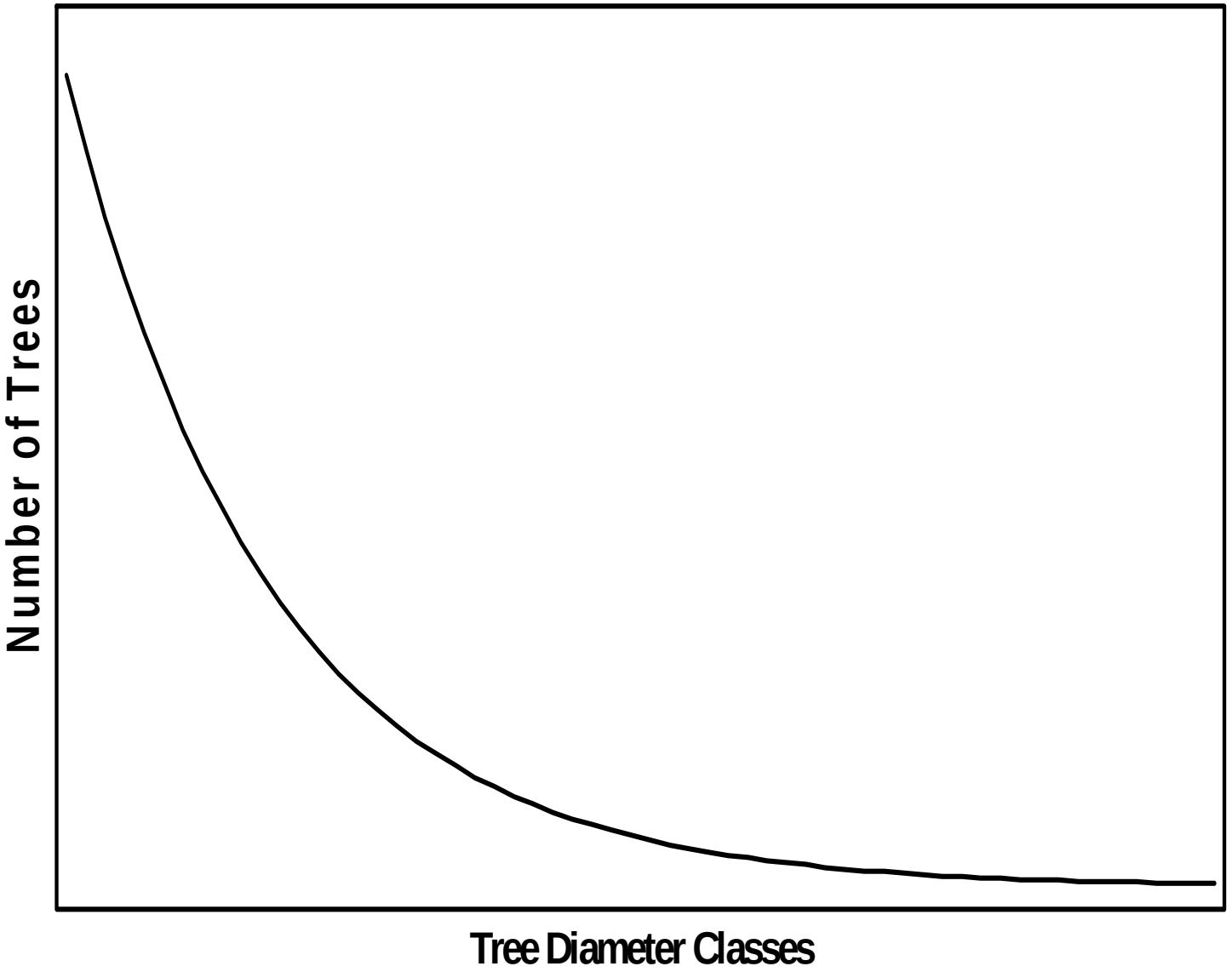
Multiaged Silviculture in Sierran Conifer Forests

Kevin L. O'Hara
Professor of Silviculture
University of California - Berkeley

Traditional Multiaged Silviculture and the “Balanced Stand”


Number of Trees
Tree Diameter Classes

One definition of a balanced stand is based on age/size classes occupying equal amounts of growing space.

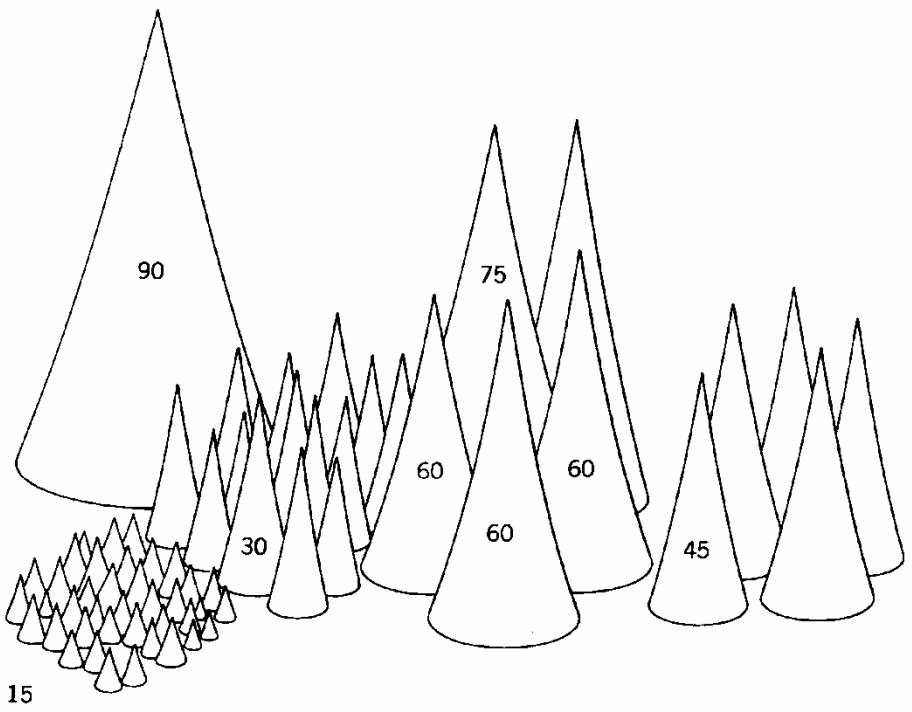


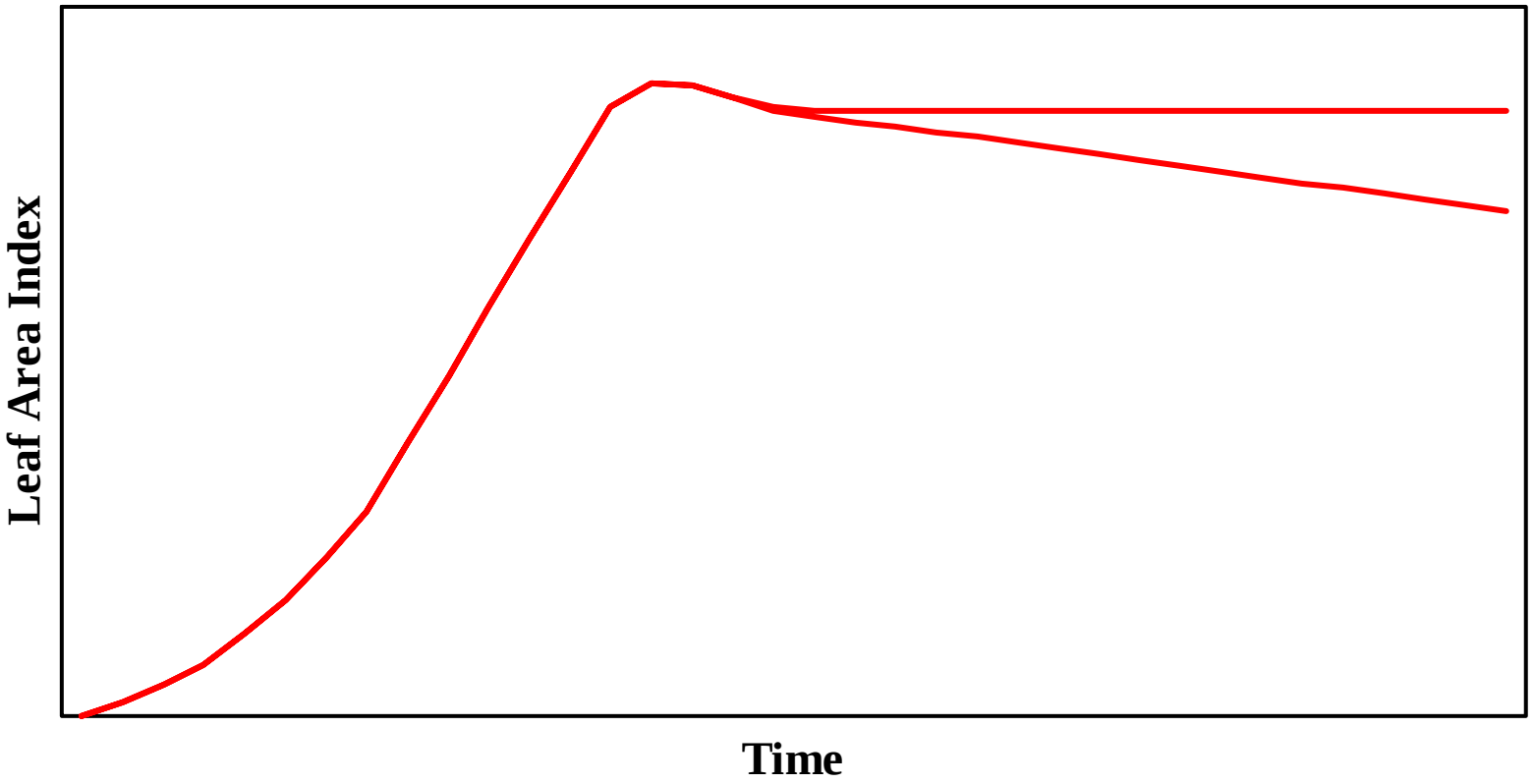
Figure 15.1 Schematic oblique view of a 1/10 hectare segment of a balanced uneven-aged stand being managed by the single-tree selection system on a 90-year rotation with a 15-year cutting cycle. Each tree is represented by a cone extending to the ground; the numbers indicate the ages. Each age group occupies about 1/60 hectare. The 90-year-old tree is now ready to be replaced by numerous seedlings while the numbers of trees in the middle-aged groups are appropriately reduced by thinning.

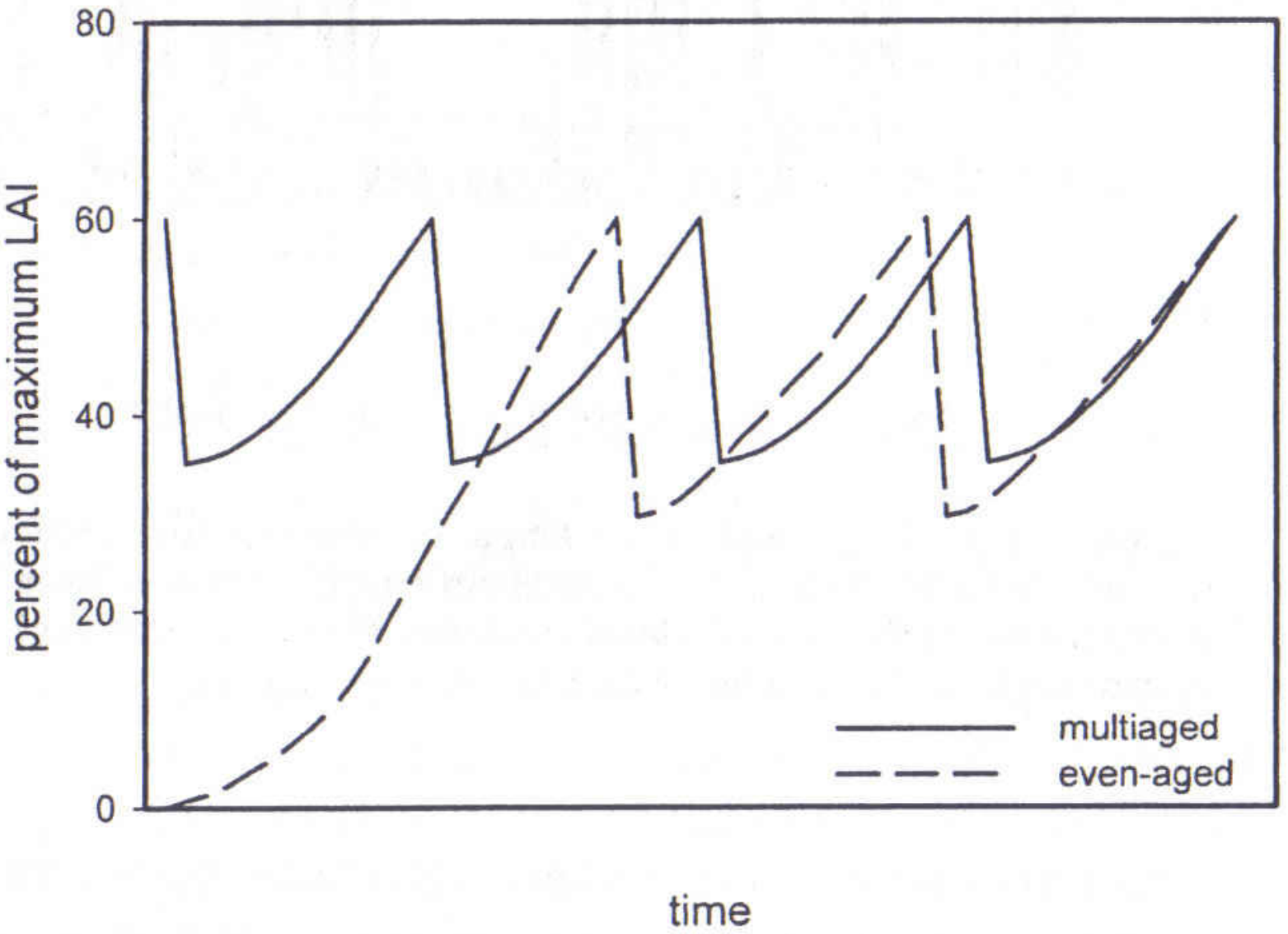
From Smith et al. 1997

Designing Multiaged Stands

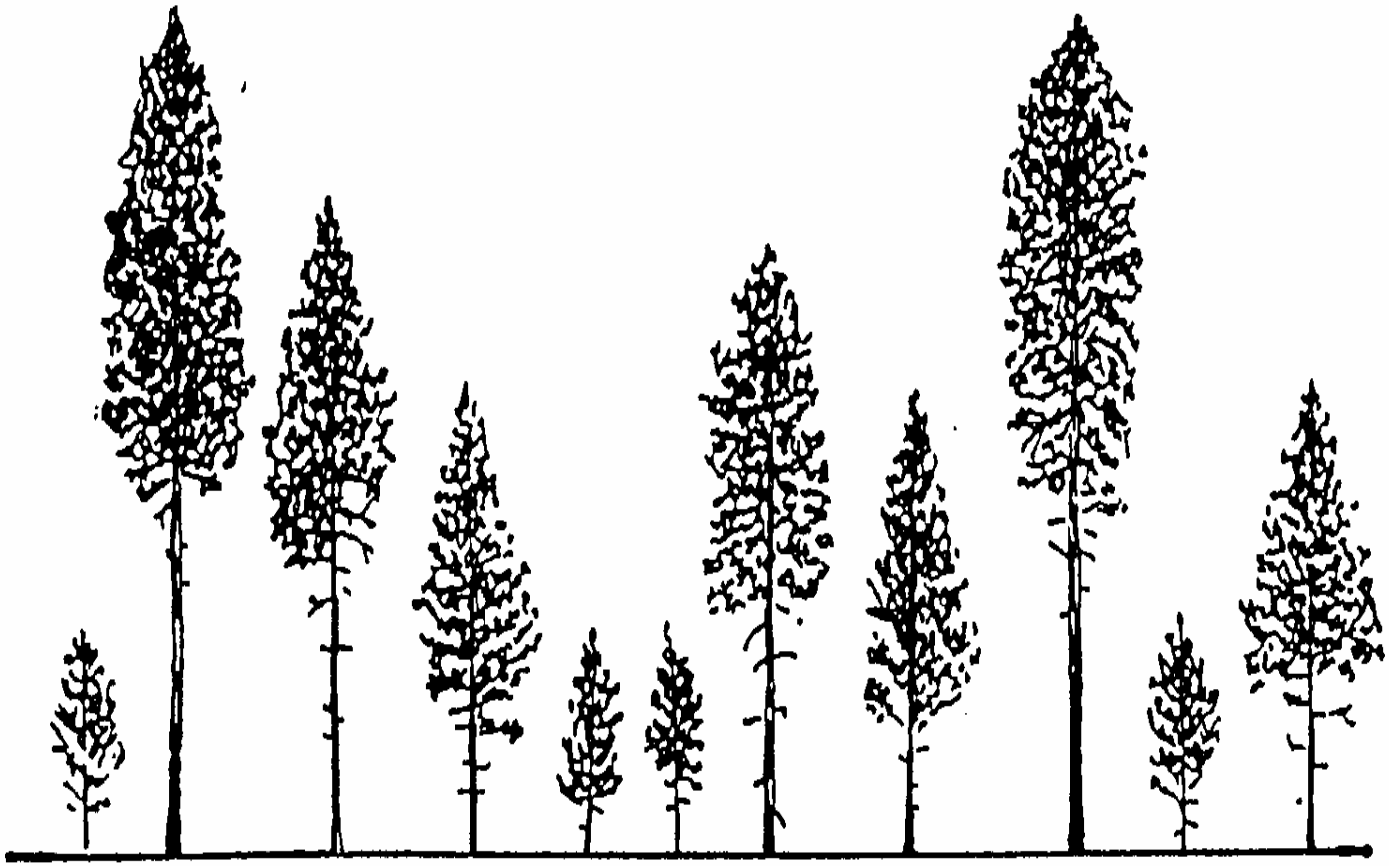
- Whereas even-aged stocking control is just trees (stocking) per area
- Multiaged stocking control requires we distribute these trees by age or size or species.
- This adds a layer of complexity.
- What can we learn from existing stands?

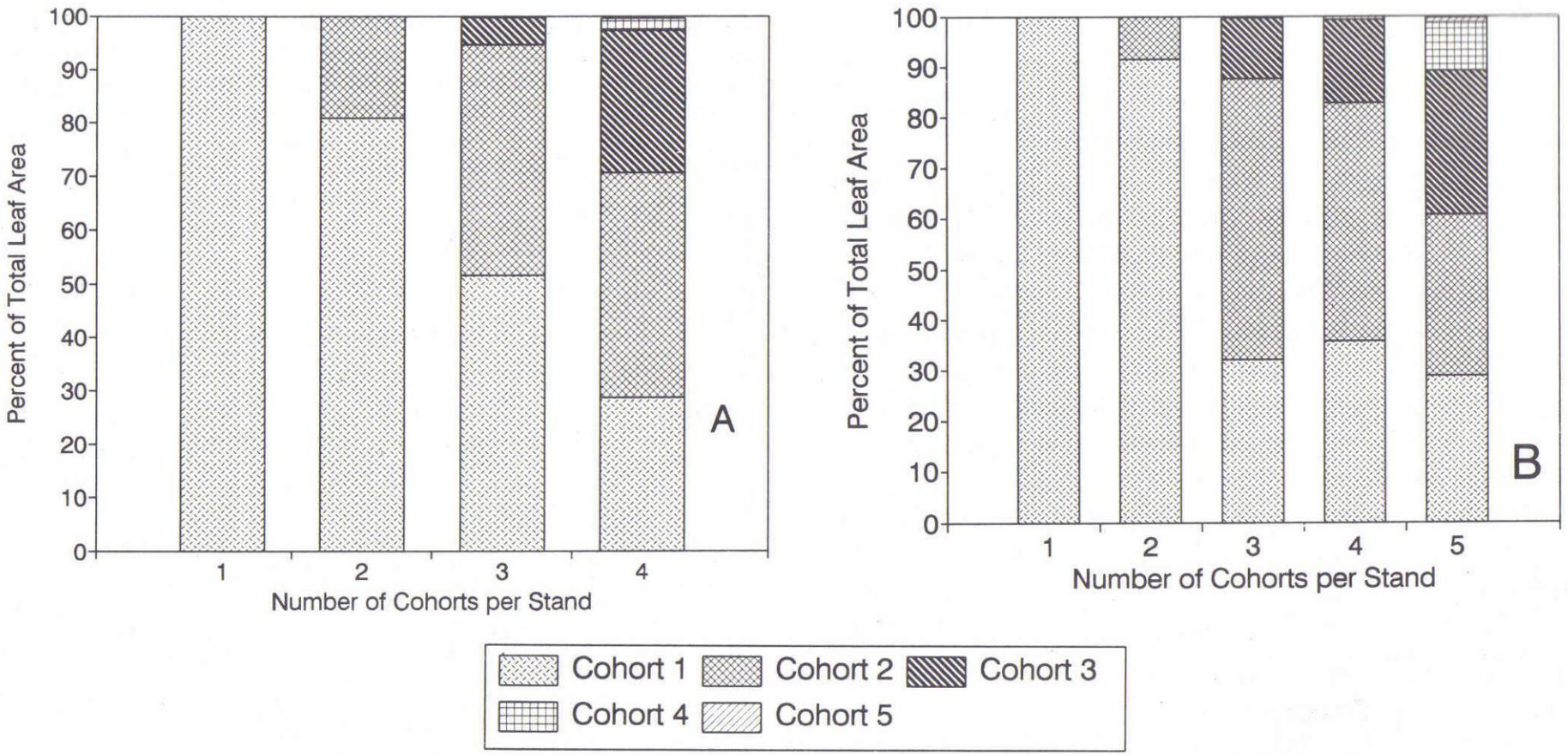
Leaf area index over time for even-aged stands

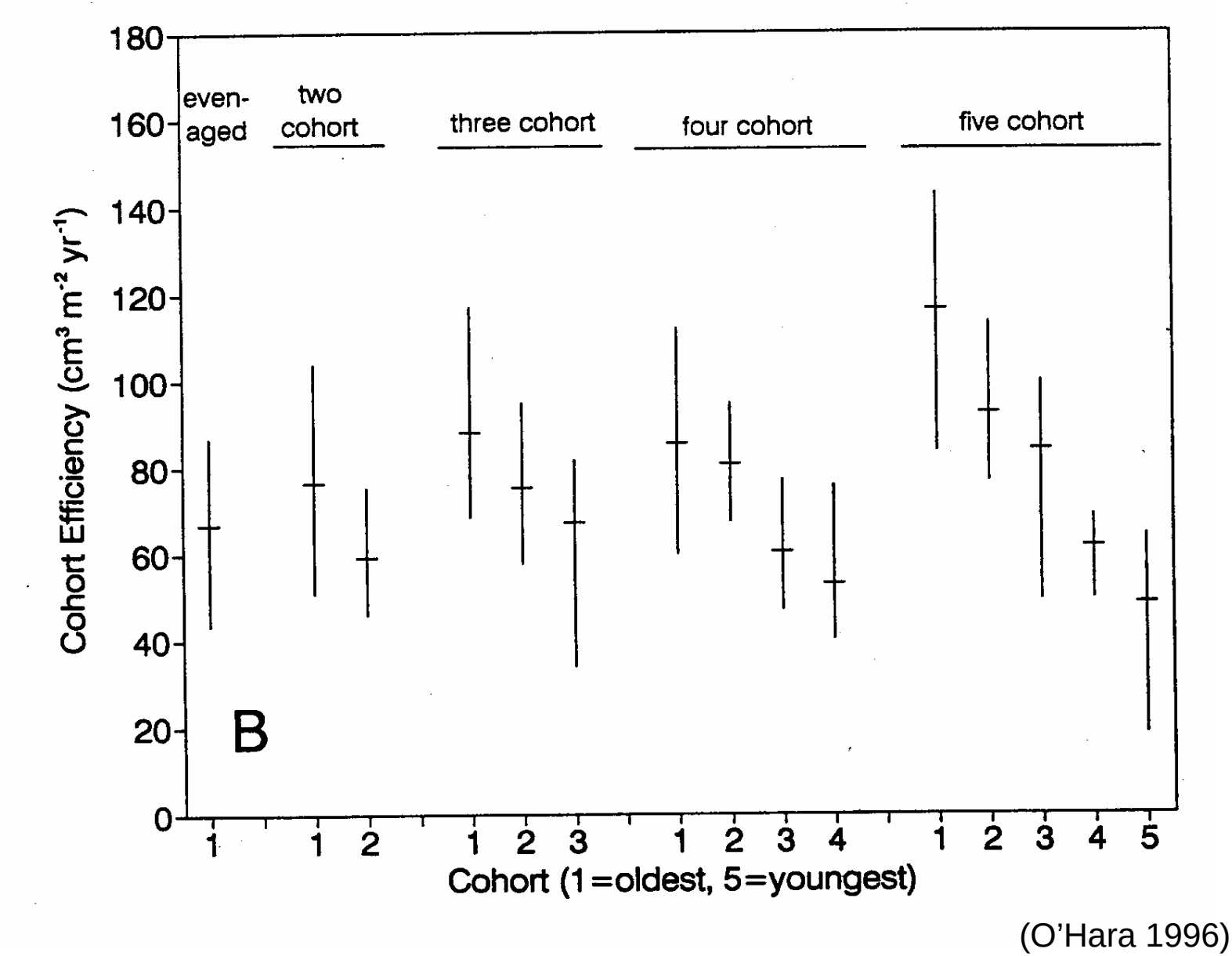



80
60
40
20
0
percent of maximum LAI
time
multiaged
even-aged

Cohorts in a Multiaged Stand




Percent of Total Leaf Area
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
Number of Cohorts per Stand
A
Percent of Total Leaf Area
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Number of Cohorts per Stand
B
Cohort 1
Cohort 2
Cohort 3
Cohort 4
Cohort 5


even-aged
two cohort
three cohort
four cohort
five cohort
Cohort Efficiency (cm³ m⁻² yr⁻¹)
180
160
140
120
100
80
60
40
20
0
B
1
1 2
1 2 3
1 2 3 4
1 2 3 4 5
Cohort (1=oldest, 5=youngest)

(O'Hara 1996)

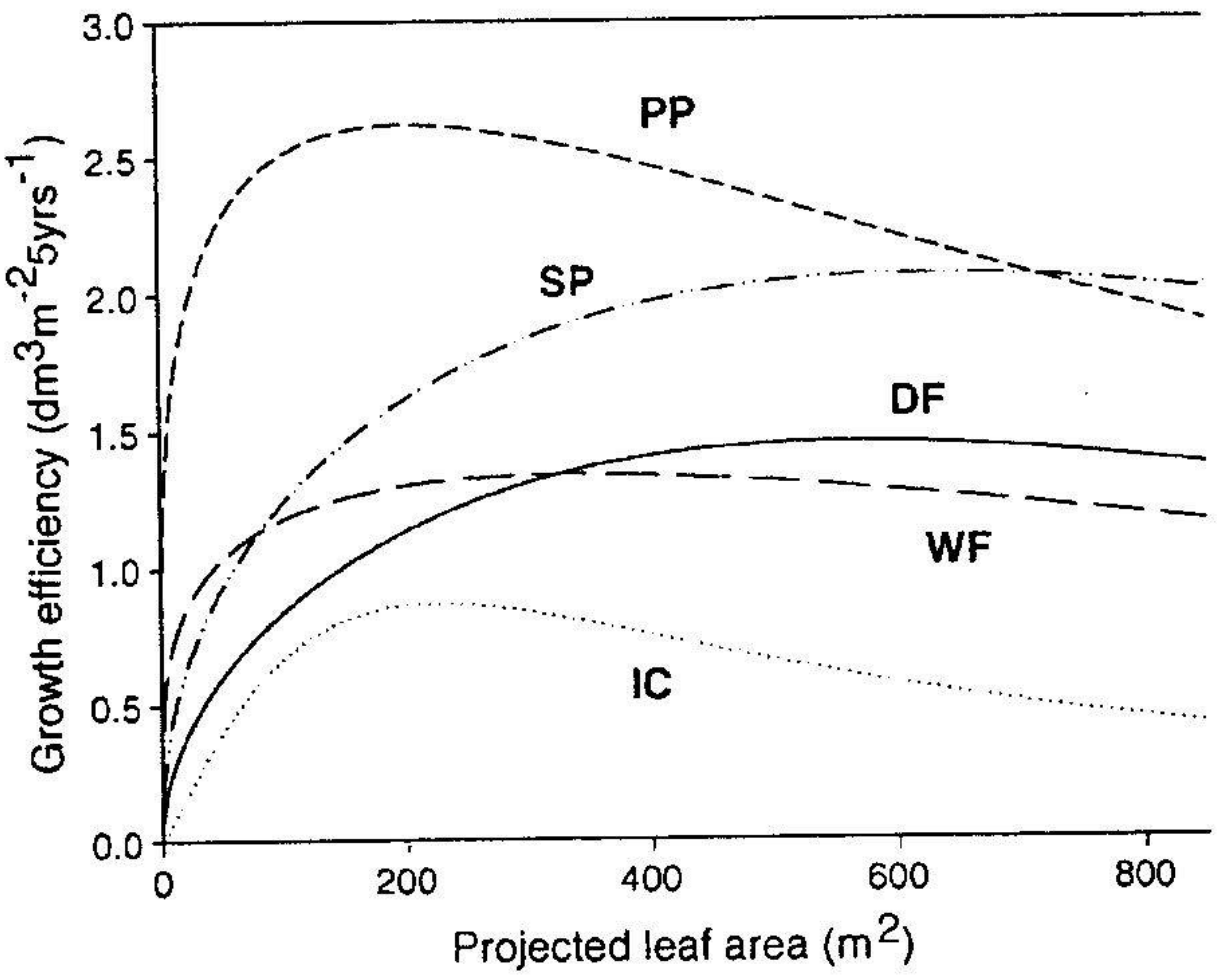
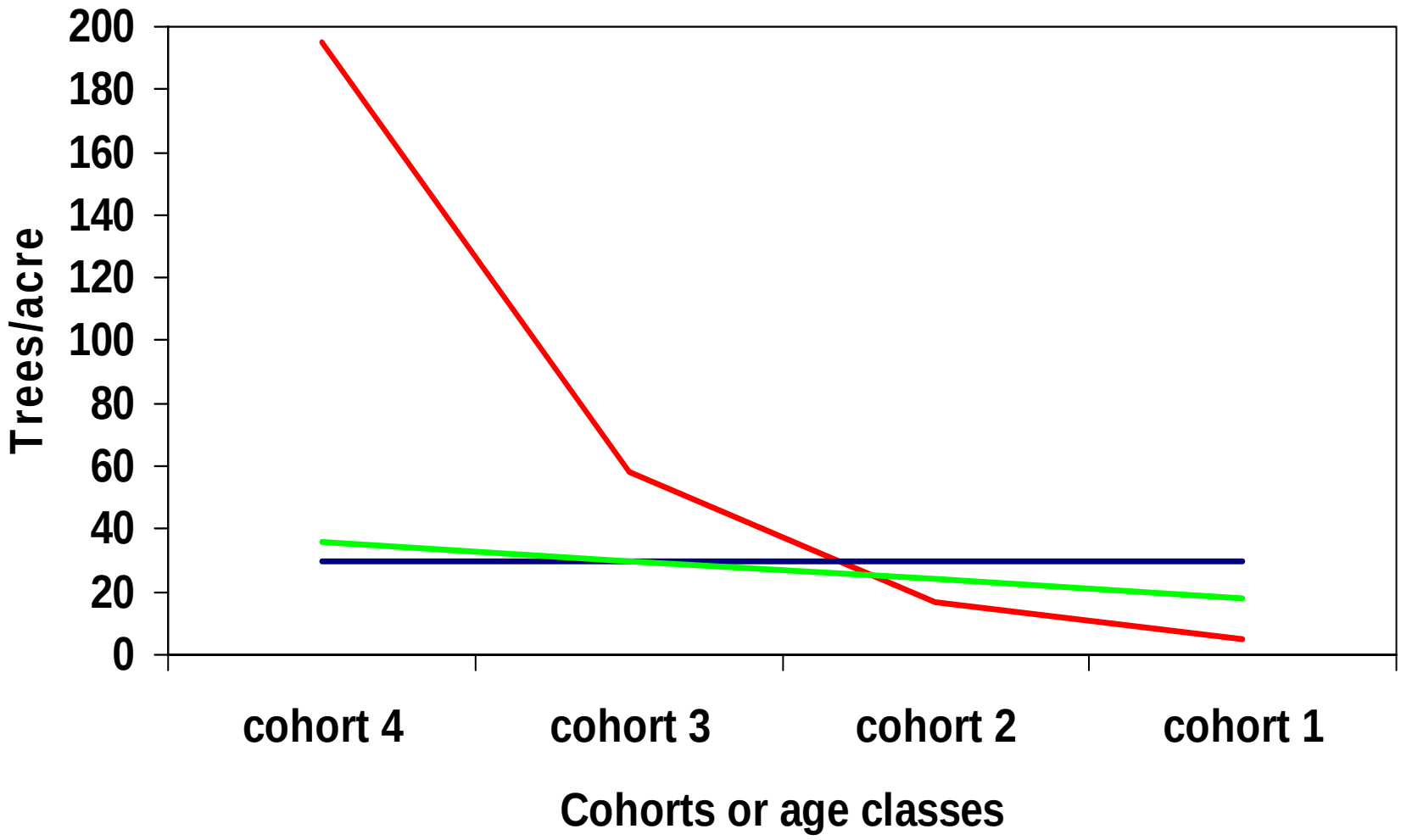


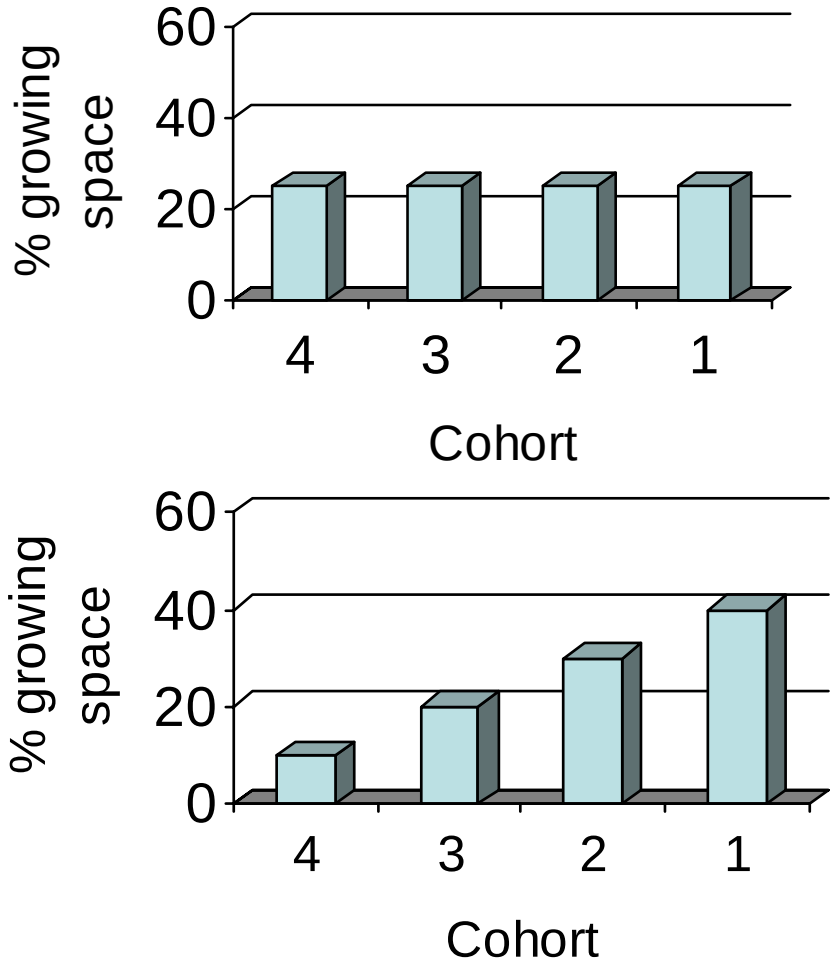
Fig. 2. Growth efficiency as a function of projected leaf area for individual species; DF: Douglas-fir, IC: incense-cedar, PP: ponderosa pine, SP: sugar pine, WF: white fir.

Gersonde and O'Hara 2005

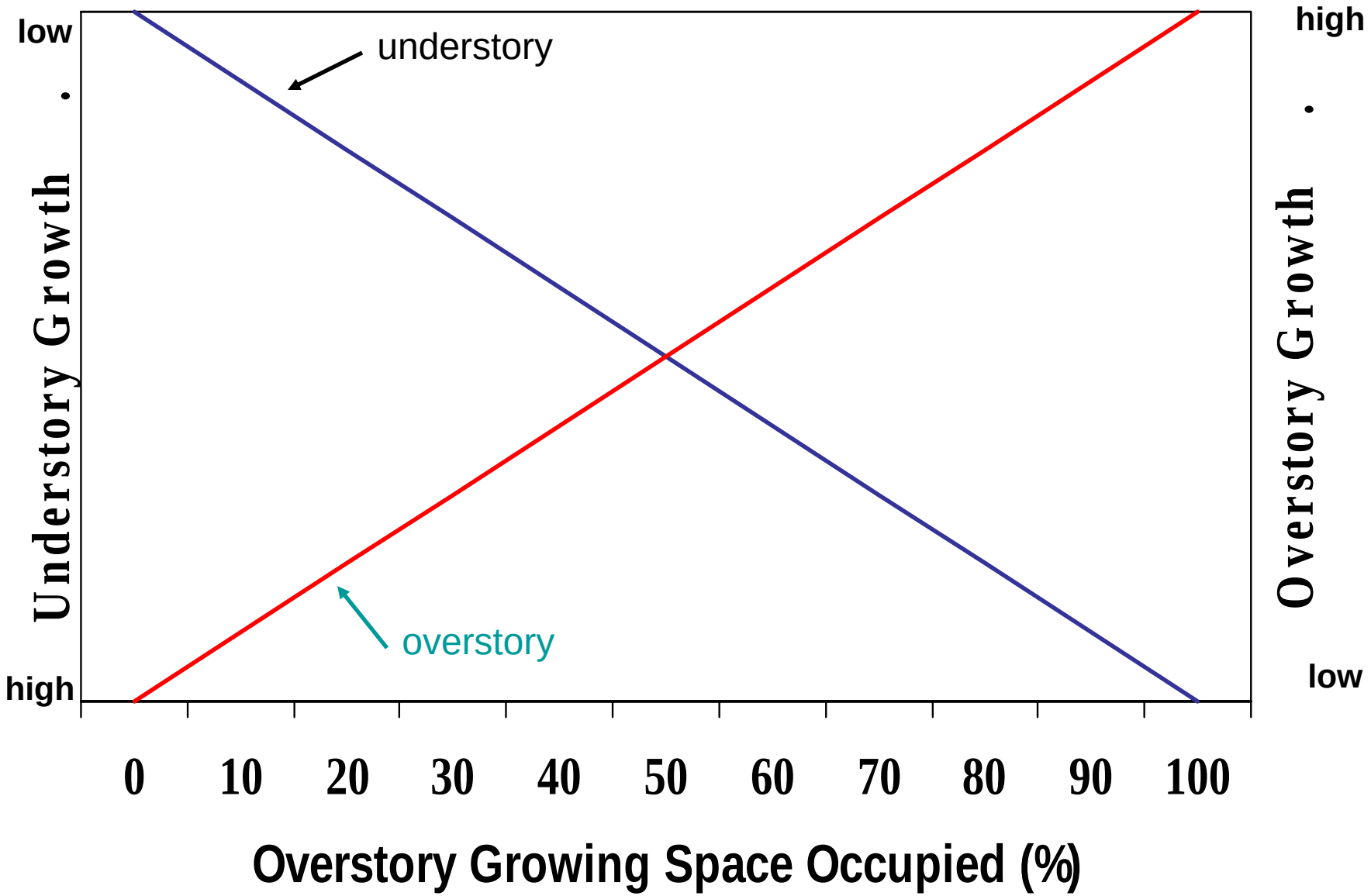
Number of trees allocation



Growing space allocation



- How should growing space be distributed?
- Equally?
- Greater amounts to older cohorts, or younger?



(from O'Hara 1998)

Ponderosa pine MASAM - MONTANA					
	USER-SPECIFIED VARIABLES				
TOTAL Leaf Area Index (LAI)	6				
	Cohort 1	Cohort 2	Cohort 3	Cohort 4	TOTAL
Number of Trees/Cohort/Acre	75	100	0	0	175
Percent of LAI/Cohort	70	30	0	0	100
	DIAGNOSTIC INFORMATION				
	Cohort 1	Cohort 2	Cohort 3	Cohort 4	TOTAL
Leaf Area Index/Cohort ECC	4.2	1.8	0.0	0.0	6.0
Leaf Area Index/Cohort BCC	1.4	0.0	0.0		1.4
Leaf Area/Tree (ft^2) ECC	2439.4	784.1	0.0	0.0	
BA/Cohort (ft^2/ac) ECC	91.4	36.4	0.0	0.0	127.7
BA/Cohort (ft^2/ac) BCC	27.3	0.0	0.0		27.3
Avg. Vol. Increment/Tree (ft^3/yr) ECC	0.52	0.19	0.00	0.00	
Avg. Vol. Increment/CC (ft^3/ac/yr)	26.8	9.7	0.0	0.0	**36.5**
Quadratic Mean DBH/Cohort (in) ECC	14.9	8.2	0.0	0.0	
Tree Vigor (in^3/ft^2/yr)	0.397	0.213	0.000	0.000	
Stand Density Index ECC	142.6	72.3	0.0	0.0	215.0
Stand Density Index BCC	54.3	0.0	0.0		54.3

Ponderosa pine MASAM - MONTANA					
	USER-SPECIFIED VARIABLES				
TOTAL Leaf Area Index (LAI)	**6**				
	Cohort 1	**Cohort 2**	**Cohort 3**	**Cohort 4**	**TOTAL**
Number of Trees/Cohort/Acre	**25**	**40**	**55**	**0**	120
Percent of LAI/Cohort	**50**	**35**	**15**	**0**	100
	DIAGNOSTIC INFORMATION				
	Cohort 1	**Cohort 2**	**Cohort 3**	**Cohort 4**	**TOTAL**
Leaf Area Index/Cohort ECC	3.0	2.1	0.9	0.0	6.0
Leaf Area Index/Cohort BCC	1.3	0.7	0.0		2.0
Leaf Area/Tree (ft^2) ECC	5227.2	2286.9	712.8	0.0	
BA/Cohort (ft^2/ac) ECC	65.5	42.2	16.7	0.0	124.4
BA/Cohort (ft^2/ac) BCC	26.4	12.1	0.0		38.5
Avg. Vol. Increment/Tree (ft^3/yr) ECC	1.48	0.50	0.18	0.00	
Avg. Vol. Increment/CC (ft^3/ac/yr)	24.7	13.5	4.9	0.0	**43.1**
Quadratic Mean DBH/Cohort (in) ECC	21.9	13.9	7.5	0.0	
Tree Vigor (in^3/ft^2/yr)	0.432	0.405	0.216	0.000	
Stand Density Index ECC	87.8	67.8	34.4	0.0	189.9
Stand Density Index BCC	42.4	25.0	0.0		67.4

Ponderosa pine MASAM - MONTANA					
	USER-SPECIFIED VARIABLES				
TOTAL Leaf Area Index (LAI)	**6**				
	Cohort 1	**Cohort 2**	**Cohort 3**	**Cohort 4**	**TOTAL**
Number of Trees/Cohort/Acre	**18**	**24**	**30**	**36**	108
Percent of LAI/Cohort	**40**	**30**	**20**	**10**	100
	DIAGNOSTIC INFORMATION				
	Cohort 1	**Cohort 2**	**Cohort 3**	**Cohort 4**	**TOTAL**
Leaf Area Index/Cohort ECC	2.4	1.8	1.2	0.6	6.0
Leaf Area Index/Cohort BCC	1.4	1.0	0.5		2.8
Leaf Area/Tree (ft^2) ECC	5808.0	3267.0	1742.4	726.0	
BA/Cohort (ft^2/ac) ECC	52.6	36.4	22.4	11.0	122.4
BA/Cohort (ft^2/ac) BCC	27.3	17.9	9.1		54.3
Avg. Vol. Increment/Tree (ft^3/yr) ECC	1.74	0.70	0.39	0.11	
Avg. Vol. Increment/CC (ft^3/ac/yr)	21.9	13.0	7.5	2.0	**44.4**
Quadratic Mean DBH/Cohort (in) ECC	23.2	16.7	11.7	7.5	
Tree Vigor (in^3/ft^2/yr)	0.443	0.377	0.324	0.263	
Stand Density Index ECC	69.0	54.4	38.5	22.6	184.5
Stand Density Index BCC	40.8	30.8	18.8		90.4

Ponderosa pine MASAM - MONTANA					
	USER-SPECIFIED VARIABLES				
TOTAL Leaf Area Index (LAI)	5				
	Cohort 1	Cohort 2	Cohort 3	Cohort 4	TOTAL
Number of Trees/Cohort/Acre	18	24	30	36	108
Percent of LAI/Cohort	40	30	20	10	100
	DIAGNOSTIC INFORMATION				
	Cohort 1	Cohort 2	Cohort 3	Cohort 4	TOTAL
Leaf Area Index/Cohort ECC	2.0	1.5	1.0	0.5	5.0
Leaf Area Index/Cohort BCC	1.1	0.8	0.4		2.3
Leaf Area/Tree (ft^2) ECC	4840.0	2722.5	1452.0	605.0	
BA/Cohort (ft^2/ac) ECC	44.1	30.5	18.6	9.1	102.3
BA/Cohort (ft^2/ac) BCC	22.9	14.9	7.6		45.3
Avg. Vol. Increment/Tree (ft^3/yr) ECC	1.31	0.59	0.33	0.09	
Avg. Vol. Increment/CC (ft^3/ac/yr)	17.1	11.0	6.3	1.7	**36.1**
Quadratic Mean DBH/Cohort (in) ECC	21.2	15.3	10.7	6.8	
Tree Vigor (in^3/ft^2/yr)	0.421	0.382	0.328	0.264	
Stand Density Index ECC	59.9	47.3	33.2	19.4	159.8
Stand Density Index BCC	35.5	26.6	16.2		78.2

USDA

United States
Department of
Agriculture

Forest Service

Pacific Southwest
Research Station

General Technical Report
PSW-GTR-220
March 2009

An Ecosystem Management Strategy for Sierran Mixed-Conifer Forests

Malcolm North, Peter Stine, Kevin O'Hara, William Zielinski, and Scott Stephens

Drawing courtesy of Robert van Pelt.

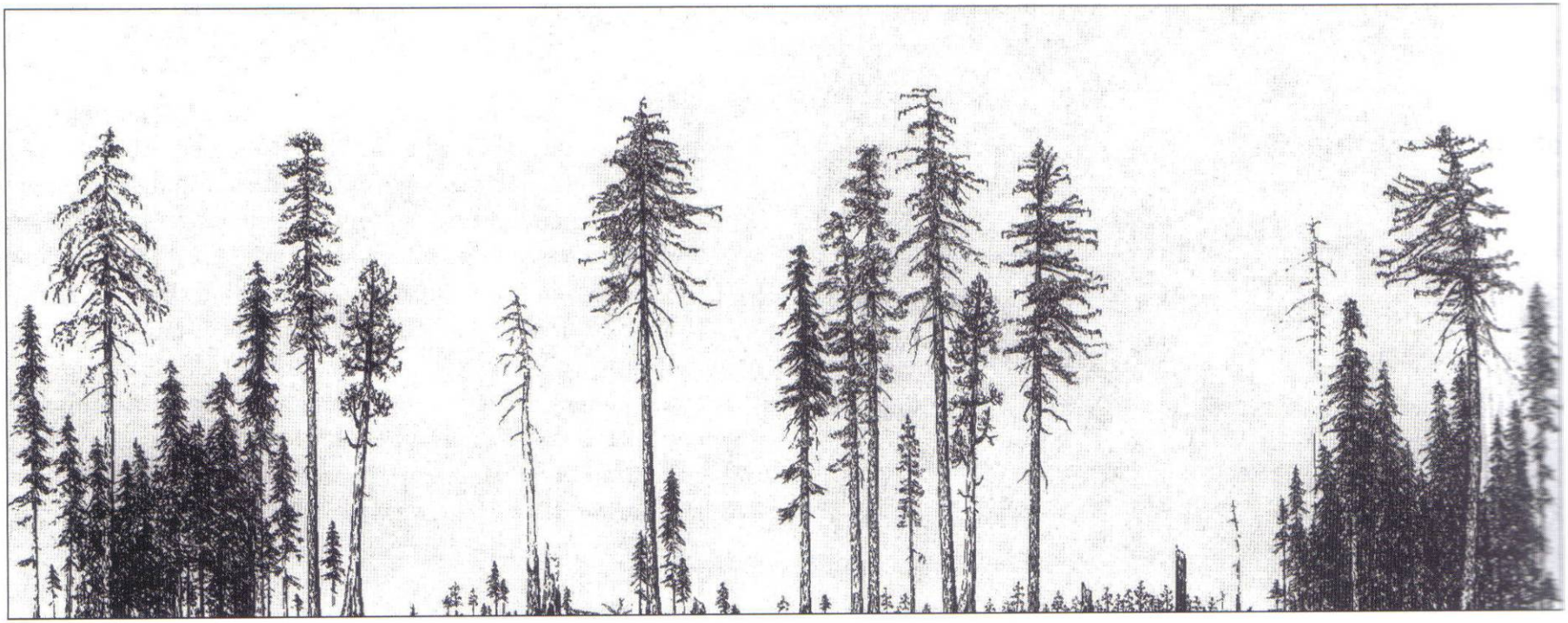
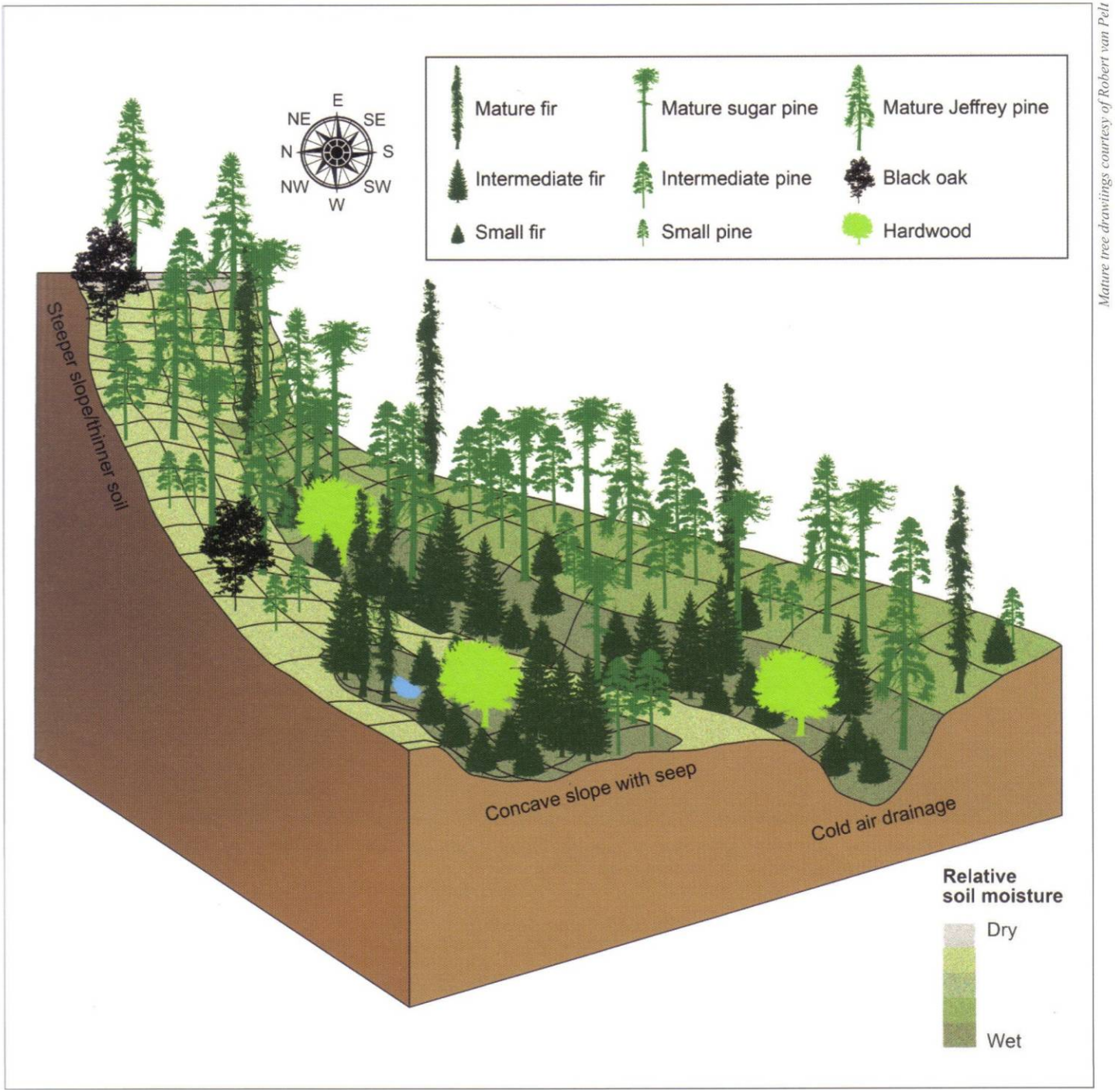
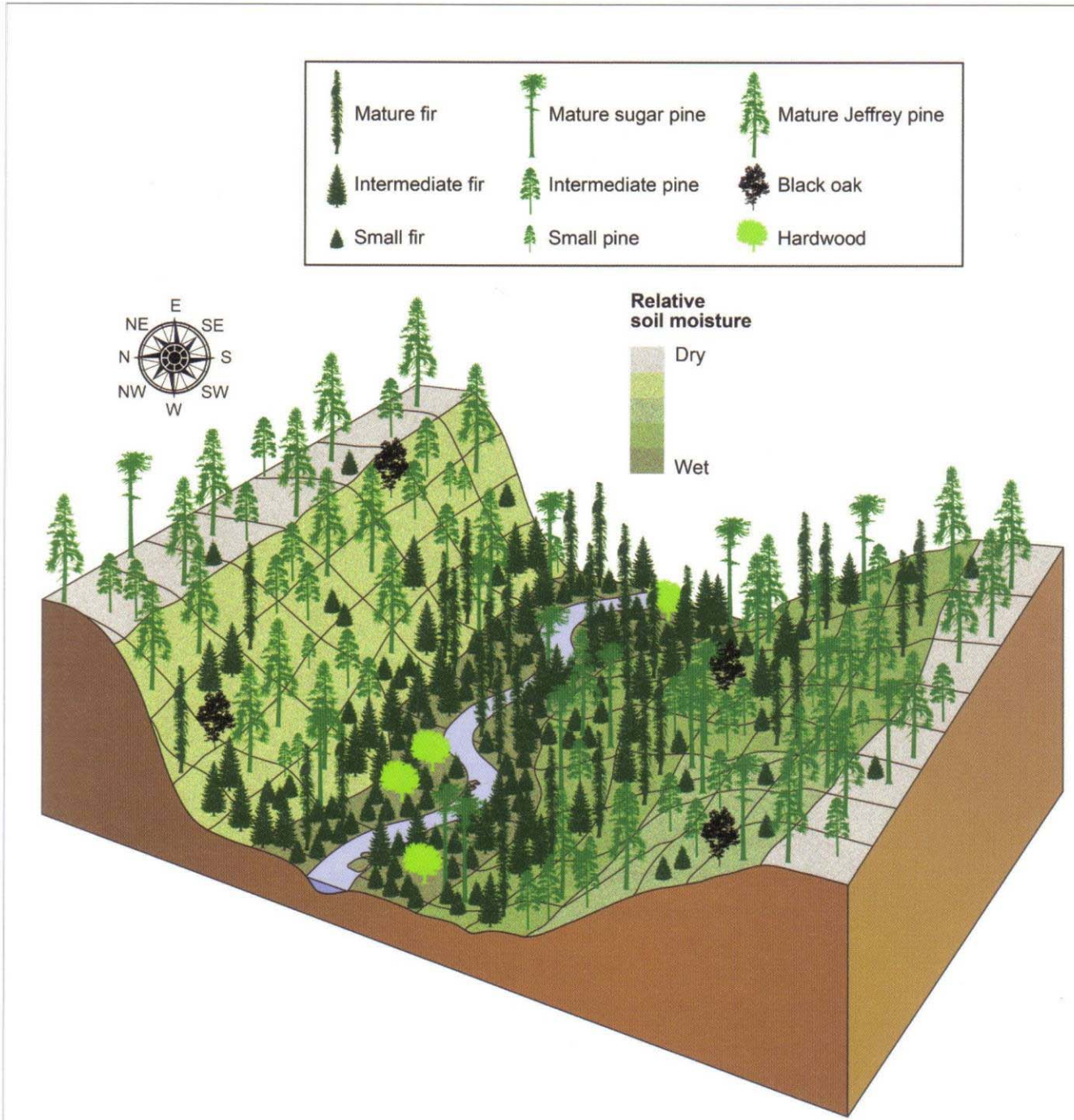


Figure 5—Transect of a mixed-conifer forest in Yosemite National Park's Aspen Valley, which has experienced three understory burns within the last 50 years. Note that the stand has vertical heterogeneity but that trees in different canopy strata tend to be spatially separated.



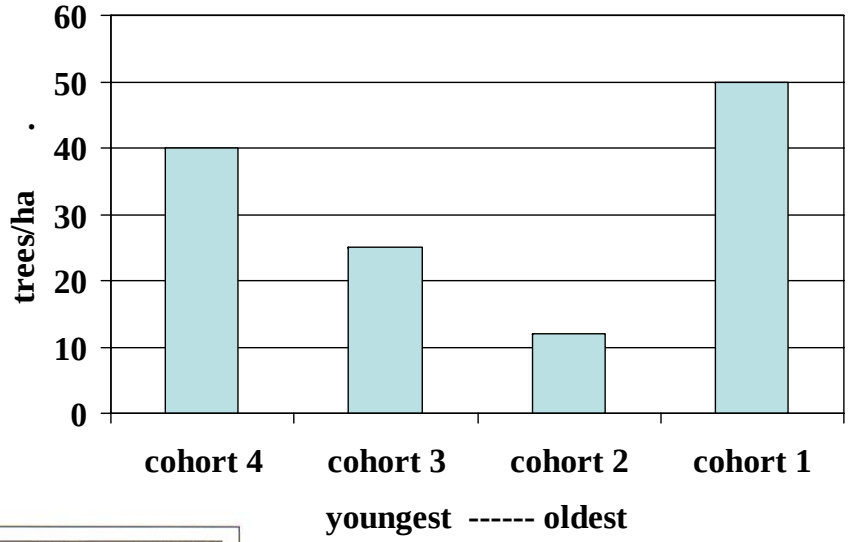
Mature tree drawiings courtesy of Robert van Pelt

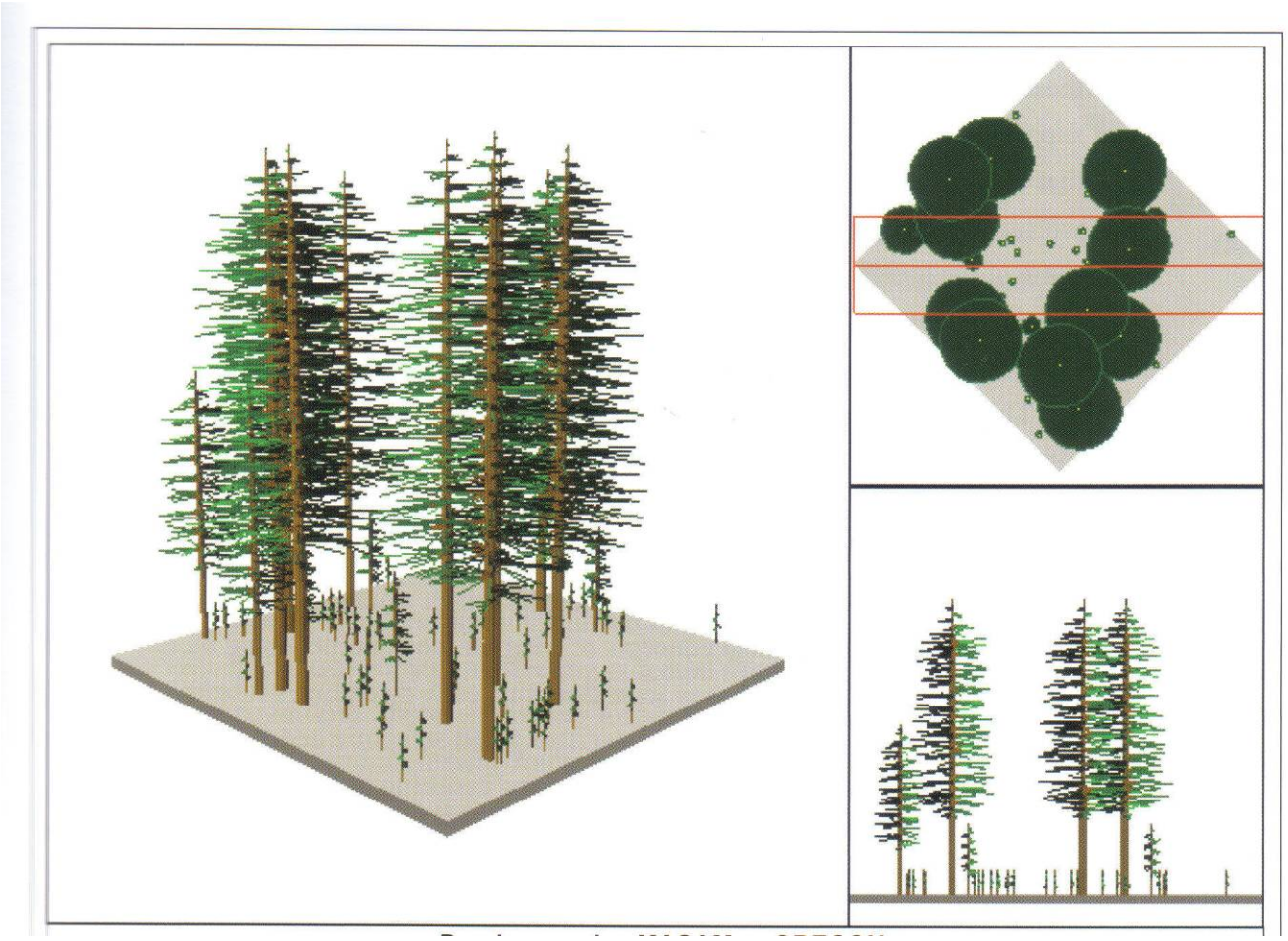


Mature tree drawing courtesy of Robert van Pelt

GTR 220 Silviculture

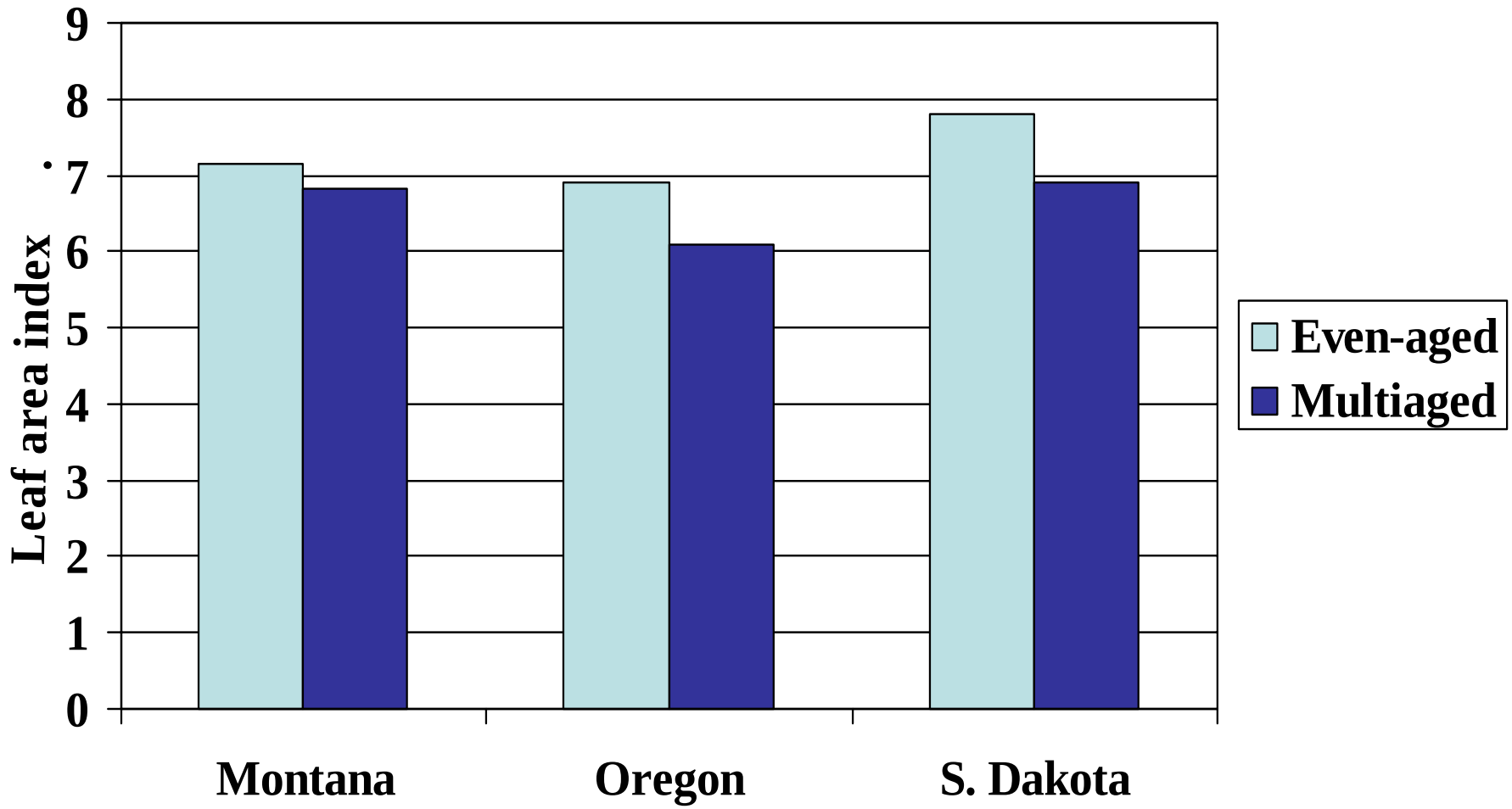
- Multiaged stands
- Spatial heterogeneity
- Mixed-species but favoring pines
- Retaining large trees
- Retaining other structural features (snags, broadleaved trees, CWD, “defect” trees, etc)


60
50
40
30
20
10
0
trees/ha
cohort 4
cohort 3
cohort 2
cohort 1
youngest ------ oldest



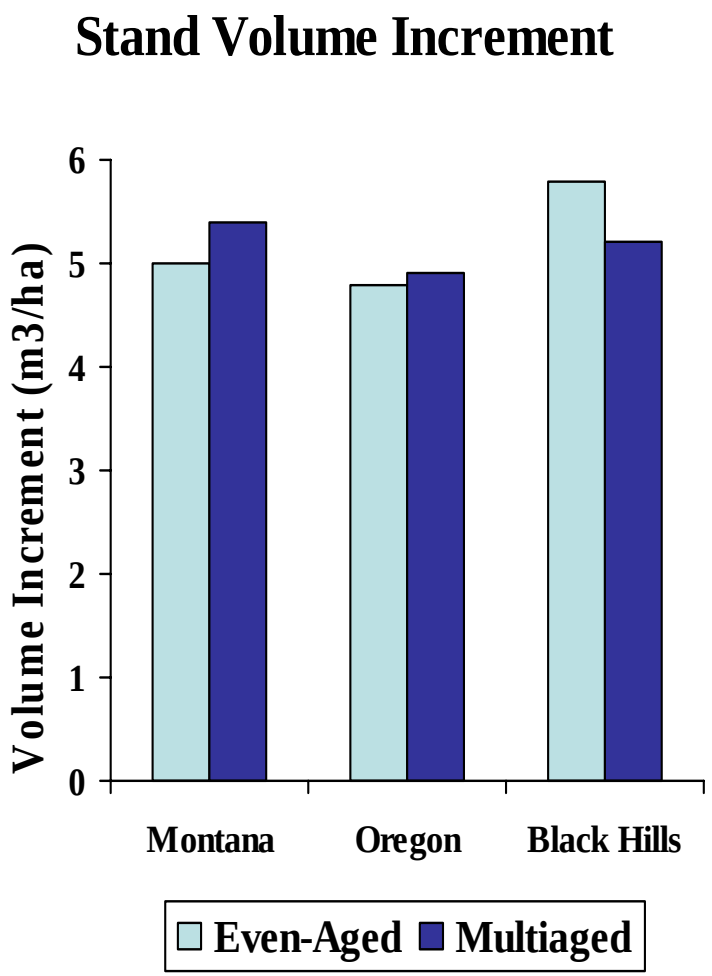
Ponderosa pine MASAM - MONTANA					
	USER-SPECIFIED VARIABLES				
TOTAL Leaf Area Index (LAI)	**6**				
	Cohort 1	**Cohort 2**	**Cohort 3**	**Cohort 4**	**TOTAL**
Number of Trees/Cohort/Acre	**20**	**5**	**10**	**15**	50
Percent of LAI/Cohort	**90**	**7**	**2**	**1**	100
	DIAGNOSTIC INFORMATION				
	Cohort 1	**Cohort 2**	**Cohort 3**	**Cohort 4**	**TOTAL**
Leaf Area Index/Cohort ECC	5.4	0.4	0.1	0.1	6.0
Leaf Area Index/Cohort BCC	4.5	0.1	0.0		4.6
Leaf Area/Tree (ft^2) ECC	10000.0	3659.0	522.7	174.2	
BA/Cohort (ft^2/ac) ECC	117.3	9.0	1.8	0.6	128.7
BA/Cohort (ft^2/ac) BCC	36.0	0.9	0.4		37.3
Avg. Vol. Increment/Tree (ft^3/yr) ECC	4.19	0.78	0.14	0.03	
Avg. Vol. Increment/CC (ft^3/ac/yr)	49.7	2.3	0.8	0.2	**53.0**
Quadratic Mean DBH/Cohort (in) ECC	32.8	18.2	5.7	2.7	
Tree Vigor (in^3/ft^2/yr)	0.546	0.415	0.369	0.275	
Stand Density Index ECC	133.8	13.0	4.0	1.8	152.6
Stand Density Index BCC	52.0	2.0	1.2		55.2

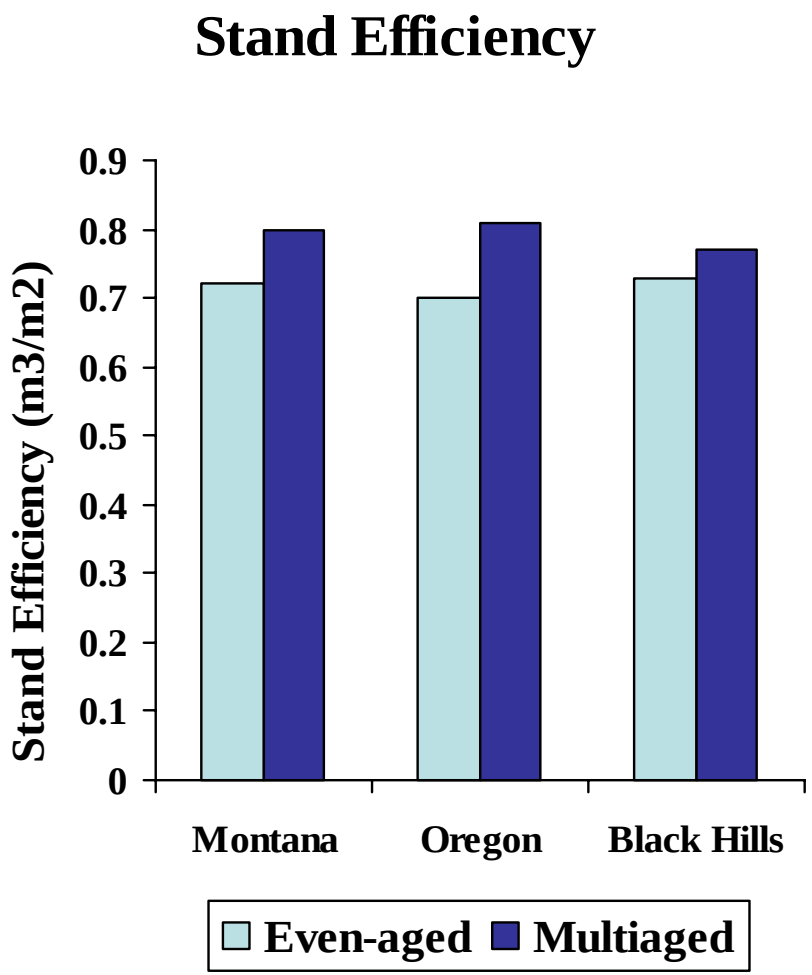
Even- vs Multiaged Stands - Ponderosa Pine



(from O'Hara and Nagel 2006)

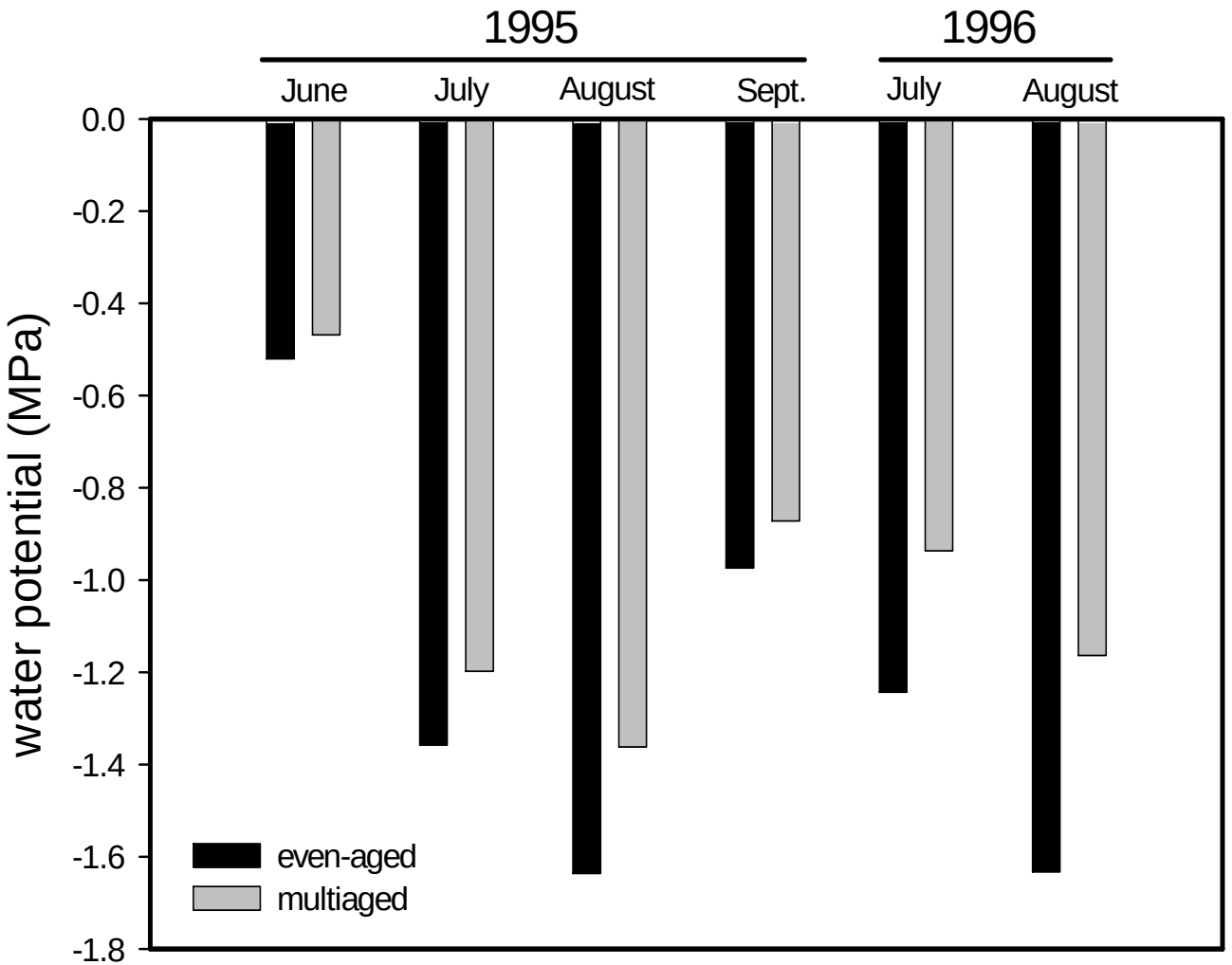
Productivity in even-aged and multiaged stands





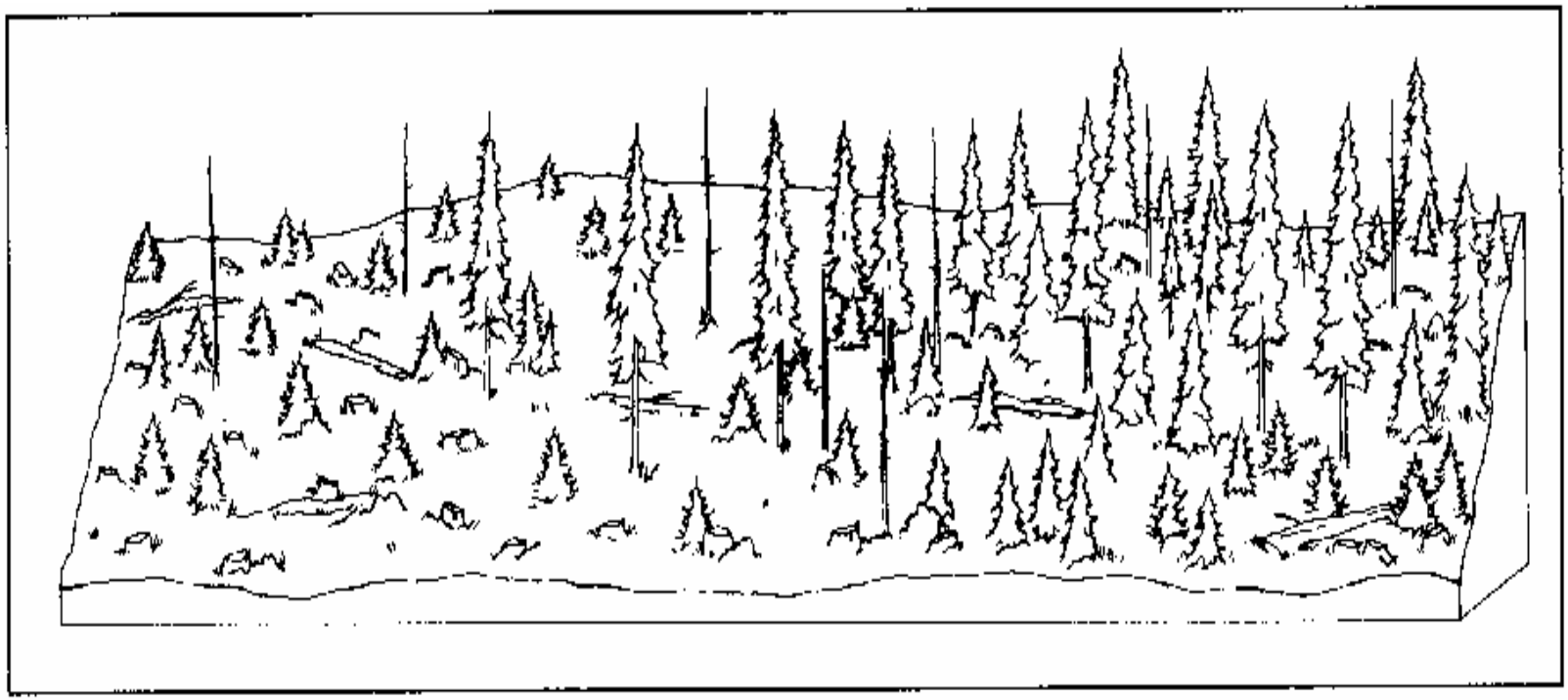
(from O'Hara and Nagel 2006)

Water potential differences between structures



(from O'Hara and Nagel 2006)

Range of silvicultural systems



Wind-up points

- Hope for the USFS?
- Lower stocking, enhancing variability
- Get rid of those reverse-J diameter distributions
- Need tools that allow us to design variable structures with unique features
- Recognize that silvicultural alternatives exist on a continuum

Biomass Implications

- Multiaged stands have same potential to produce biomass
- Probably also more dispersed spatially (e.g., less biomass per acre)
- Less economical to remove than even-aged stands.

References

- Gersonde, R.F., and K.L. O'Hara. 2005. Comparative tree growth efficiency in Sierra Nevada mixed-conifer forests. Forest Ecology and Management 219: 95-108.

- North, M., P. Stine, K. O'Hara, W. Zielinski, and S. Stephens. 2009. An ecosystem management strategy for Sierran mixed-conifer forests. USDA Forest Service General Technical report PSW-GTR-220.

- O'Hara, K. L. 1996. Dynamics and stocking-level relationships of multi-aged ponderosa pine stands. Forest Science 42(4): 1-34, Suppl. 33.

- O'Hara, K.L. 1998. Silviculture for structural diversity: A new look at multiaged systems. Journal of Forestry 96(7) 4-10.

- O'Hara, K.L., and N.I. Valappil. 1999. MASAM – A flexible stand density management model for meeting diverse structural objectives in multiaged stands. Forest Ecology and Management 118(1-3)57-71.

- O'Hara, K.L., and L.M. Nagel. 2006. A functional comparison of productivity in even-aged and multiaged stands: A synthesis for *Pinus ponderosa*. Forest Science 52: 290-303.

- Smith, D.M., et a.. 1997. Practice of silviculture: Applied forest ecology. John Wiley & Sons, New York.

Thanks!

- The GTR- 220 (PSW-GTR-220) can be downloaded at:
- http://www.fs.fed.us/psw/publications/documents/psw_gtr220/
- Or ordered from Richard Schneider (PSW pubs) at:
- rschneider@fs.fed.us