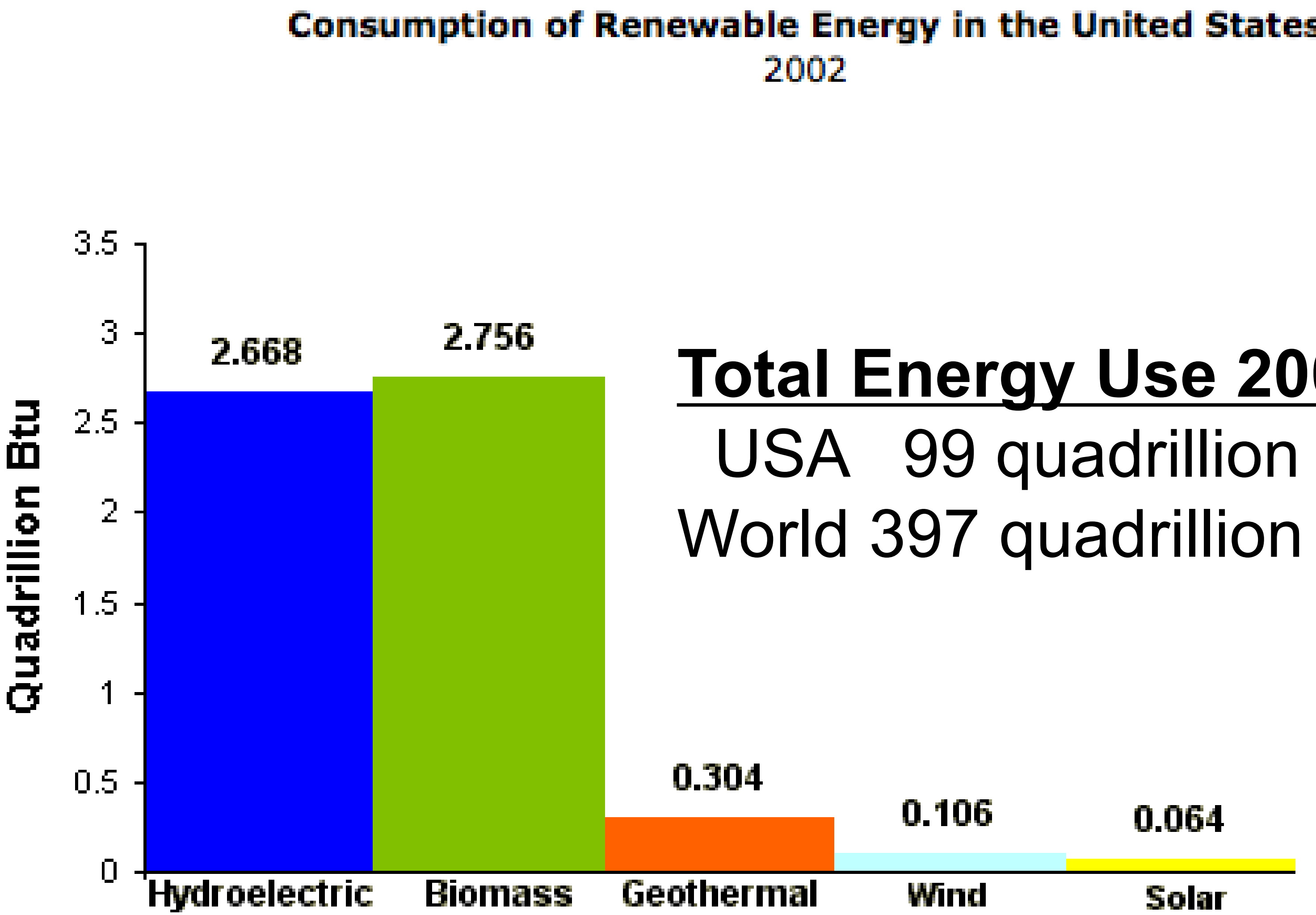
PNW Forest Veg. Mgt. Conf.

Nutrient Limitations on Intensive Biomass Production in PNW DF Plantations

Rob Harrison, Univ. Washington

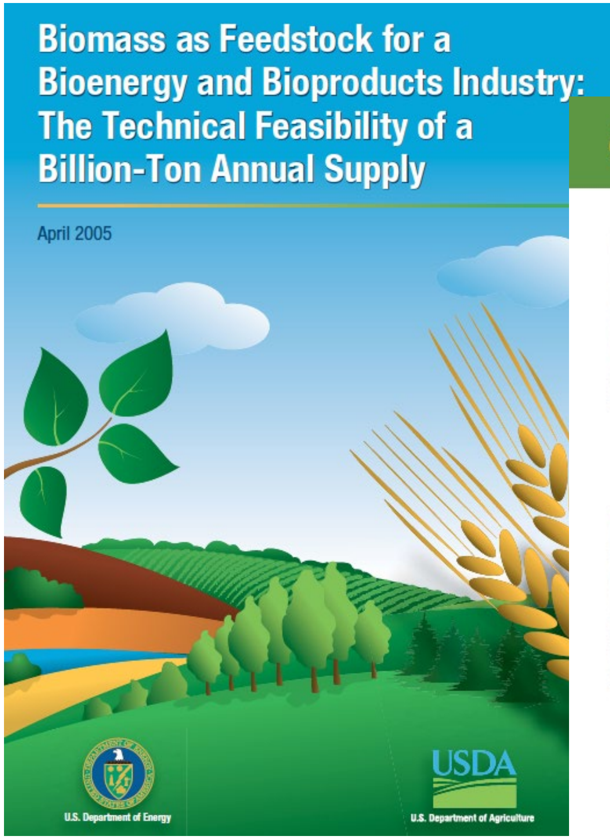


Total Energy Use 2000

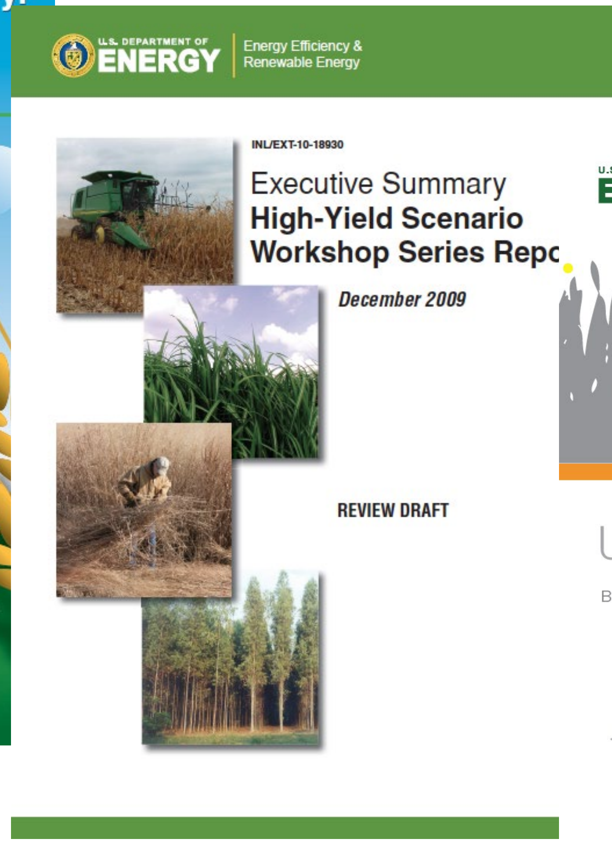
USA 99 quadrillion BTU

World 397 quadrillion BTU

Renewable energy in US in 2002 (www.oregon.gov/energy).



2005

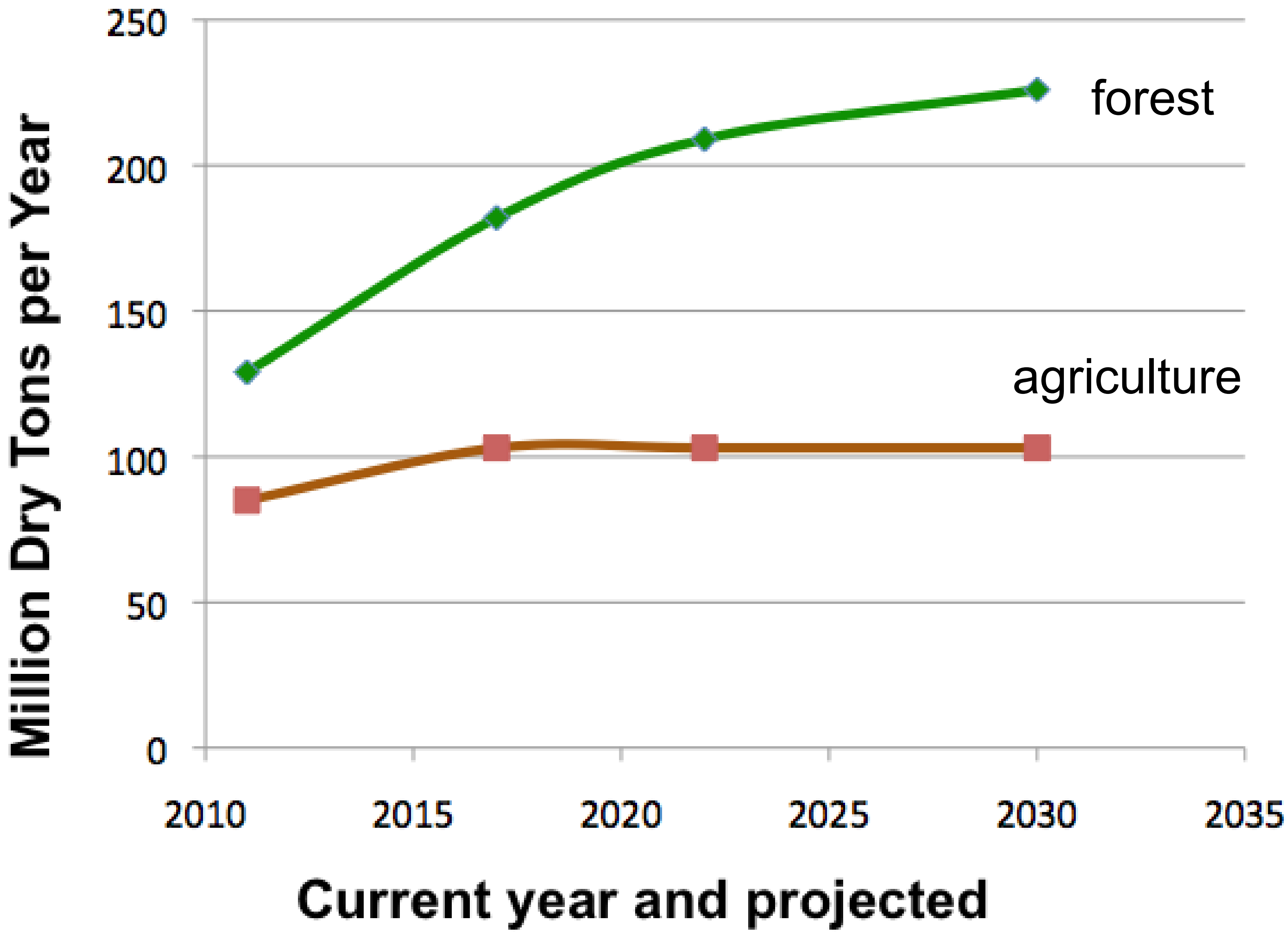


2009

2011

Table 2.1 Projected Consumption of Currently Used Biomass Feedstocks (Million Dry Tons per Year)

Source	Current	2017	2022	2030
Forest				
Fuelwood	38	72	96	106
Mill residue	32	38	39	42
Pulping liquors	45	52	54	58
MSW sources	14	20	20	20
Total forest	**129**	**182**	**209**	**226**
Agriculture				
Ethanol [a]	76 (109)	88 (127)	88 (127)	88 (127)
Biodiesel [b]	2	4	4	4
MSW sources	7	11	11	11
Total agricultural resources currently used	**85 (118)**	**103 (142)**	**103 (142)**	**103 (142)**
Total currently used resources	**214 (247)**	**285 (342)**	**312 (351)**	**329 (368)**



250
200
150
100
50
0
Million Dry Tons per Year
forest
agriculture
2010
2015
2020
2025
2030
2035
Current year and projected

harvest residue ready for transport from field to utilization site

harvest residue transport from field

Hazard fuel reduction treatment in NE Washington State

Piled logging slash in NE Washington State

Current bioenergy production in the PNW is limited.

- biomass to electricity plant at Kettle Falls, WA, opened 1983, currently burns about 500K tons wood/y and generates 53 megawatts max of electricity from biomass (additional 8 MW from natural gas)

Business News Print Email Share +1 0

$250M biomass energy plant planned in Shelton

Credit: John Deere

by KING5.com Staff and Associated Press

Recommend

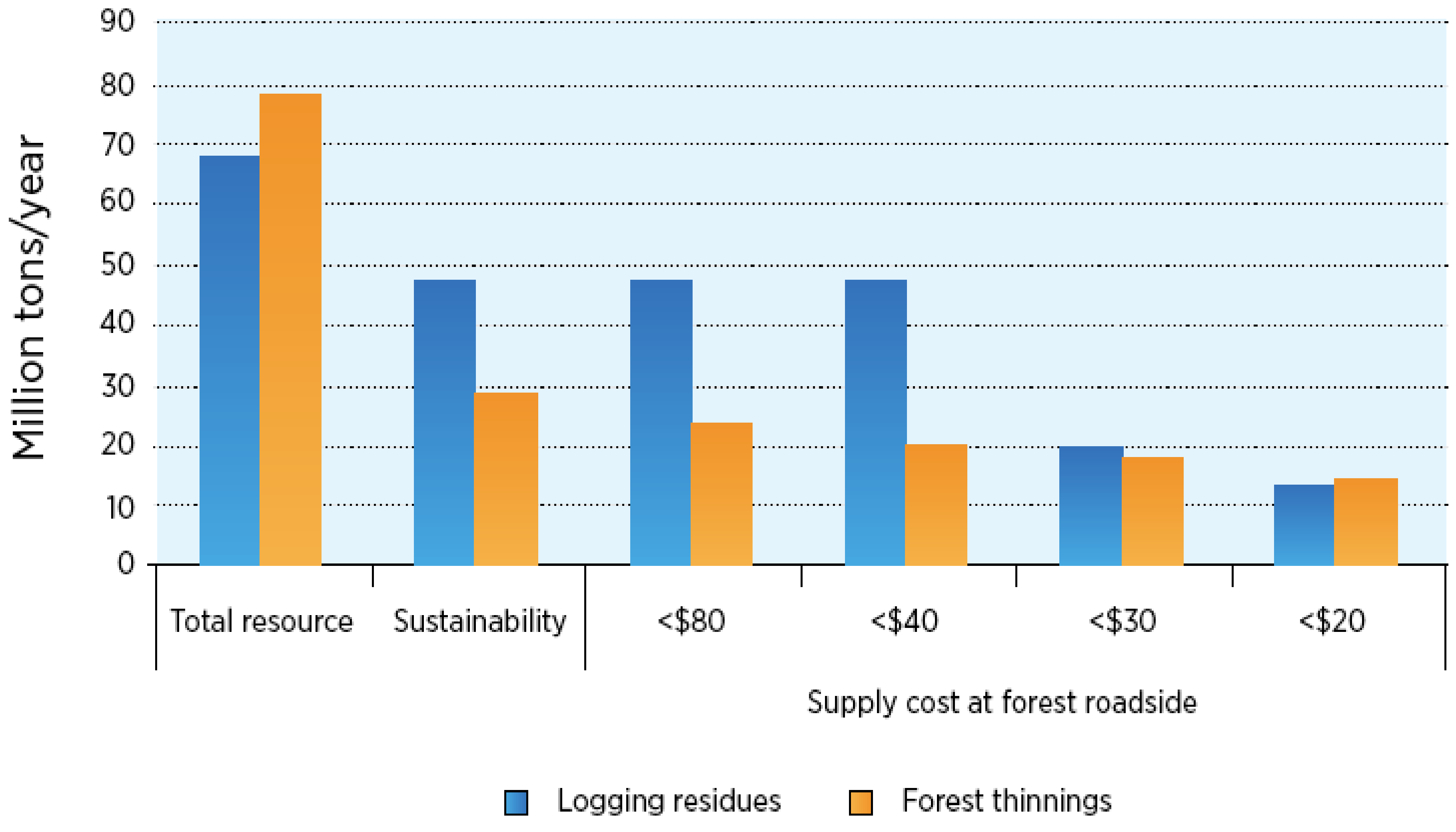
Posted on February 8, 2010 at 12:39 PM

Updated Monday, Feb 8 at 2:10 PM

First of Its Kind: WSU Led Bio-Jet Fuel Project Officially Gets Off the Ground

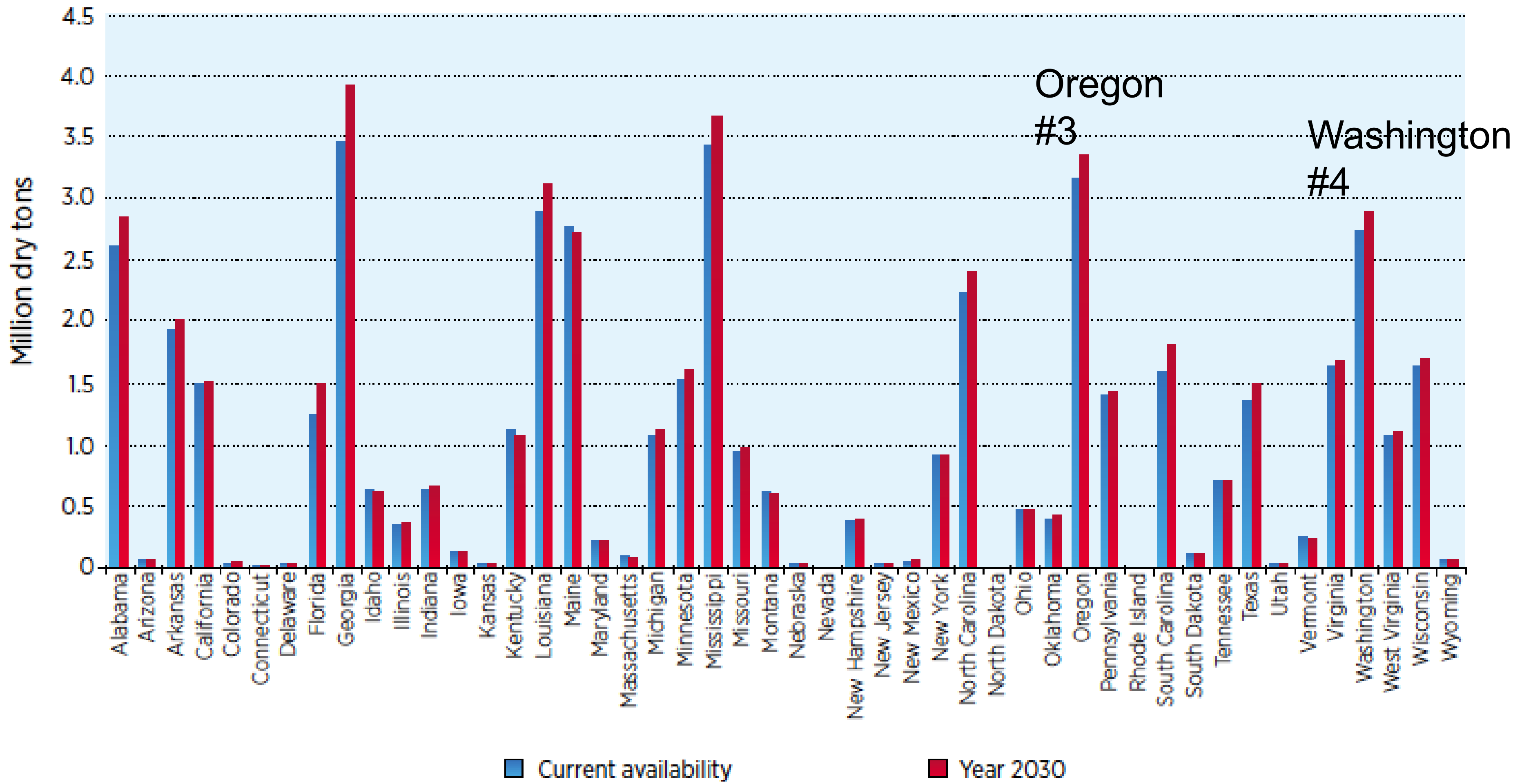
PULLMAN, Wash. -- A major Washington State University effort to develop aviation bio-fuel is underway with the announcement of a strategic initiative called the "Sustainable Aviation Fuels Northwest" project; the first of its kind in the U.S. In partnership with Alaska Airlines, Boeing, the Port of Seattle, The Port of Portland, and Spokane International Airport, the project will look at biomass options within a four-state region as possible sources for creating renewable jet fuel.

"This really is an exciting development from both the economic impact to the Northwest, but also to the advancement of clean fuel technologies world-wide," said John Gardner, vice president of Economic Development and Global Engagement at WSU.



from "Billion ton biomass update, 2011"

Figure 3.7 Current and year 2030 state quantities of logging residue available annually at $80 per dry ton



from "Billion ton biomass update, 2011"

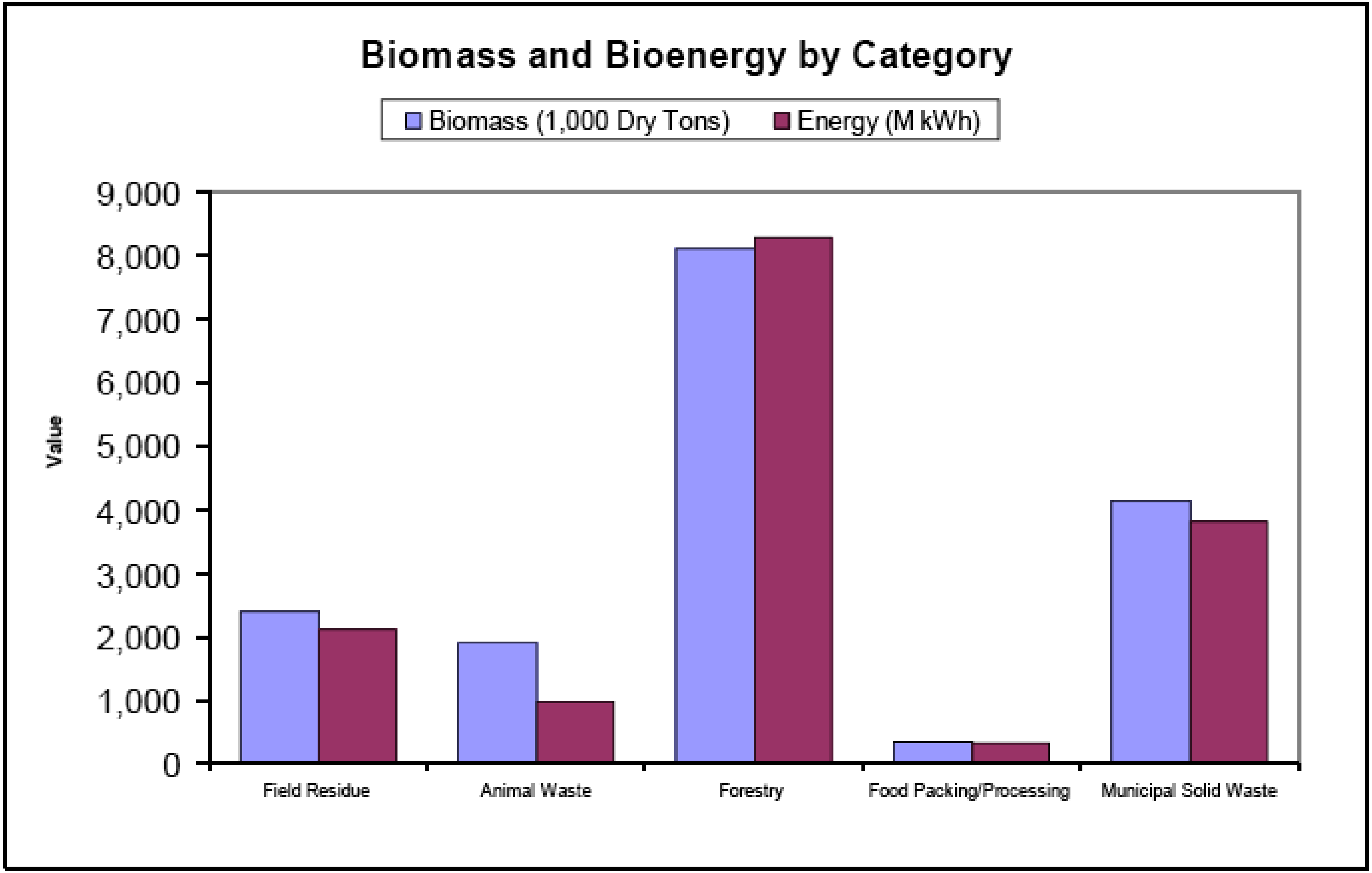


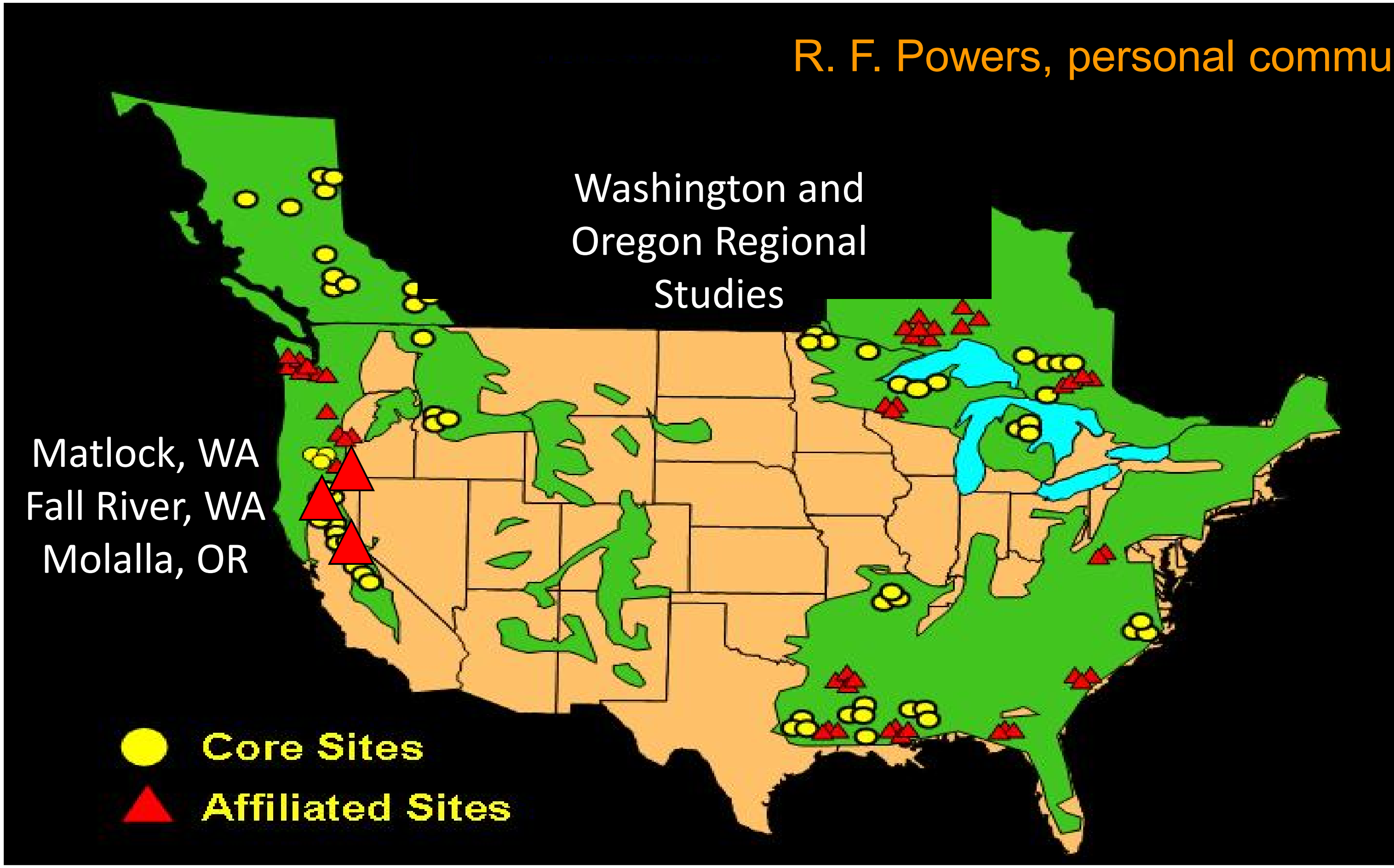
Figure 1. Washington State Biomass availability by sector (Frear et al. 2005)

Key Needs: Long-term Soil Productivity Studies Background:

- Needed long-term studies to access effects of practices on soil productivity
- Study treatments were based on a literature review (Powers and others)
  - Two ecosystem properties—organic matter and soil porosity—were most apt to be influenced by management, and have subsequent long-term impacts on soil productivity
  - Vegetation control added as an additional treatment to reduce confounding effects

Long-Term Soil Productivity Network

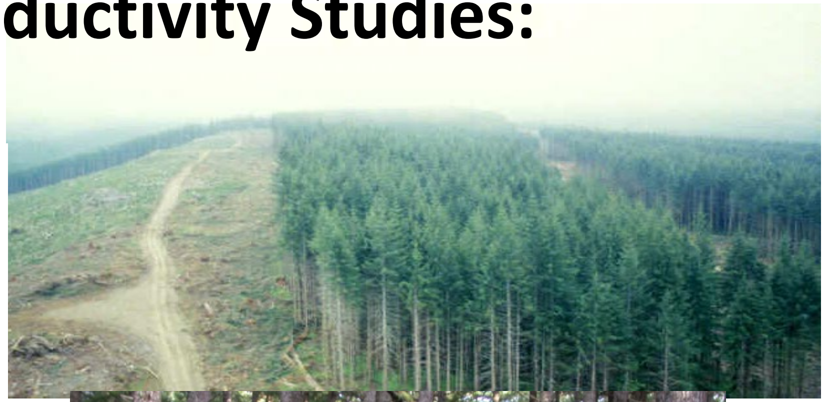
R. F. Powers, personal communication



Includes more than 62 sites on major soil and forest types in the United States and Canada. These studies looked at the effects of biomass removal, soil compaction and vegetation control on forest productivity

Regional Long-term Soil Productivity Studies:

Initial Stand Conditions:

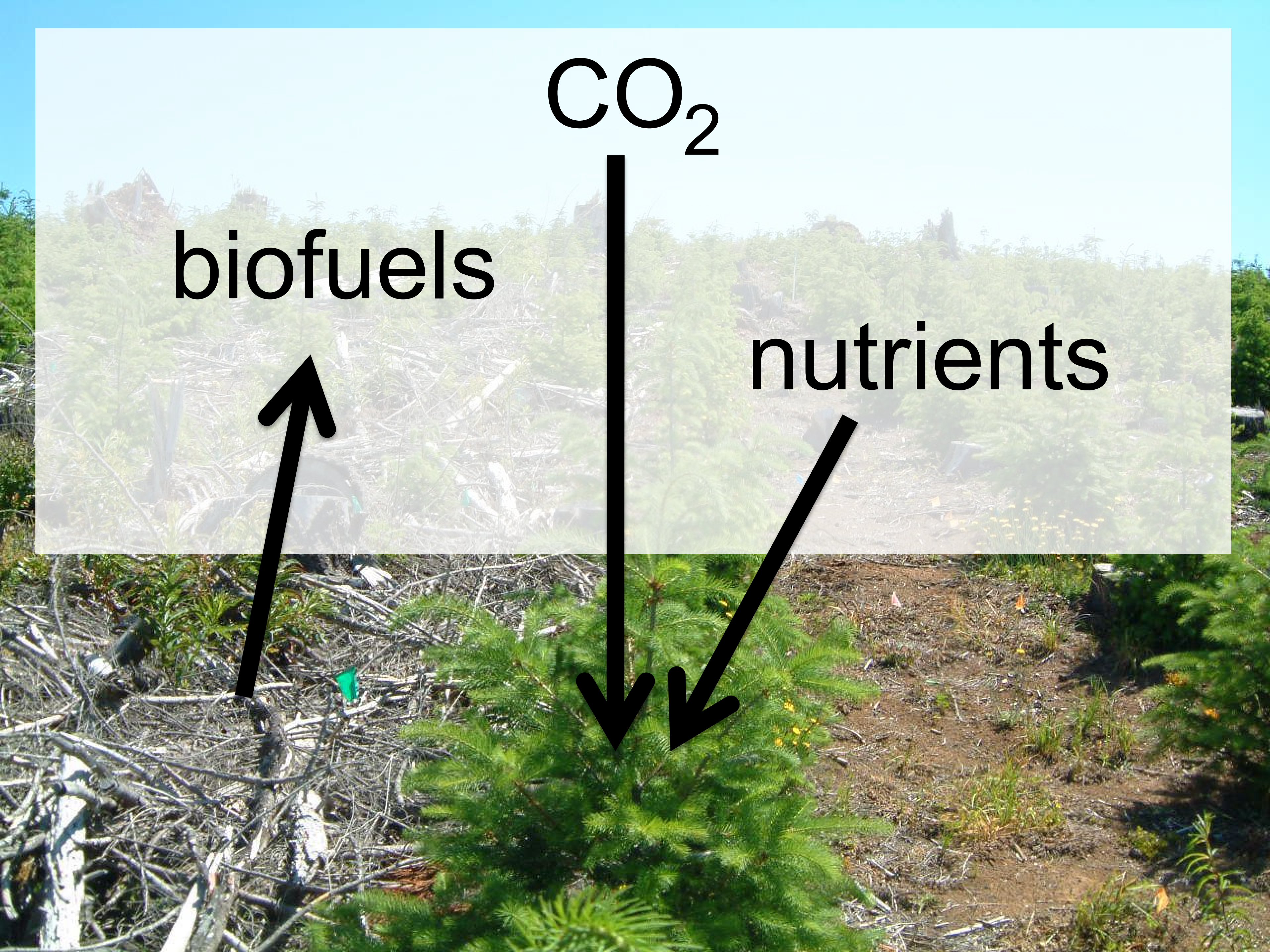


<u>Fall River, WA</u>: Planted, age 47 (seed) Douglas-fir / natural hemlock stand; Site Index of 41- to 43-m (135-140 ft)*

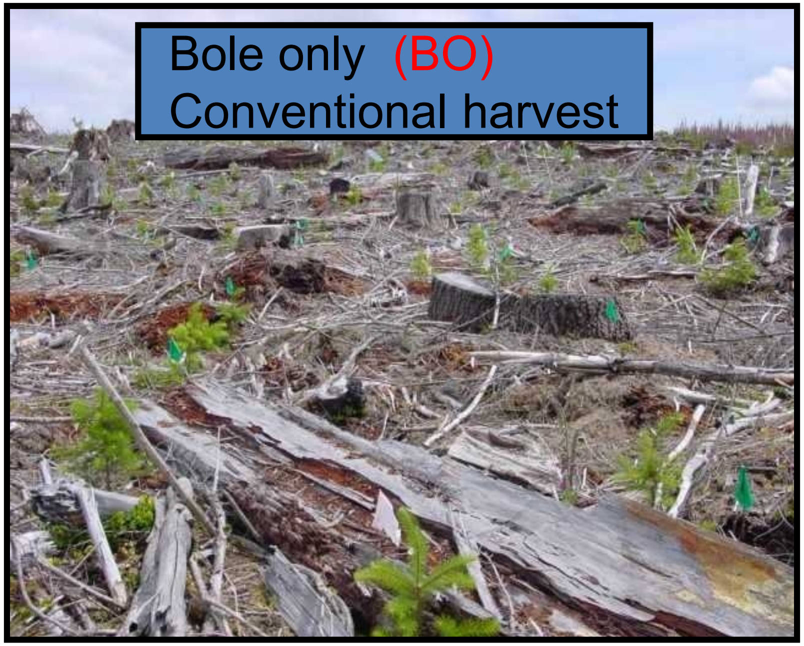
<u>Molalla, OR</u>: Natural stand, age 56, Douglas-fir; Site Index 36-m (118 ft.)*

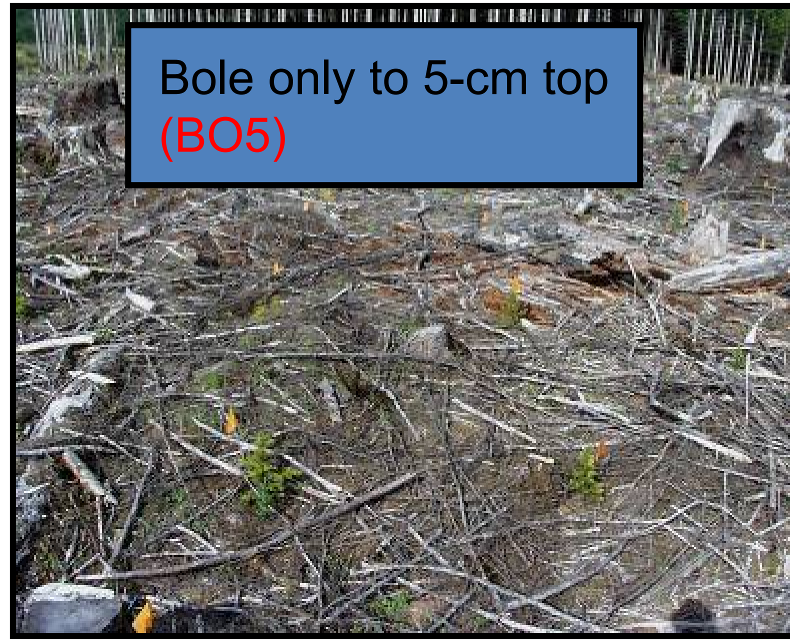
<u>Matlock, WA</u>: Natural stand, age 45, Douglas-fir; Site Index 36-m (118 ft.)*

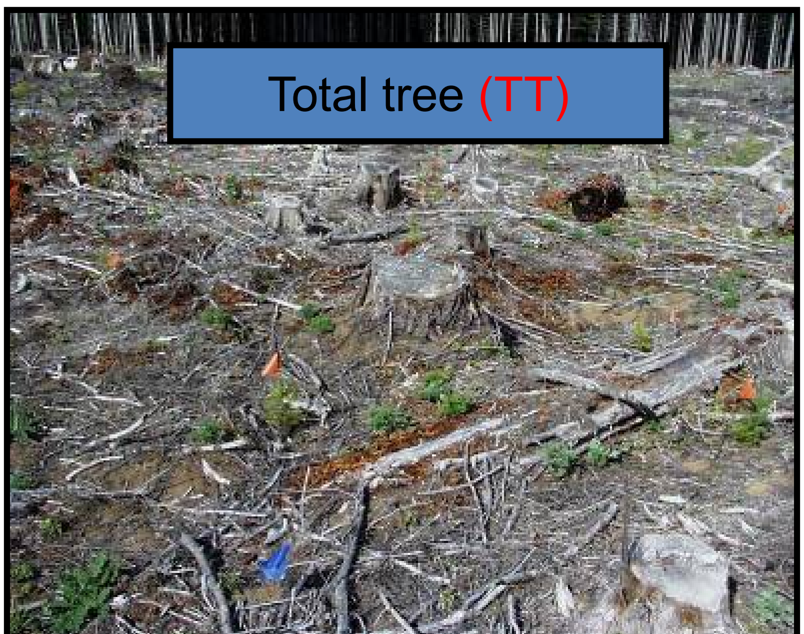
(*Site Index after King 1966)

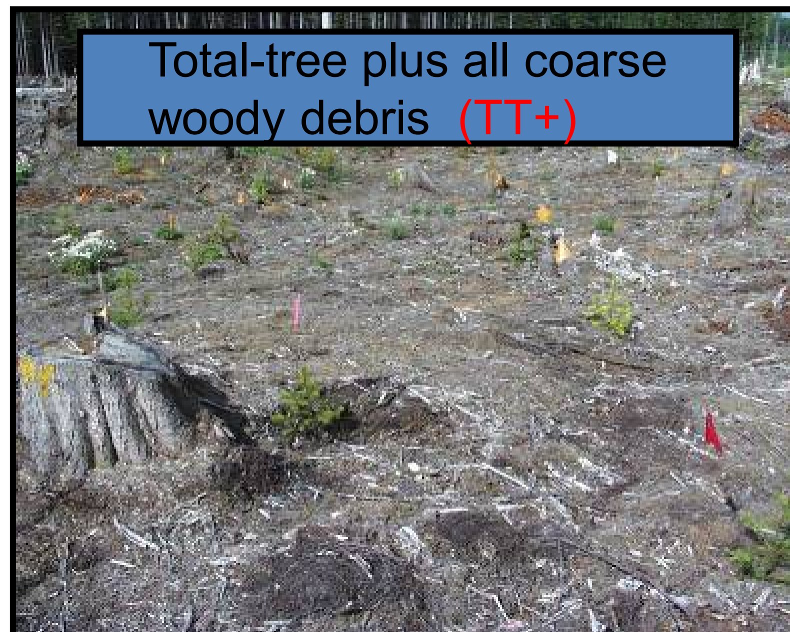

CO_2
biofuels
nutrients

Biomass Removal Treatments: Fall River









Summary of biomass and carbon and nitrogen stores in the preharvest forest stand at Fall River

	Biomass		Carbon		Nitrogen	
	Mg/ha	*%*	*Mg/ha*	*%*	*kg/ha*	*%*
Live trees	392.8	34.2	192.9	33.2	604.5	4.1
Dead trees	4.5	.4	2.1	.4	8.4	0
Snags	9.7	.8	4.8	.8	30.4	.2
Understory vegetation	.2	0	.1	0	4.9	0
Coarse woody debris[a]	22.3	2.0	11.4	1.9	74.3	.5
Old-growth stumps or snags	29.5	2.6	17.3	3.0	25.6	.2
Old-growth logs	73.2	6.4	36.9	6.3	122.3	.8
Forest floor	70.6	6.1	27.1	4.6	452.8	3.1
Coarse roots (> 5 mm)	82.2[b]	7.2	39.6[c]	6.8	180.8[d]	1.2
Small roots (2-5 mm) 0-45 cm	1.5	.1	.5[e]	.1	9.7[f]	.1
Fine roots (< 2mm) 0-45 cm	2.3[g]	.2	.8[e]	.1	14.9[f]	.1
Mineral soil 0-80 cm	458.7[h]	40.0	248.5	42.8	13 143.0	89.8
Total	1147.5		582		14 671.6	

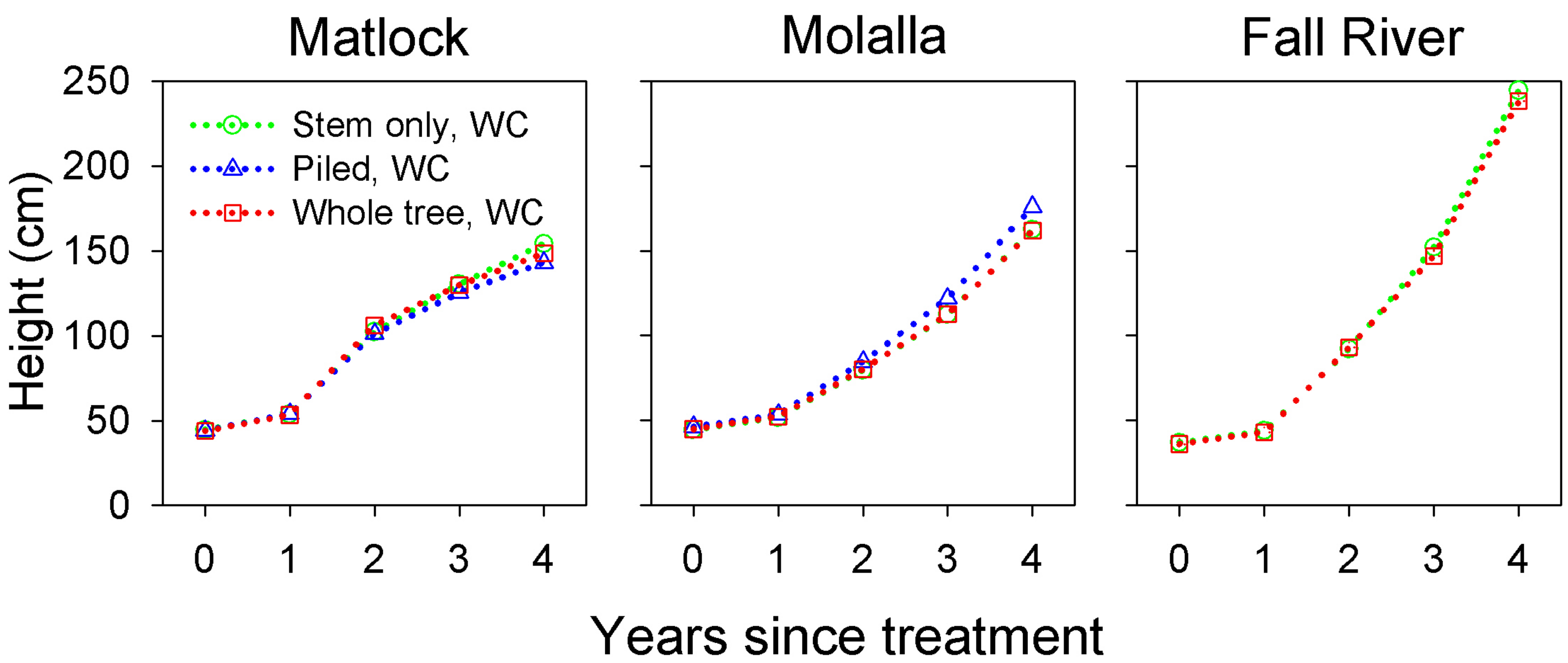
summary table from Ares *et al.* 2007

Biomass and carbon and nitrogen stores in the pre-harvest Douglas-fir/western hemlock stand at Fall River

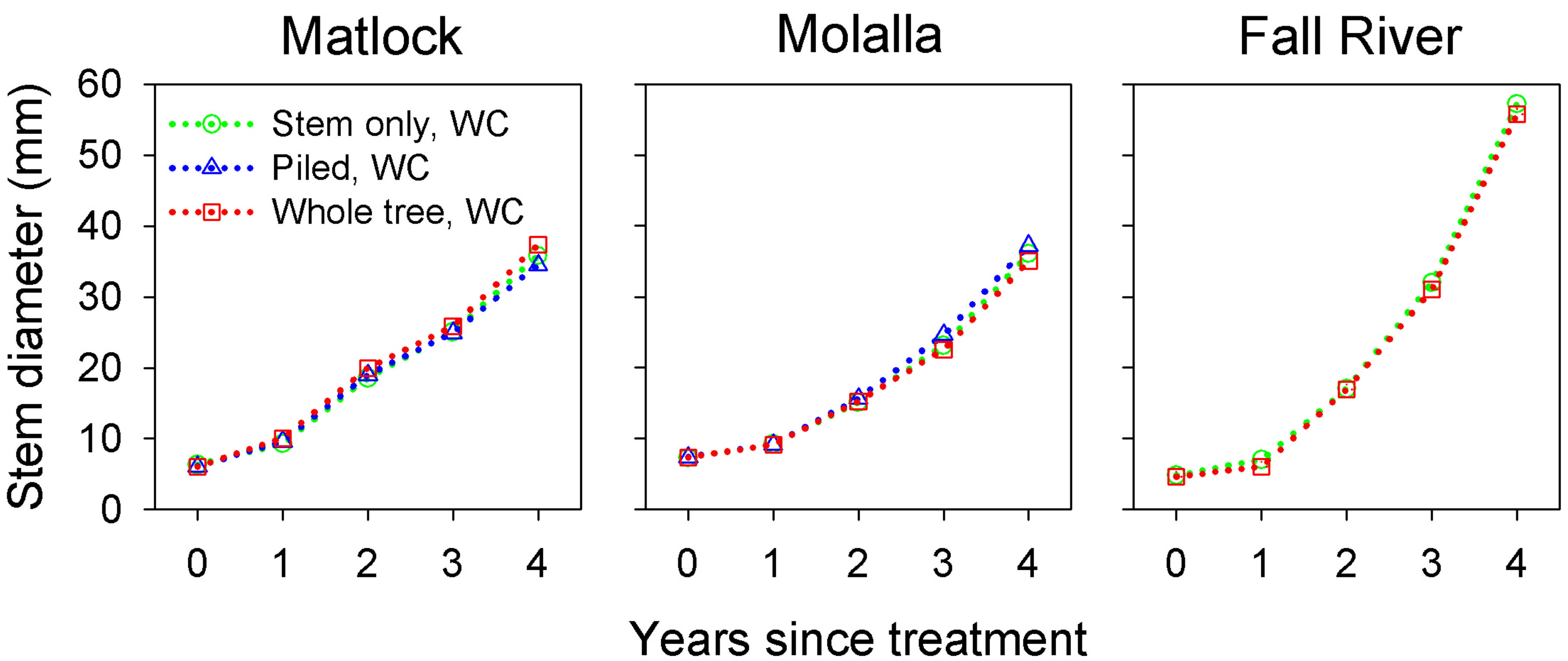
	Biomass		Carbon		Nitrogen	
Tree component	*Mg/ha*	*%*	*Mg/ha*	*%*	*kg/ha*	*%*
Stand total:						
Foliage	9.5	2.4	4.9	2.5	161.7	26.8
Live branches	29.3	7.5	14.4	7.5	62.9	10.4
Dead branches	12.9	3.3	6.3	3.3	20.9	3.4
Bole wood	308.4	78.5	149.9	77.7	233.7	38.7
Bole bark	32.7	8.3	17.4	9.0	125.3	20.7
Total aboveground	392.8		192.9		604.5	

summary table from Ares *et al.* 2007

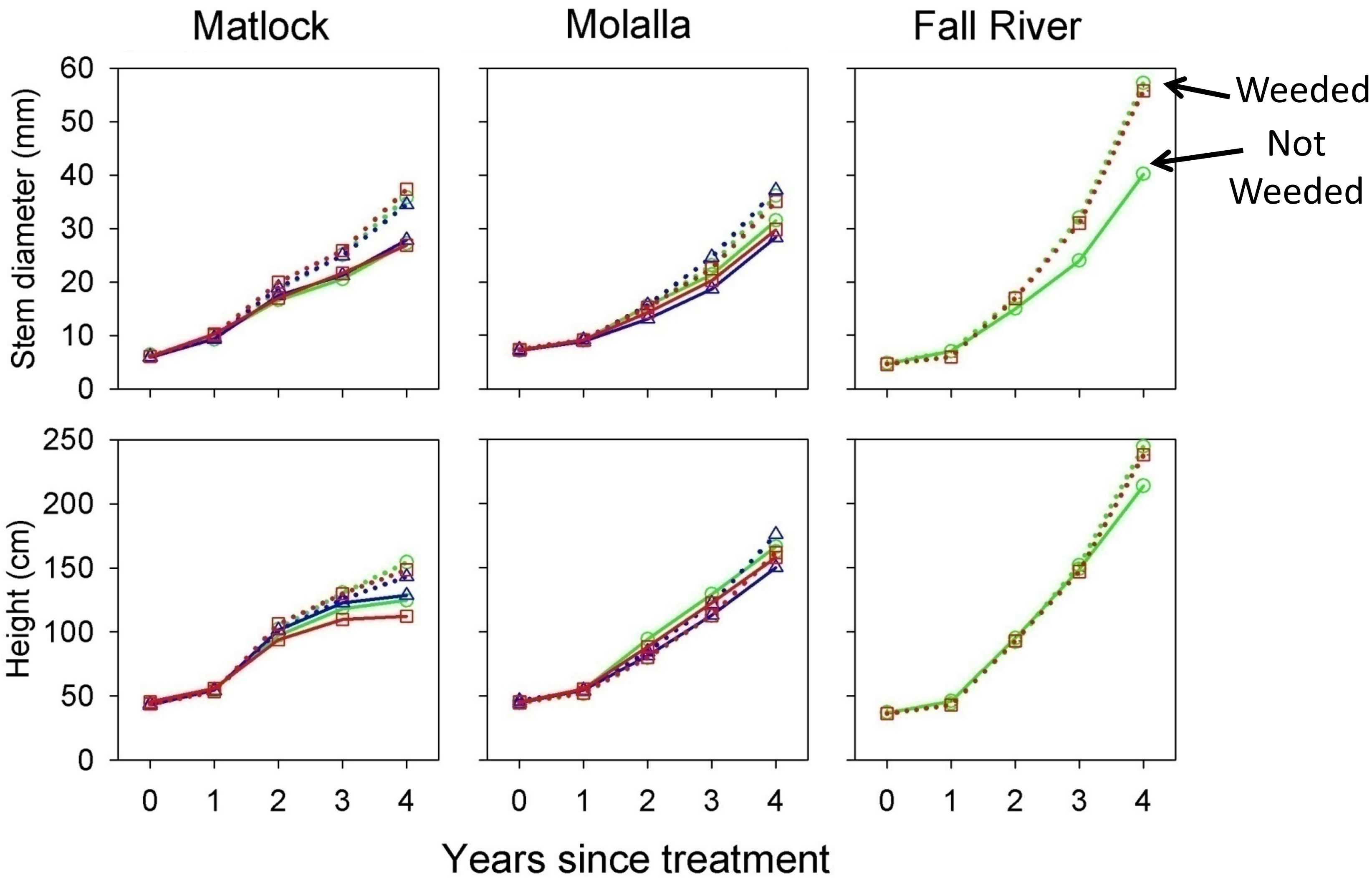
Mean Seedling Heights: Matlock and Molalla by Year and OM removal Treatment Weeded treatments only

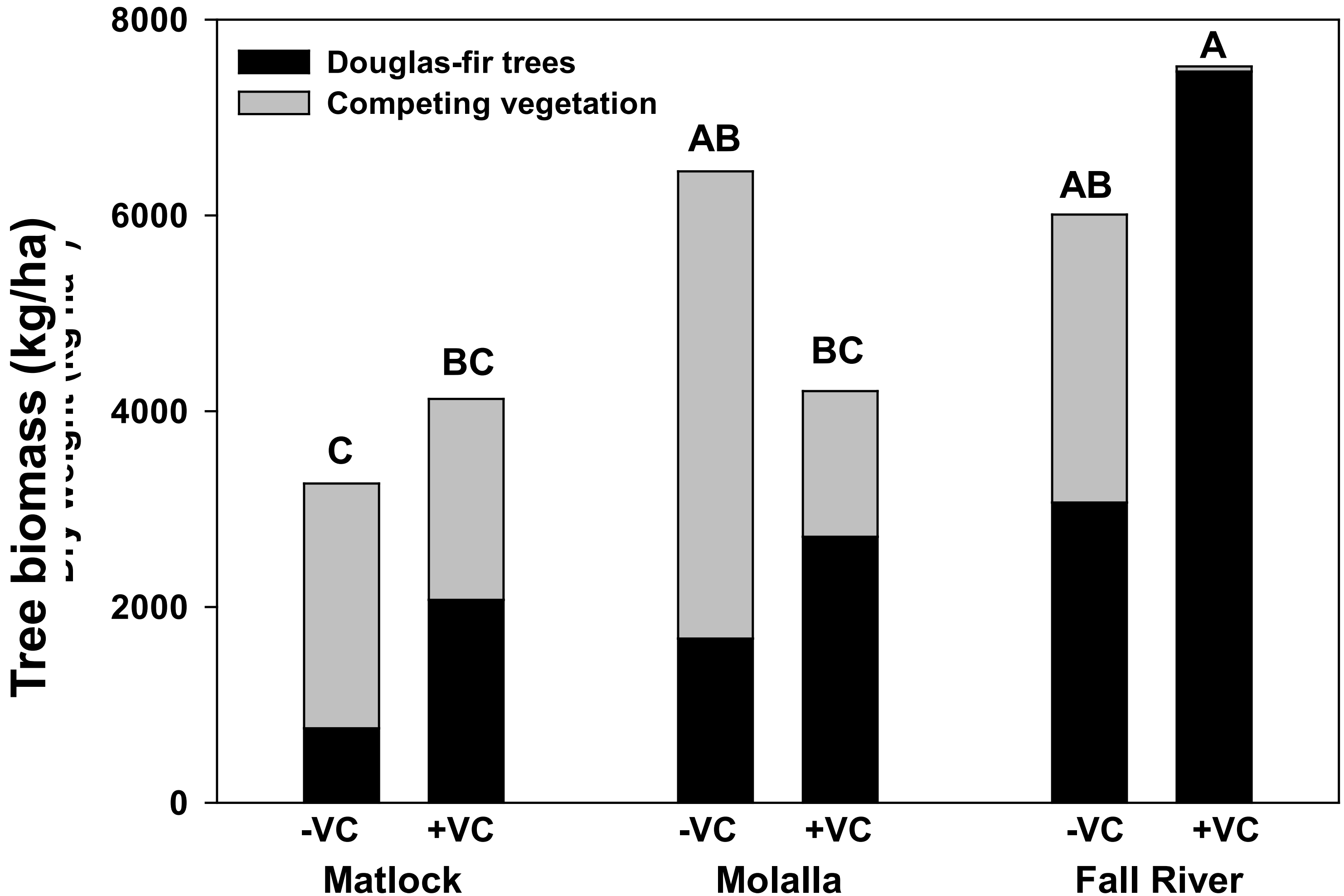


Mean Seedling Caliper (15 cm): Matlock and Molalla by Year and OM Removal Treatment
Weeded treatments only



Seedling Mean Diameter and Heights w and w/o Vegetation Control by Location and Organic Removal Treatment





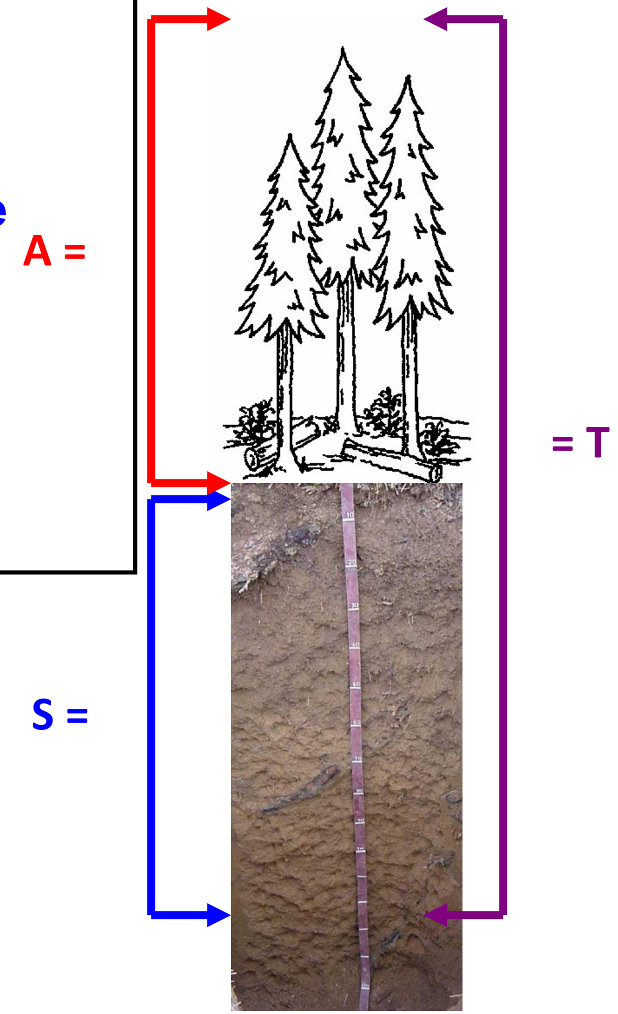
Aboveground dry weight of Douglas-fir trees and competing vegetation, at plantation age five years, without (-VC) and with (+VC) annual vegetation control at three sites. Site/treatment combinations accompanied by the same letter do not differ in total dry weight (trees plus competing vegetation) at $\alpha=0.05$ according to Tukey's test (Sokal and Rohlf 1995).

Nitrogen Risk Ratings - Generalized Concept

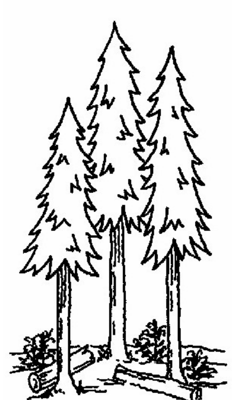
Proportion of site N pool removed:

Increasing N limitation risk **(after Evans, 1999)**

Low	Serious	Imminent decline
0.1	0.3	0.5



Example Analysis: Fall River LTSP Nutrient Risk Ratings for N loss from Harvest



Ecosystem Part	Biomass	Carbon	Nitrogen	N Risk Rating	Harvest Scenario
	– Mg/ha –	*– Mg/ha –*	*– kg/ha –*		
Bole	341	167	359	0.02	bole-only harvest
Branches	42	21	84		
Foliage	9.5	4.9	162		
Tree AG	393	193	604	0.04	total-tree harvest
CWD	22	11	75		
Stumps/Snags	29	17	26	0.05	add stumps/snags
Understory	0.2	0.09	5		
Forest Floor	71	27	453	0.08	add forest floor
Roots	86	41	215	0.09	add roots
Soil (0-80cm)	459	239	13143		
Ecosystem Total	**1147**	**582**	**14672**		

	Removal vs. N Risk Rating
0.10	low chance of decline
0.30	serious chance of decline
0.50	imminent decline

Source for risk rating: Evans, J. 1999 Sustainability of plantation forestry: impact of species change and successive rotations of pine in the Usutu Forest, Swaziland. *Southern Africa Forestry Journal 184: 63–70.*

Nitrogen Risk Ratings - Generalized Concept

Proportion of site N pool removed:

Increasing risk (after Evans, 1999)

Low	Serious	Imminent decline
0.1	0.3	0.5

Fall River : Total-tree plus forest floor = 0.09

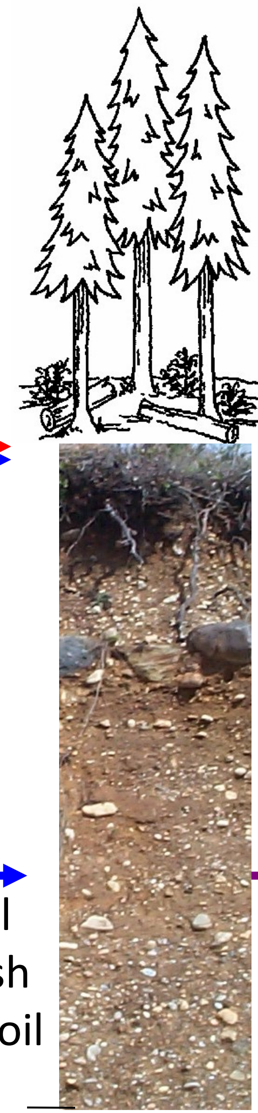
Matlock: Total-tree plus forest floor removal = 0.16

Bole-only removal = 0.05 (5%) [Johnson et al. 1982]

Total-tree removal = 0.10 (10%)

A =

S =



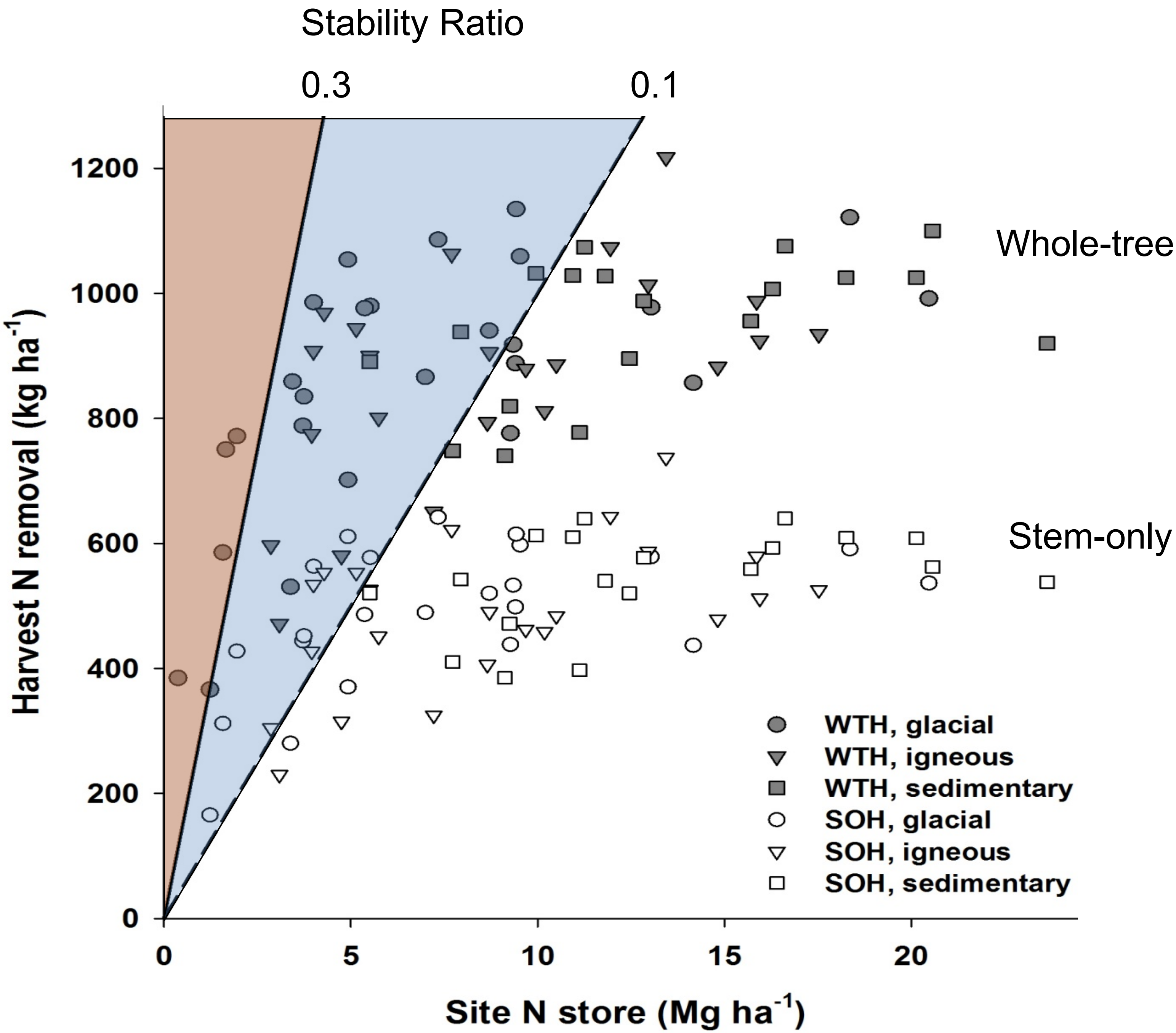
= T

Glacial outwash Grove soil

Risk to Long-term Site Productivity Due to Whole-tree Harvesting in The Coastal Pacific Northwest

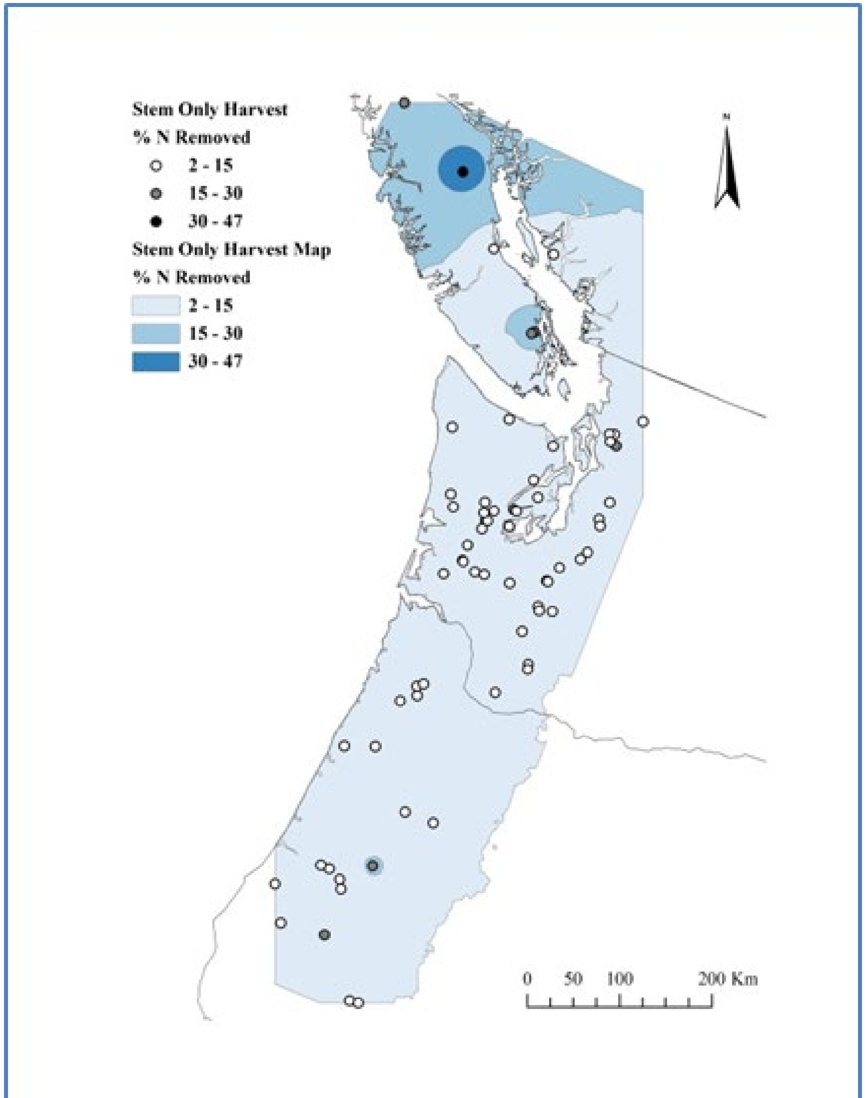
Austin Himes thesis work,

pub in Forest Science



Stability Ratio
0.3
0.1
Whole-tree
Stem-only
Harvest N removal (kg ha-1)
Site N store (Mg ha-1)
0
200
400
600
800
1000
1200
0
5
10
15
20
WTH, glacial
WTH, igneous
WTH, sedimentary
SOH, glacial
SOH, igneous
SOH, sedimentary

Results



Stem Only Harvest
% N Removed
2 - 15
15 - 30
30 - 47
Stem Only Harvest Map
% N Removed
2 - 15
15 - 30
30 - 47
N
0 50 100 200 Km

FUNDAMENTAL RESEARCH

For. Sci. 60(x):000–000
http://dx.doi.org/10.5849/forsci.13-009

soils & hydrology

Predicting Risk of Long-Term Nitrogen Depletion Under Whole-Tree Harvesting in the Coastal Pacific Northwest

Austin J. Himes, Eric C. Turnblom, Robert B. Harrison, Kimberly M. Littke, Warren D. Devine, Darlene Zabowski, and David G. Briggs

In many forest plantation ecosystems, concerns exist regarding nutrient removal rates associated with sustained whole-tree harvesting. In the coastal North American Pacific Northwest, we predicted the depletion risk of nitrogen (N), the region's most growth-limiting nutrient, for 68 intensively managed Douglas-fir (*Pseudotsuga menziesii* var. *menziesii* [Mirb.] Franco) plantations varying widely in productivity. We projected stands to rotation age using the individual-tree growth model ORGANON and then calculated a stability ratio for each stand, defined as the ratio of N removed during harvest to total site N store (soil and forest floor). We assigned a risk rating to each site based on its stability ratio under whole-tree and stem-only harvest scenarios. Under whole-tree harvest, 49% of sites were classified as potentially at risk of long-term N depletion (i.e., ≥10% N store removed in harvest), whereas under stem-only harvest, only 24% of sites were at risk. Six percent and 1% of sites were classified as under high risk of N depletion (i.e., ≥30% N store removed in harvest) under whole-tree and stem-only harvest, respectively. The simulation suggested that sites with <9.0 and <4.0 Mg ha^{-1} site N store are potentially at risk for long-term N depletion and productivity loss under repeated whole-tree and stem-only harvest, respectively. Sites with <2.2 and <0.9 Mg ha^{-1} site N store are at high risk of N depletion under whole-tree and stem-only harvest, respectively. The areas with the highest concentrations of at-risk sites were those with young, glacially derived soils on Vancouver Island, Canada, and in the Puget Sound region of Washington.

Keywords: Douglas-fir, plantation, sustainability, stability ratio, nutrient

Conclusions: Recommendations for Harvest Residuals Management

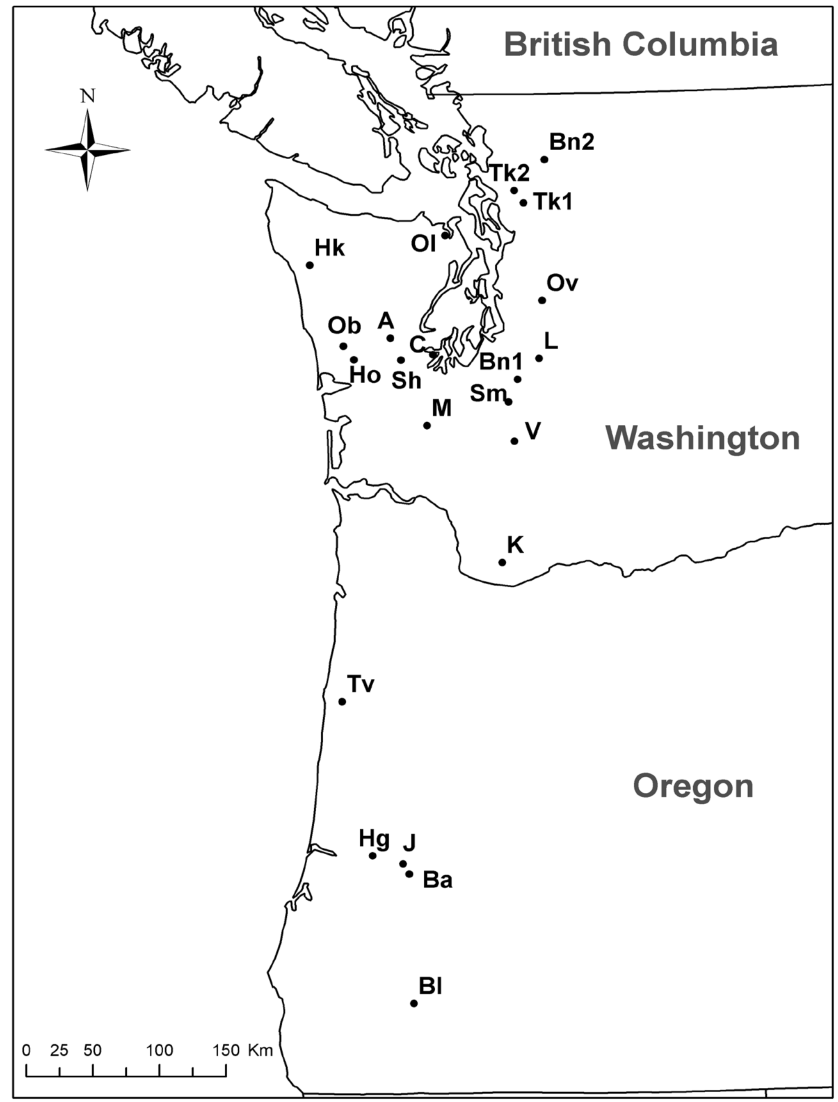
	Low-Risk Site	High-Risk Site
Forest floor	Retain	Retain
Legacy wood	Retain	Retain
Wood	Meet FP regulations for large woody debris	Meet FP regulations for large woody debris
Fine slash and needles	Conserve, e.g., pile thick slash after needle fall; "total-tree" harvesting is less of a concern	Retain in place / Bole-only harvest; cut-to-length thinning with slash in place
Debris concentrations at landings	Utilize wood but retain fine slash covering after needle fall and retain and scatter legacy wood	Utilize wood but retain fine slash covering after needle fall and retain and scatter legacy wood

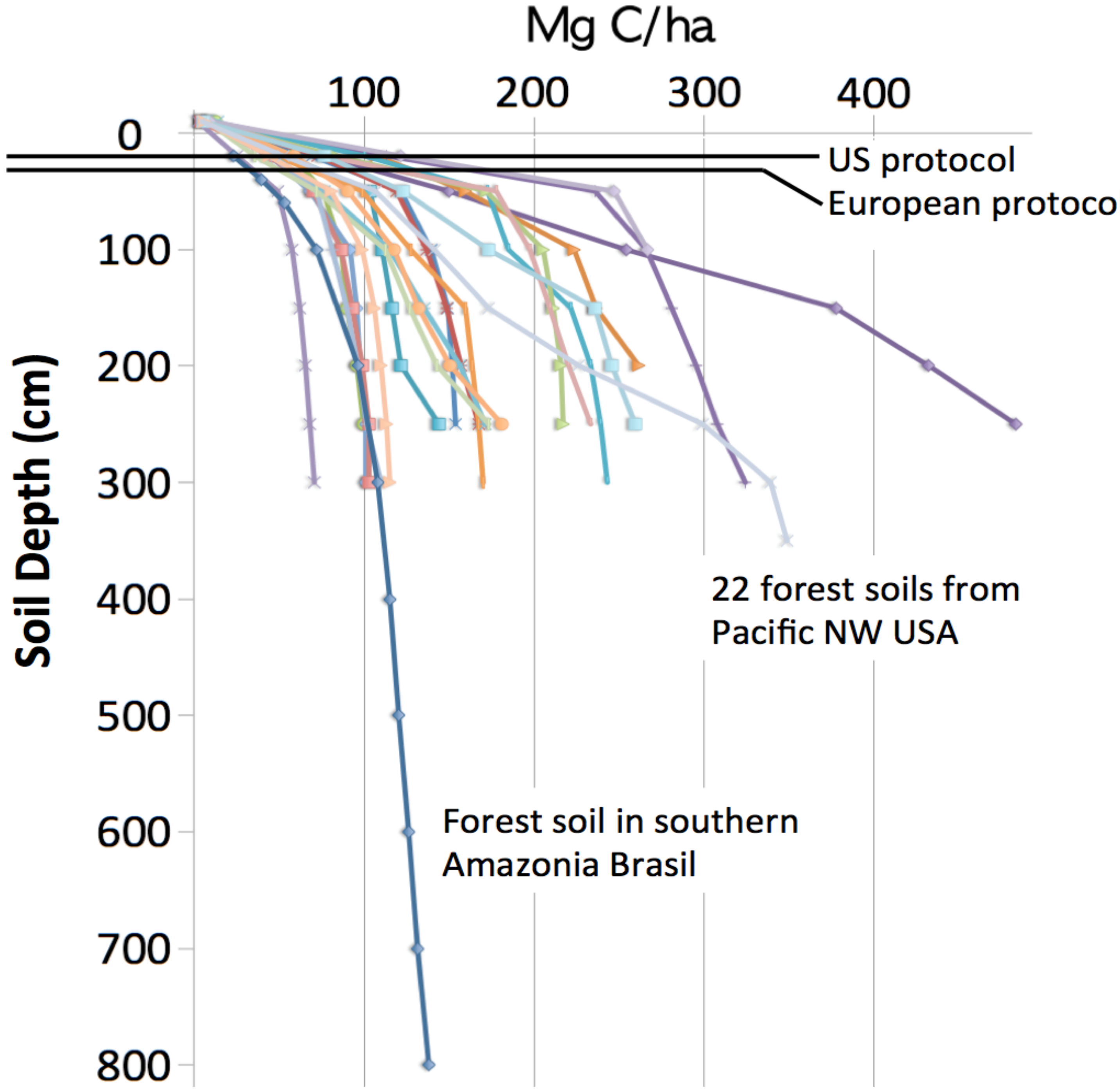
Assumes only hazard / consequence is nutrient pool reduction

Deep Soil Carbon & Nitrogen

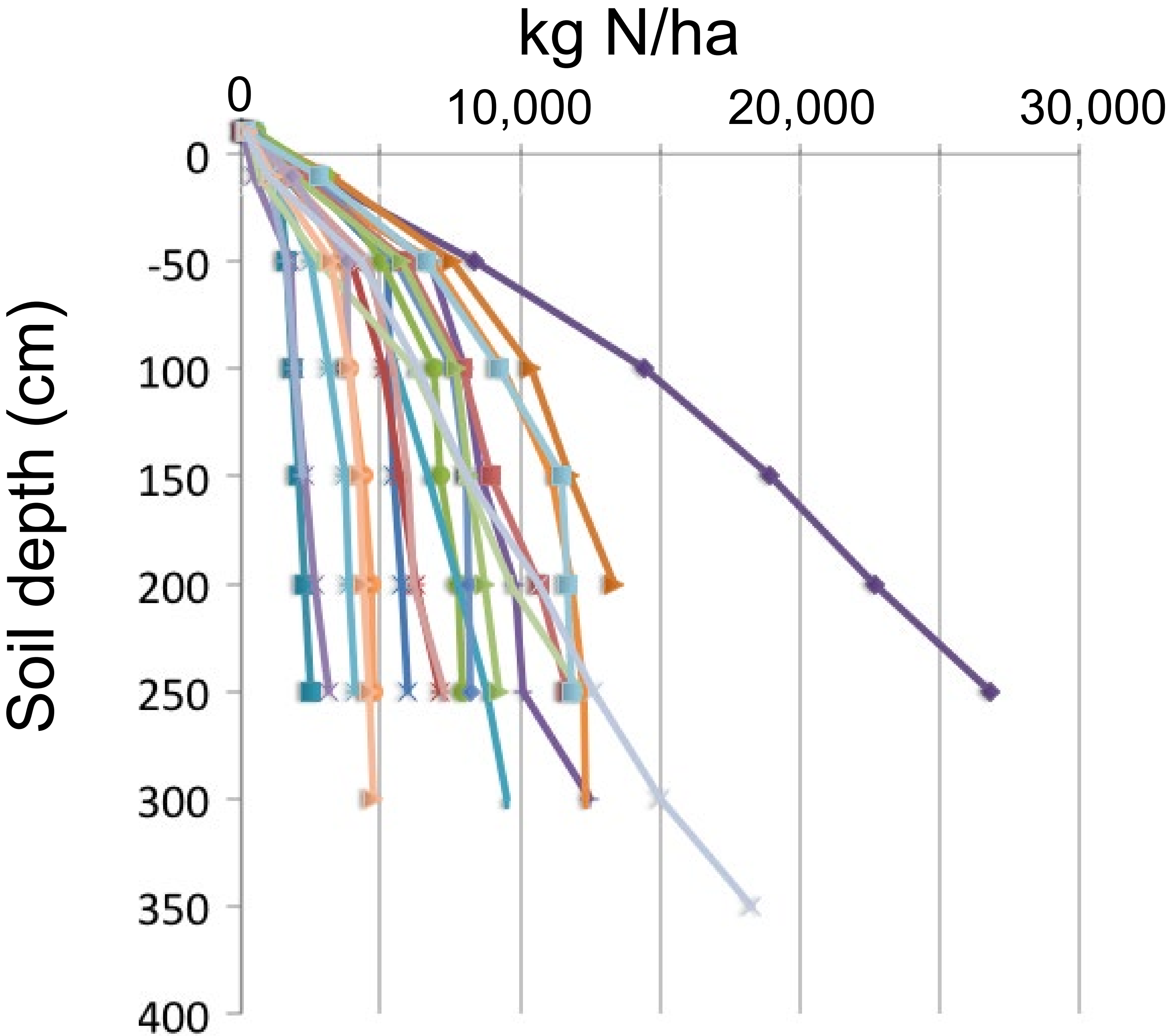
Methods

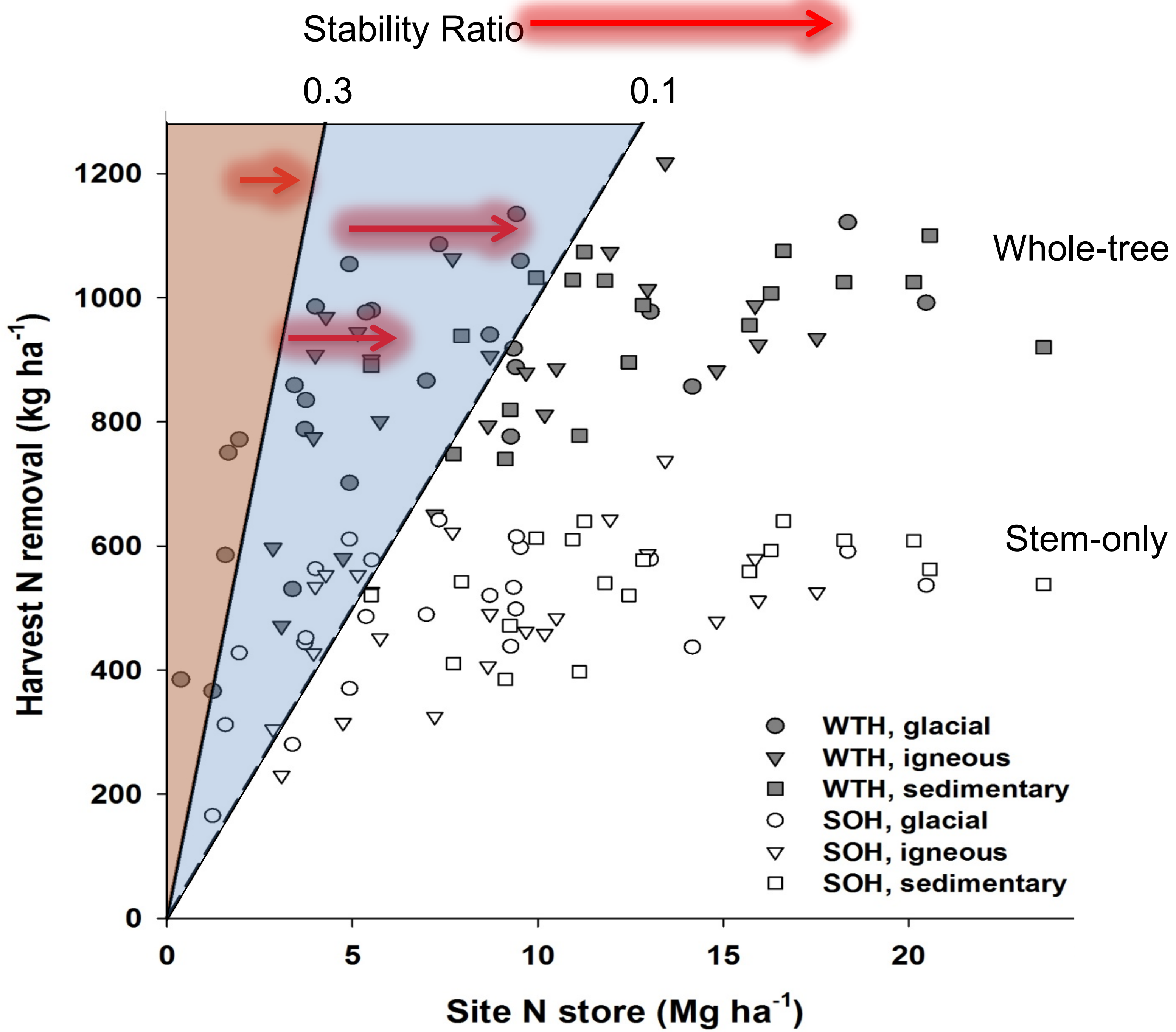
- 22 study sites in intensively managed plantations across the Pacific Northwest Douglas-fir zone
- Excavator used to dig at least 2.5 m deep soil pits
- Bulk density samples taken at intervals of:
  - 0.0-0.2 m
  - 0.2-0.5 m
  - 0.5-1.0 m
  - 1.0-1.5 m
  - 1.5-2.0 m
  - 2.0-2.5 m
- Forest floor gathered from randomly placed 0.3 x 0.3 m quadrat
- Samples analyzed for C & N





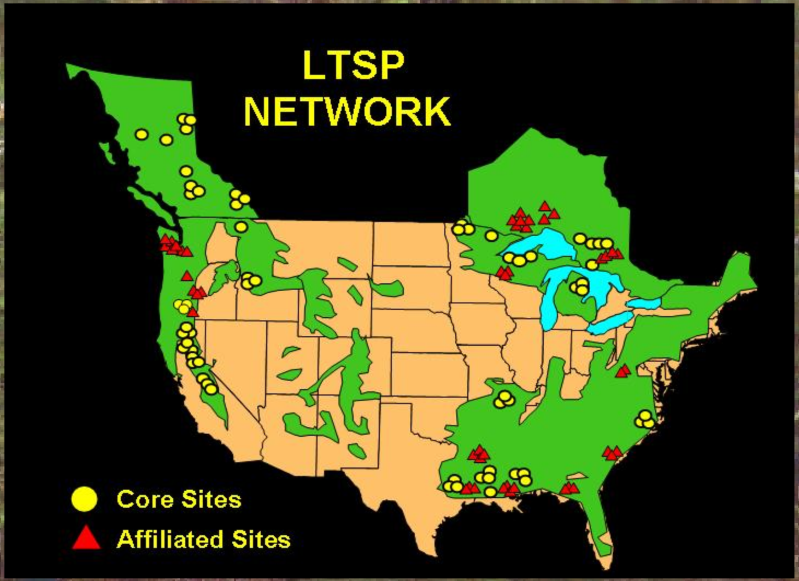
Mg C/ha
100
200
300
400
0
100
200
300
400
500
600
700
800
Soil Depth (cm)
US protocol
European protocol
22 forest soils from
Pacific NW USA
Forest soil in southern
Amazonia Brasil


kg N/ha
0
10,000
20,000
30,000
Soil depth (cm)
0
-50
100
150
200
250
300
350
400



Stability Ratio
0.3
0.1
Whole-tree
Stem-only
Harvest N removal (kg ha-1)
1200
1000
800
600
400
200
0
0
5
10
15
20
Site N store (Mg ha-1)
WTH, glacial
WTH, igneous
WTH, sedimentary
SOH, glacial
SOH, igneous
SOH, sedimentary

Thanks to PNW Stand Management Cooperative (26 members), National Council for Air and Stream Improvement, USFS/DOE Agenda 2020, NSF Center for Advanced Forest Systems, Univ. Washington Kreuter/Gessel Scholarships. These are affiliate sites of the USFS long-term soil prod. network.



Stand Management Cooperative
SILVICULTURE ▪ NUTRITION
WOOD QUALITY ▪ MODELING

NARA

Weyerhaeuser

Long-Term Soil Productivity Study
LTSP
Est. 1989

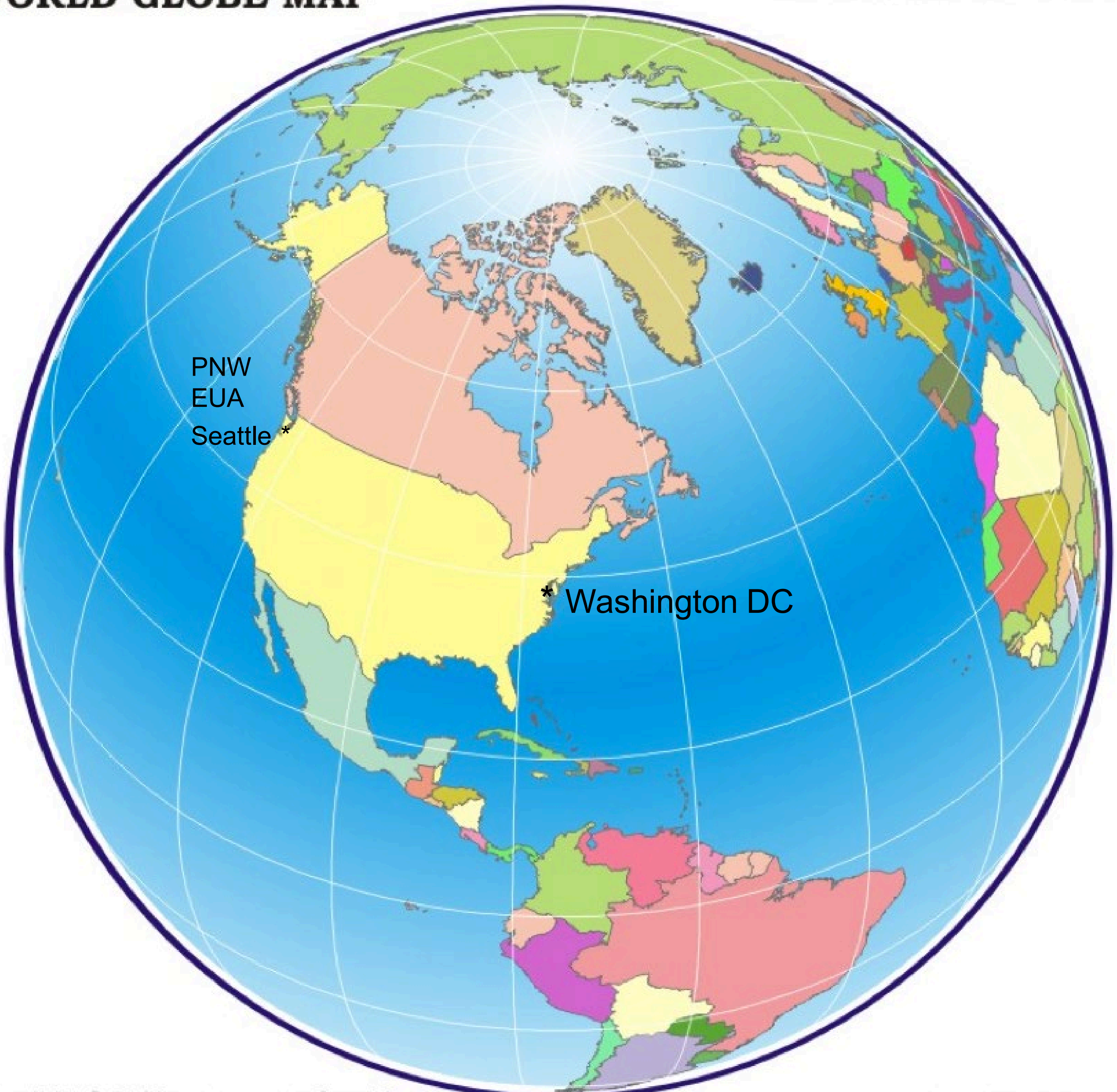
ncasi
National Council for Air and Stream Improvement, Inc.

CAFS Center for Advanced Forestry Systems

NSF

AMERICA CENTRIC
WORLD GLOBE MAP

Central Meridian : 75°W
Central Parallel : 42°N



Scale- 1:70,000,000


BR 374
Rod. Pres. Castelo Branco
SP-280
BR 374
Rod. Pres. Castelo Branco
SP-280
BR 374
SP-280
BR 374
Rod. Pres. Castelo Branco
BR 374
SP-280
SP-209


Atlantic forest
Eucaluptus
urograndis
Atlantic forest
Eucaluptus
urograndis
Atlantic forest
Eucaluptus
urograndis