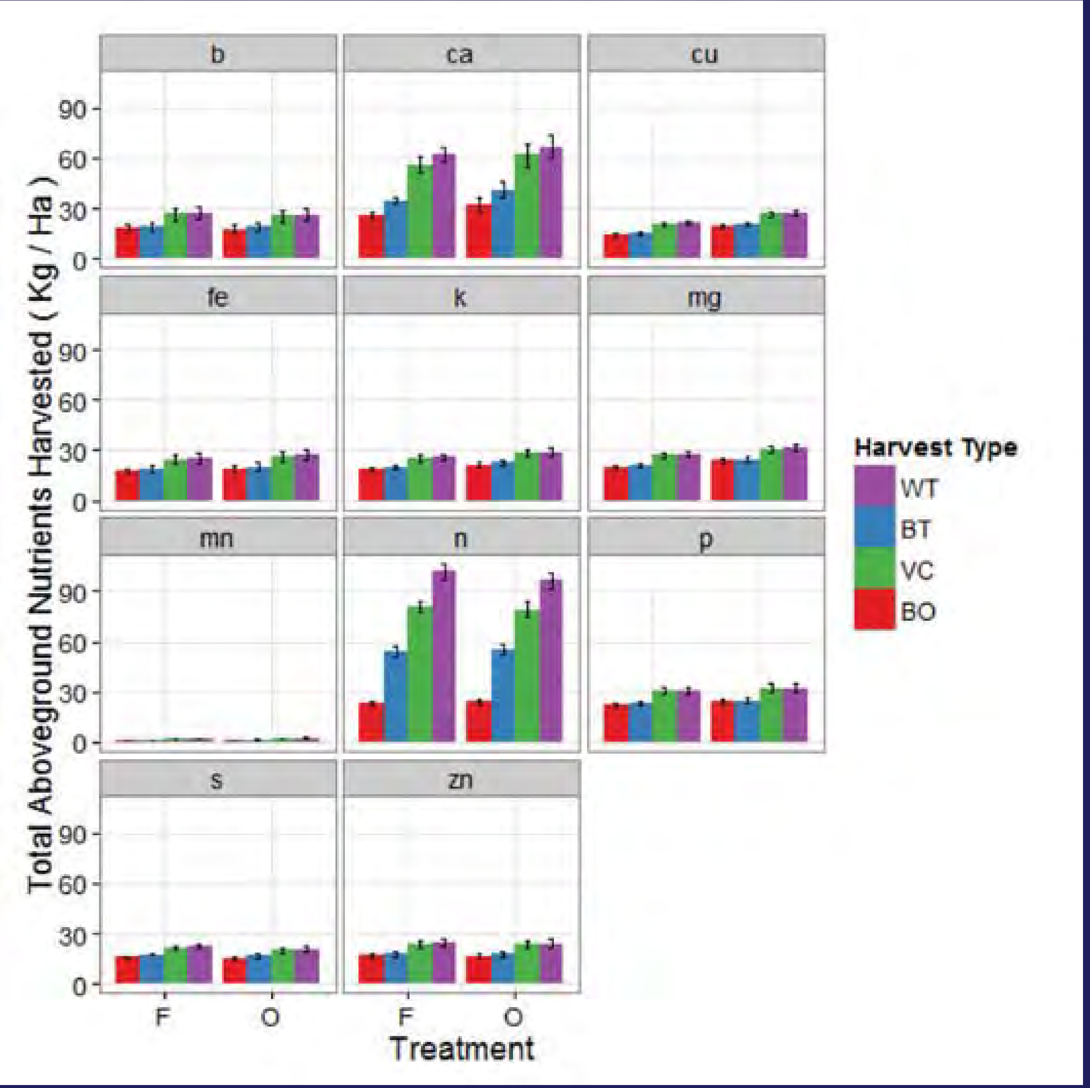
Douglas-fir biomass distribution (28-35-yr-old plantations)

Coons 2014

Douglas-fir nutrient distribution



Coons 2014



Douglas-fir nutrient removals under four scenarios:

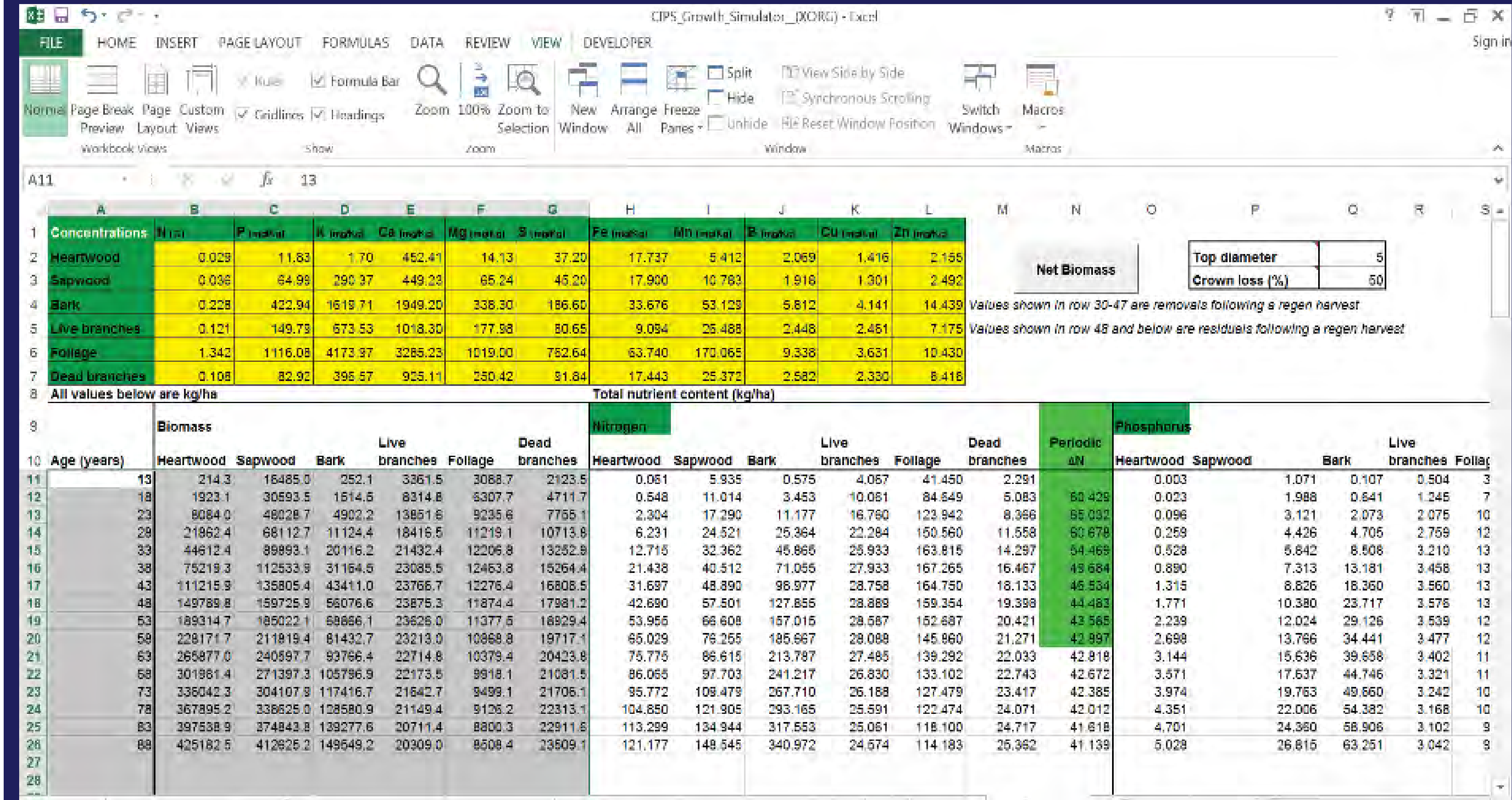
WT: whole tree
BT: bole minus top
VC: bole minus half crown
BO: bole only

Implications for managing nutrition under intensive silivculture

Coons 2014

XORG – CIPS growth simulator (Doug Mainwaring)

Includes biomass and nutrient content by tree component



CIPS_Growth_Simulator_(XORG) - Excel

A11 | 13

Concentrations	N (%)	P (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	S (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	B (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
Heartwood	0.029	11.83	1.70	452.41	14.13	37.20	17.737	5.412	2.069	1.416	2.155
Sapwood	0.036	64.99	290.37	449.23	65.24	46.20	17.900	10.783	1.918	1.301	2.492
Bark	0.228	422.94	1619.71	1949.20	338.30	186.60	33.676	53.129	5.812	4.141	14.439
Live branches	0.121	149.73	673.53	1018.30	177.98	80.65	9.094	25.488	2.448	2.461	7.175
Foliage	1.342	1116.08	4173.97	3285.23	1019.00	752.64	63.740	170.065	9.338	3.631	10.430
Dead branches	0.108	82.92	396.57	925.11	250.42	91.84	17.443	25.372	2.582	2.330	8.418

Net Biomass

Top diameter	5
Crown loss (%)	50

Values shown in row 30-47 are removals following a regen harvest
Values shown in row 48 and below are residuals following a regen harvest

All values below are kg/ha

Total nutrient content (kg/ha)

	Biomass						Nitrogen						
Age (years)	Heartwood	Sapwood	Bark	Live branches	Foliage	Dead branches	Heartwood	Sapwood	Bark	Live branches	Foliage	Dead branches	Periodic ΔN
13	214.3	16485.0	252.1	3361.5	3088.7	2123.5	0.061	5.935	0.575	4.067	41.450	2.291	
18	1923.1	30593.5	1514.6	8314.8	6307.7	4711.7	0.548	11.014	3.453	10.061	84.649	5.083	60.429
23	8084.0	48028.7	4902.2	13851.6	9235.6	7765.1	2.304	17.290	11.177	16.760	123.942	8.366	65.032
28	21862.4	68112.7	11124.4	18416.5	11219.1	10713.8	6.231	24.521	25.364	22.284	150.560	11.558	60.678
33	44612.4	89893.1	20116.2	21432.4	12206.8	13252.9	12.715	32.362	45.866	25.933	163.815	14.297	54.469
38	75219.3	112533.9	31164.5	23085.5	12463.8	15264.4	21.438	40.512	71.055	27.933	167.265	16.467	49.684
43	111215.9	135805.4	43411.0	23766.7	12276.4	16808.5	31.697	48.890	98.977	28.758	164.750	18.133	46.534
48	149789.8	159725.9	56076.6	23875.3	11874.4	17981.2	42.690	57.501	127.855	28.889	159.354	19.398	44.483
53	189314.7	185022.1	68866.1	23626.0	11377.6	18929.4	53.956	66.608	157.016	28.587	152.687	20.421	43.565
58	228171.7	211819.4	81432.7	23213.0	10868.8	19717.1	65.029	76.255	185.667	28.088	145.860	21.271	42.997
63	265877.0	240597.7	93766.4	22714.8	10379.4	20423.8	75.775	86.615	213.787	27.485	139.292	22.033	42.818
68	301981.4	271397.3	105796.9	22173.5	9918.1	21081.5	86.065	97.703	241.217	26.830	133.102	22.743	42.672
73	336042.3	304107.9	117416.7	21642.7	9499.1	21706.1	95.772	109.479	267.710	26.188	127.479	23.417	42.385
78	367895.2	338625.0	128580.9	21149.4	9126.2	22313.1	104.850	121.905	293.165	25.591	122.474	24.071	42.012
83	397538.9	374843.8	139277.6	20711.4	8800.3	22911.6	113.299	134.944	317.553	25.061	118.100	24.717	41.618
88	425182.5	412625.2	149549.2	20309.0	8508.4	23509.1	121.177	148.545	340.972	24.674	114.183	25.362	41.139

	Phosphorus				
Age (years)	Heartwood	Sapwood	Bark	Live branches	Foliag
13	0.003	1.071	0.107	0.504	3
18	0.023	1.988	0.641	1.245	7
23	0.096	3.121	2.073	2.075	10
28	0.259	4.426	4.705	2.759	12
33	0.528	5.842	8.508	3.210	13
38	0.890	7.313	13.181	3.458	13
43	1.315	8.826	18.360	3.560	13
48	1.771	10.380	23.717	3.576	13
53	2.239	12.024	29.126	3.539	12
58	2.698	13.766	34.441	3.477	12
63	3.144	15.636	39.658	3.402	11
68	3.571	17.637	44.746	3.321	11
73	3.974	19.763	49.660	3.242	10
78	4.351	22.006	54.382	3.168	10
83	4.701	24.360	58.906	3.102	9
88	5.028	26.815	63.251	3.042	9

Growing Confidence in Forestry's Future

24-25 March 2015, Christchurch, NZ

XORG – CIPS growth simulatior (Doug Mainwaring)

Includes biomass and nutrient content by tree component

Nutrient concentrations by tree component

Concentrations	N (%)	P (mg/Kg)	K (mg/Kg)	Ca (mg/Kg)	Mg (mg/Kg)	S (mg/Kg)	Fe (mg/Kg)	Mn (mg/Kg)	B (mg/Kg)	Cu (mg/Kg)	Zn (mg/Kg)
Heartwood	0.029	11.83	1.70	452.41	14.13	37.20	17.737	5.412	2.069	1.416	2.155
Sapwood	0.036	64.99	290.37	449.23	65.24	45.20	17.900	10.783	1.918	1.301	2.492
Bark	0.228	422.94	1619.71	1949.20	338.30	186.60	33.676	53.129	5.812	4.141	14.439
Live branches	0.121	149.79	673.53	1018.30	177.98	80.65	9.094	26.488	2.448	2.461	7.175
Foliage	1.342	1116.08	4173.97	3285.23	1019.00	762.64	63.740	170.065	9.338	3.631	10.430
Dead branches	0.108	82.92	396.57	925.11	250.42	91.84	17.443	25.372	2.582	2.330	8.418

All values below are kg/ha   Total nutrient content (kg/ha)

XORG – CIPS growth simulatior (Doug Mainwaring)

Biomass per ha by tree component for each year

All values below are kg/ha

Age (years)	Biomass Heartwood	Sapwood	Bark	Live branches	Foliage	Dead branches
13	214.3	16485.0	252.1	3361.5	3088.7	2123.5
18	1923.1	30593.5	1514.5	8314.8	6307.7	4711.7
23	8084.0	48028.7	4902.2	13851.6	9235.6	7755.1
28	21862.4	68112.7	11124.4	18416.5	11219.1	10713.8
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48	149789.8	159725.9	56076.6	23875.3	11874.4	17981.2
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63	265877.0	240597.7	93766.4	22714.8	10379.4	20423.8
68	301981.4	271397.3	105796.9	22173.5	9918.1	21081.5
73	336042.3	304107.9	117416.7	21642.7	9499.1	21706.1
78	367895.2	338625.0	128580.9	21149.4	9126.2	22313.1
83	397538.9	374843.8	139277.6	20711.4	8800.3	22911.6
88	425182.5	412625.2	149549.2	20309.0	8508.4	23509.1

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XORG – CIPS growth simulatior (Doug Mainwaring)

Nutrient content per ha by tree component for each year

	All values below	Total nutrient content (kg/ha)						
9		Nitrogen						
10	Age (years)	Heartwood	Sapwood	Bark	Live branches	Foliage	Dead branches	Periodic ΔN
11	13	0.061	5.935	0.575	4.067	41.450	2.291	
12	18	0.548	11.014	3.453	10.061	84.649	5.083	60.429
13	23	2.304	17.290	11.177	16.760	123.942	8.366	65.032
14	28	6.231	24.521	25.364	22.284	150.560	11.558	60.678
15	33	12.715	32.362	45.865	25.933	163.815	14.297	54.469
16	38	21.438	40.512	71.055	27.933	167.265	16.467	49.684
17	43	31.697	48.890	98.977	28.758	164.750	18.133	46.534
18	48	42.690	57.501	127.855	28.889	159.354	19.398	44.483
19	53	53.955	66.608	157.015	28.587	152.687	20.421	43.585
20	58	65.029	76.255	185.667	28.088	145.860	21.271	42.897
21	63	75.775	86.615	213.787	27.485	139.292	22.033	42.818
22	68	86.065	97.703	241.217	26.830	133.102	22.743	42.672
23	73	95.772	109.479	267.710	26.188	127.479	23.417	42.385
24	78	104.850	121.905	293.165	25.591	122.474	24.071	42.012
25	83	113.299	134.944	317.553	25.061	118.100	24.717	41.618
26	88	121.177	148.545	340.972	24.574	114.183	25.362	41.139
27								
28								

CONIF | eList | Completed TreeList | Projection | Treelist output | **nutrient_con**

Periodic uptake (kg/ha/5yrs)

Silvicultural technology

Advances in productivity research in the Pacific Northwest?

- Silvicultural research on productivity is very fragmented (need for more information, but equal or greater need to synthesize existing information)
- Productivity of a Douglas-fir rotation depends on interaction of silvicultural activities implemented at very different phases of the rotation
- Interactions of treatments at a single point in time are relatively well understood, or at least tractable
- Interactions among activities in the chain of silvicultural activities are poorly understood, and not so easy to track
- Integration with models can helpful but can also introduce biases, so ultimately require field testing.


Thanks for your attention !