Reflections on
Inland Northwest Silviculture

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Thinning and Nitrogen Fertilization in a Grand Fir Stand Infested with Western Spruce Budworm. Part II: Tree Growth Response

Boyd E. Wickman
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ABSTRACT. The effects of thinning and nitrogen fertilization on tree growth in a grand fir (*Abies grandis* [Dougl.] Forbes) stand infested with western spruce budworm (*Choristoneura occidentalis* Freeman) were evaluated over 5 years by a replicated split-plot experiment. Fertilization treatments resulted in significantly reduced defoliation and significantly heavier biomass of shoots and foliage for the last 3 years of the study. There were, however, 30% fewer buds on fertilized grand fir midcrown branches at the end of the study. Height growth of fertilized trees was significantly greater than unfertilized trees 3 to 5 years after treatment and was almost double that of controls. Radial growth measured at breast height and base of live crown was significantly greater for fertilized trees 3 to 5 years after treatment; 5 years after treatment, radial growth of thinned trees also was significantly greater than the controls. Trees thinned and fertilized had almost double the growth of controls 2 to 5 years after treatment. Fertilized trees apparently produced fewer buds m^{-2} of foliage but more foliage per shoot than budworm larvae could destroy, and this resulted in significantly increased tree growth. The results of the study have implications for using fertilization as a management option for some budworm outbreaks.
FOR. SCI. 38(2):252–264.
ADDITIONAL KEY WORDS. *Abies grandis*, defoliation, foliage production.

We became interested in fertilization (and IFTNC) following a study in which fertilized trees produced more foliage than budworm larvae could consume. So, our interest wasn't directed at tree growth, but at budworm resistance and forest health.

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Foliar nutrient and tree growth response of mixed-conifer stands to three fertilization treatments in northeast Oregon and north central Washington

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Abstract

The results of two studies evaluating nutrient uptake in mixed-conifer stands following fertilization are reported. The four species examined were Douglas-fir, grand fir, lodgepole pine and ponderosa pine. The fertilization treatments were 224 kg ha^{-1} nitrogen, 224 kg ha^{-1} nitrogen plus 112 kg ha^{-1} sulfur, and 224 kg ha^{-1} nitrogen plus 190.4 kg ha^{-1} potassium. Foliar nutrient concentrations, contents and ratios were analyzed, as well as four-year volume response. Douglas-fir showed both N and S deficiencies in control foliage samples, and produced significant growth response to the N + S treatment, but not to the N-alone treatment. Grand fir also showed foliar N and S deficiencies, but produced significant growth response to both N and N + S fertilization. This suggests that grand fir was better able to utilize N than Douglas-fir even under S-limiting conditions. Lodgepole pine showed deficient foliar N and S concentrations, and produced significant volume responses to N and N + K fertilization. Lodgepole volume response to N + S fertilization was highly variable, and appeared to be site-specific. Ponderosa pine did not show nutrient deficiencies for N or K, and did not respond significantly in either foliar K or S levels or in growth to N, N + K or N + S fertilization. This suggests that nutrient deficiency may not have been a factor limiting foliar nutrient response and growth for ponderosa pine.

Keywords: Forest nutrition; Fertilization; Nitrogen; Sulfur; Potassium; Volume; Mixed conifer

IFTNC fertilized 8 mixed-conifer plots on the Umatilla NF in 1991. The study examined both multi-species & multi-nutrient responses. The same study design was used on the Okanogan NF in 1993.

In the 1990s, we joined a Stressed Sites Coop; they were working on a stand density project at the time. But, which density metric to use?

Characteristics of a good index of stand density (Daniel et al. 1979):

- Quantitative.
- Easily applied or calculated.
- Independent of site quality.
- Independent of stand age.
- Independent of forest stand dynamics.

PERFECTING A STAND-DENSITY INDEX FOR EVEN-AGED FORESTS[1]

By L. H. Reineke

Associate Silviculturist, California Forest Experiment Station, Forest Service, United States Department of Agriculture

Stand density index was first presented by Lester Henry Reineke in the Journal of Agricultural Research on April 1, 1933. He used size-density data for 14 forest types from across the U.S., and discovered that fully-stocked, even-aged stands of a given diameter had about the same trees per acre as other fully-stocked stands for the same species and diameter. And, this relationship occurred ***regardless of site quality or stand age***.

SITE INDEX	STAND AGE	QUAD. MEAN DIAMETER	TREES PER ACRE
70	160	10.0	510
90	100	10.0	510
130	60	9.9	510
170	50	10.0	510

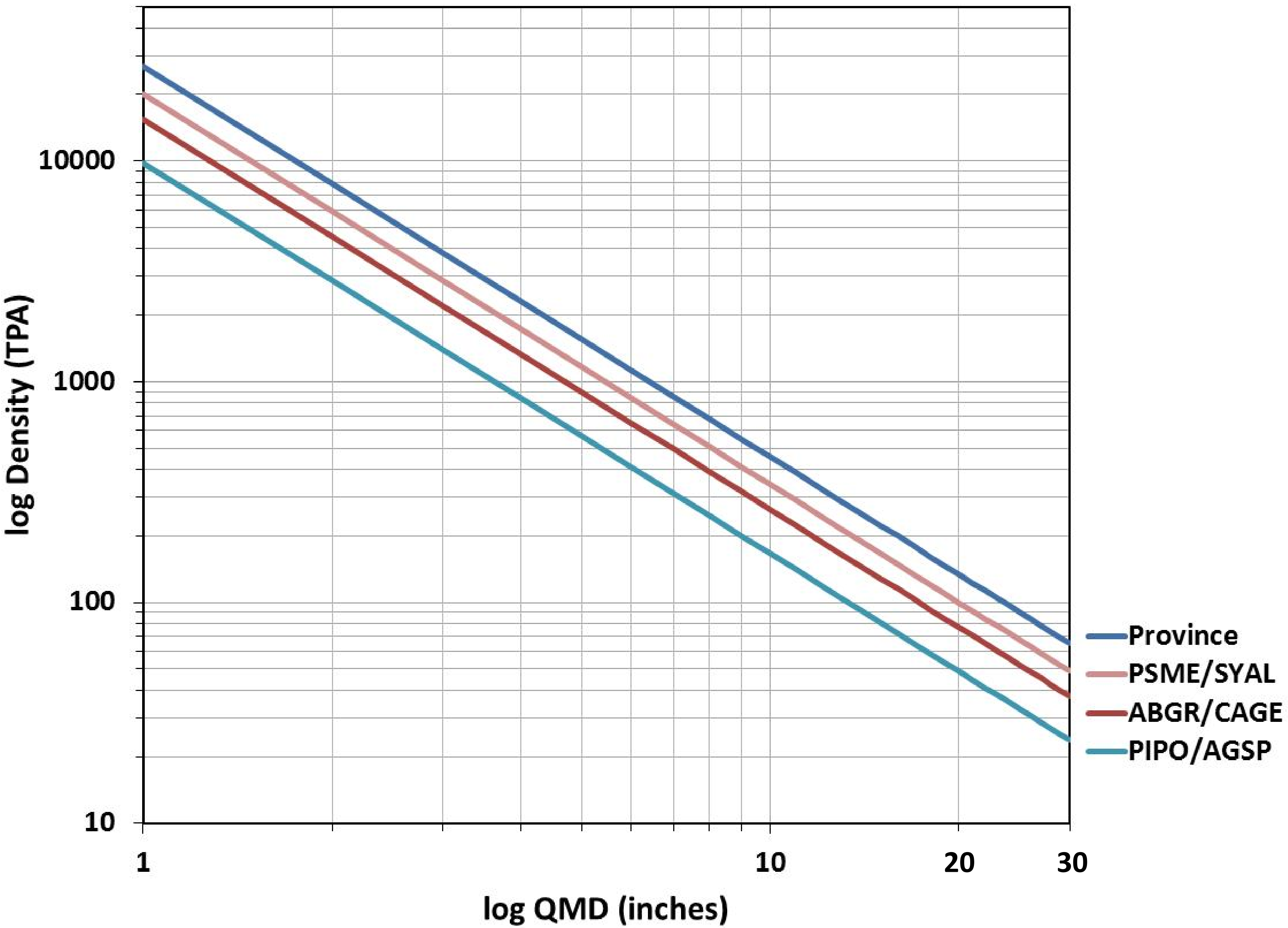
Source: Barnes 1962 (and adapted from Daniel et al. 1979, specifically table 12.2, page 262 in that source)

Reineke (1933) provides some of what was needed for the Blue Mountains stand density work, but…

Since Reineke’s work in 1933, it has been discovered that:

- Slope of the boundary line is more variable than he thought (<u>not</u> just 1.605).
- Slope of the boundary line varies by species, cohort (dominants have a steeper slope), conifer versus broadleaf, shade tolerance, **and biophysical environment**.
- Intercepts vary to same extent as the slopes.

Maximum density varies by biophysical environment



PP Max SDI	
Province	456
PSME/SYAL	341
ABGR/CAGE	263
PIPO/AGSP	166

A Practical Approach to Density Management

by

James N. Long[1]

Abstract

Density management is the control of growing stock, through initial spacing or subsequent thinning, to achieve specific management objectives. A biologically sound and easily applied approach to density management is illustrated for a hypothetical, even-aged stand under two contrasting types of management objectives.

Résumé

L'aménagement par densité est le contrôle du volume sur pied grâce à l'esplacement initial et aux éclaircies subséquentes pour atteindre des objectifs d'aménagement spécifiques. Une approche biologiquement solide et facilement applicable de l'aménagement par densité est illustrée pour un peuplement équienne hypothétique selon deux différents types d'objectifs d'aménagement.

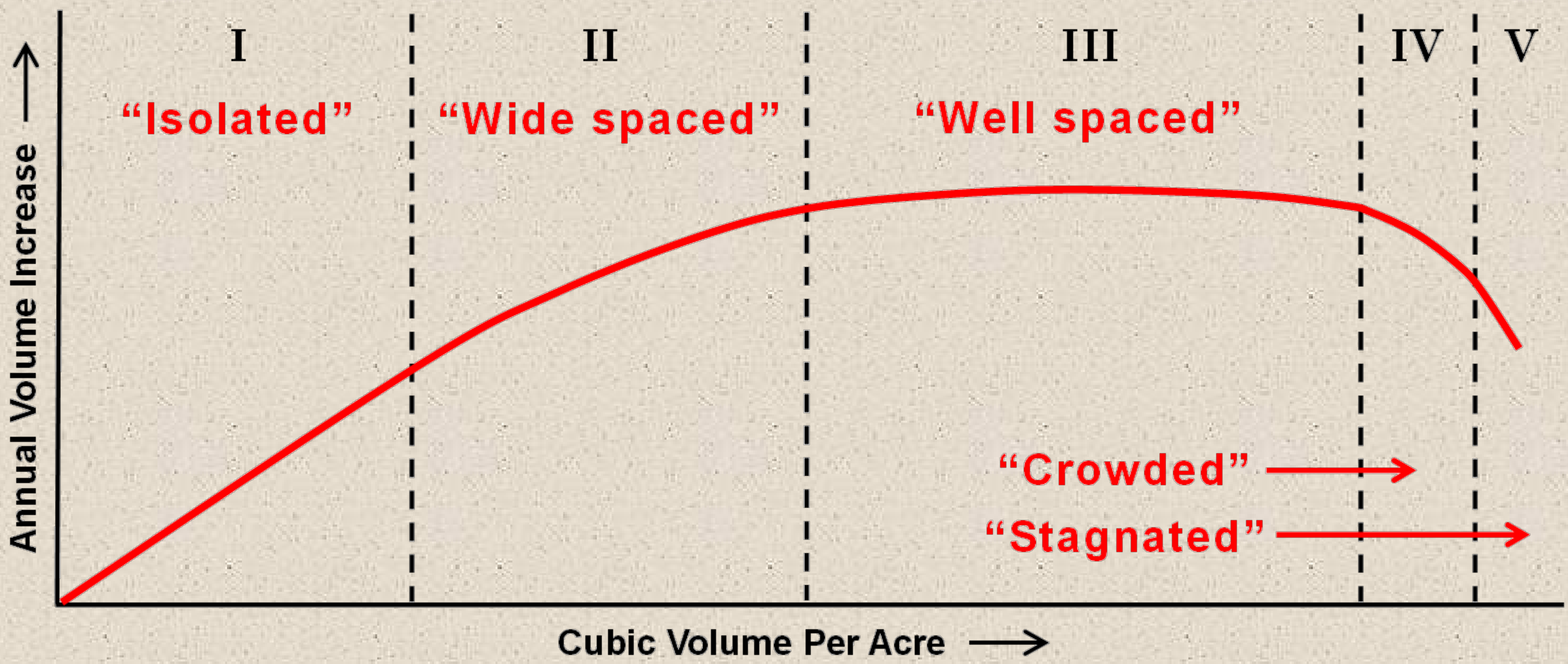
Long (1985) quantified 3 stand development thresholds:

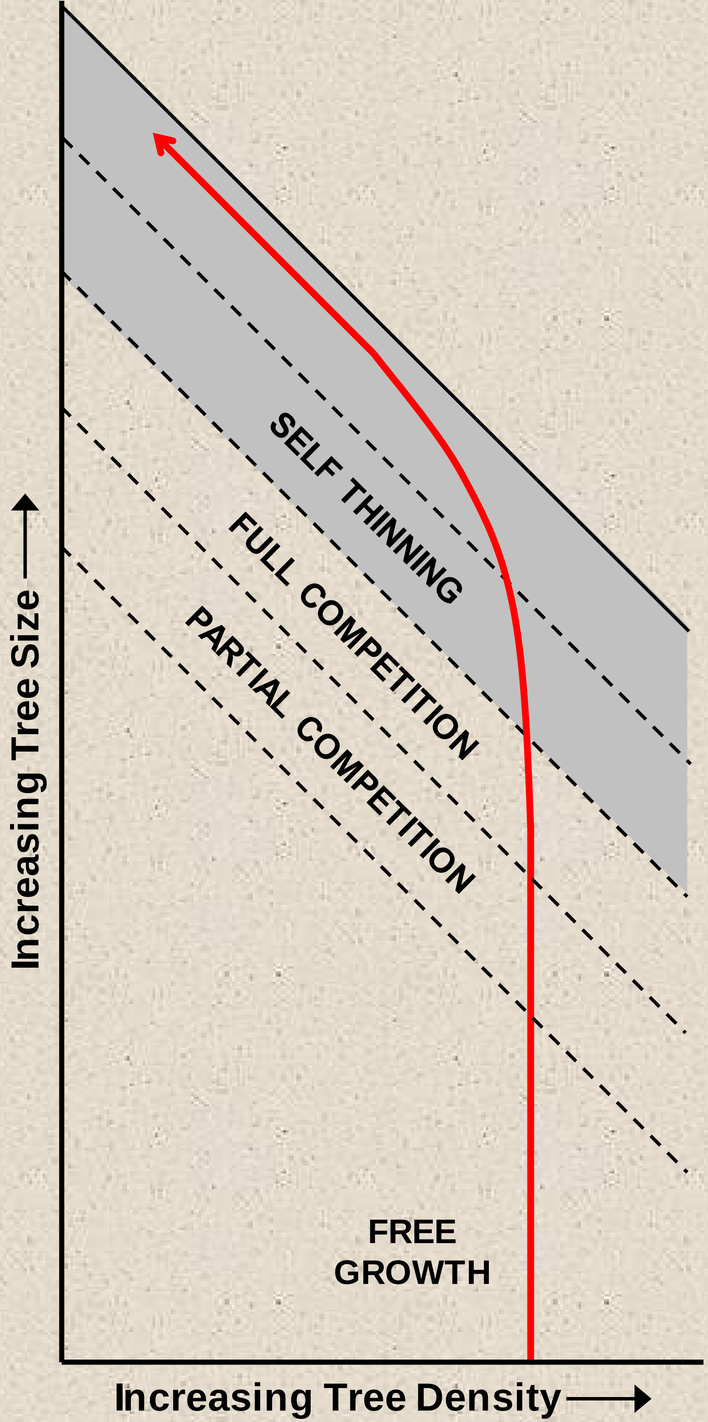
- lower limit of self-thinning zone (60% of maximum)
- lower limit of full site occupancy (35% of maximum)
- crown closure/onset of intertree competition (25% of maximum)

Growth-Growing Stock Relationships

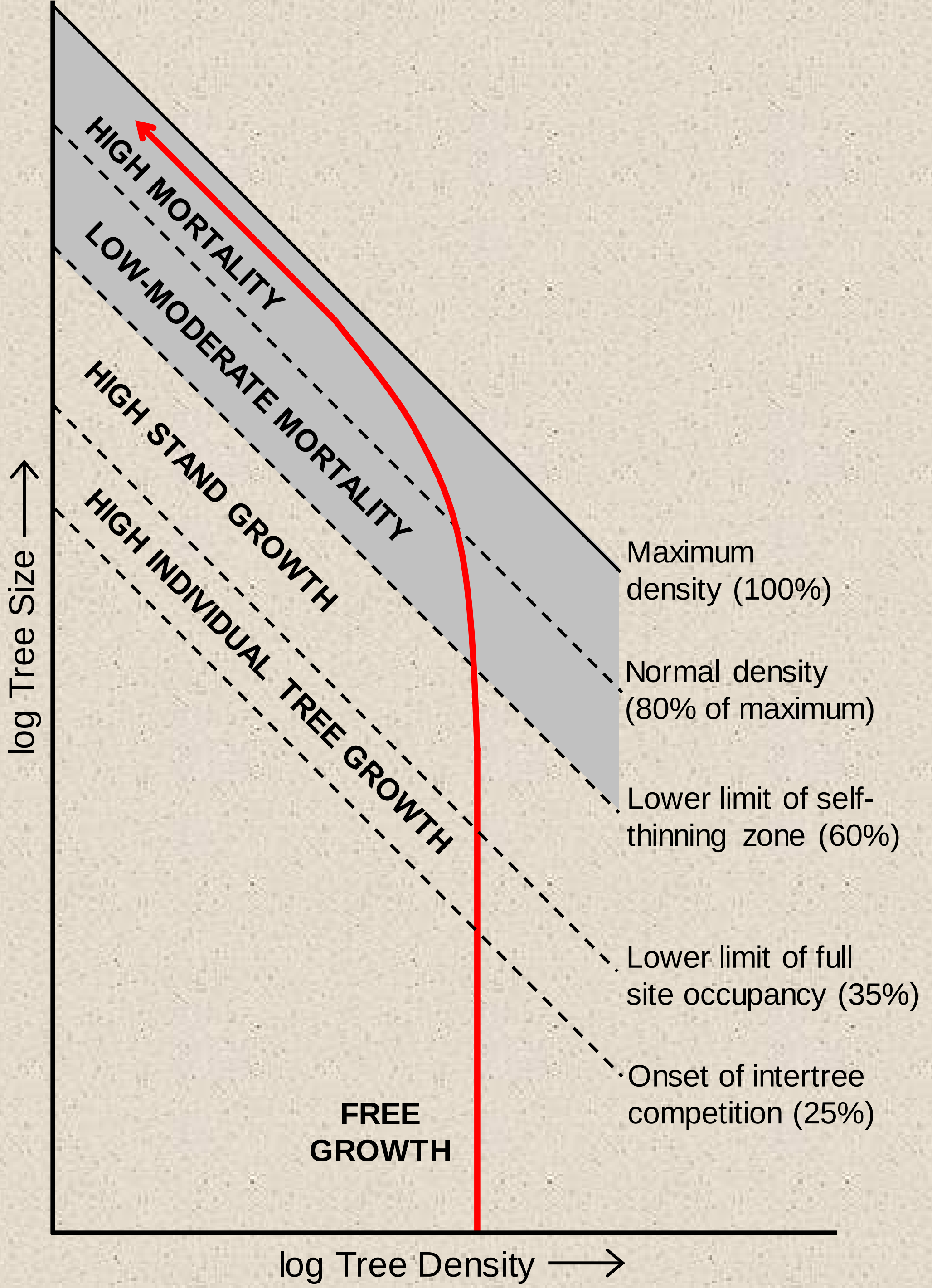
Langsaeter's Curve (Daniel et al. 1979):

Stand cubic-foot volume growth follows consistent and predictable patterns portrayed as five stages: I through V. Langsaeter's stages relate to stand development and competition.





As a stand develops, it passes through successive density thresholds. This chart illustrates them by using a format similar to Reineke's graph (sloping line at top of gray zone is Reineke's maximum density). A young stand has little or no tree competition – this is 'free growth' because it is free of competition (Langsaeter's stage I). Competition begins when crowns or roots interact – this is partial and then full competition (Langsaeter stages II/III). As competition intensifies, the self-thinning zone is reached, when overstory trees suppress and kill understory trees (Langsaeter stages IV/V). [Dotted line in self-thinning zone is normal density or full stocking.]



This slide shows names and percentages for stocking thresholds. Solid line at top is maximum density. Dashed lines show stocking thresholds. Gray shading is self-thinning zone. Areas between thresholds show Langsaeter growth and mortality relationships. Bottom three thresholds are from Long (1985), normal density reflects normal yield tables, and max density is from Reineke 1933. Why is high stand growth area wider than others? (Remember Lansaeter's stage III plateau.)

Let's quantify the density management zones shown in previous slide for 3 species on the GF/big huckleberry plant association (% of max SDI).

Free Growth 0-25%	High Tree Growth 25-35%	High Stand Growth 35-60%	Low-Mod Mortality 60-80%	High Mortality 80-100%

Western larch (maximum SDI is 512 on GF/big huckleberry)				
0-128	128-179	179-307	307-410	410-512
Douglas-fir (maximum SDI is 475 on GF/big huckleberry)				
0-119	119-166	166-285	285-380	380-475
Grand fir (maximum SDI is 569 on GF/big huckleberry)				
0-142	142-199	199-341	341-455	455-569

United States
Department of
Agriculture

Forest Service

Pacific Northwest
Research Station

Research Note
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Suggested Stocking Levels for Forest Stands in Northeastern Oregon and Southeastern Washington[1]

P.H. Cochran, J.M. Geist, D.L. Clemens, Rodrick R. Clausnitzer, and David C. Powell

Abstract

Catastrophes and manipulation of stocking levels are important determinants of stand development and the appearance of future forest landscapes. Managers need stocking level guides, particularly for sites incapable of supporting stocking levels presented in normal yield tables. Growth basal area (GBA) has been used by some managers in attempts to assess inherent differences in site occupancy but rarely has been related to Gingrich-type stocking guides. To take advantage of information currently available, we used some assumptions to relate GBA to stand density index (SDI) and then created stocking level curves for use in northeastern Oregon and southeastern Washington. Use of these curves cannot be expected to eliminate all insect and disease problems. Impacts of diseases, except dwarf mistletoe (*Arceuthobium campylopodum* Engelm.), and of insects, except mountain pine beetle (*Dendroctonus ponderosea* Hopkins) and perhaps western pine beetle (*Dendroctonus brevicomis* LeConte), may be independent of density. Stands with mixed tree species should be managed by using the stocking level curves for the single species prescribing the fewest number of trees per acre.

Keywords: Forest health, growth basal area, mountain pine beetle, stand density index, stressed sites, Oregon—northeast, Washington—southeast.

Introduction

Concerns about forest health east of the crest of the Cascade Range in Oregon and Washington have highlighted the need for site-specific information for a range of management practices, including stocking level control. Unfortunately, several insect pests and disease problems in northeastern Oregon and southwestern Washington cannot be prevented or controlled by density management. For example, spruce beetle (*Dendroctonus rufipennis* Kirby), western spruce budworm (*Choristoneura occidentalis* Freeman), Douglas-fir tussock moth (*Orgyia pseudotsugata* McDunnough), and laminated root rot (*Phellinus weirii* (Murr) Gilbertson) attack trees regardless of stand density. Thinning, however, is a

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[1] Contribution of the Stressed Sites Cooperative in northeastern Oregon, an informal team formed to implement existing science and stimulate applied research.

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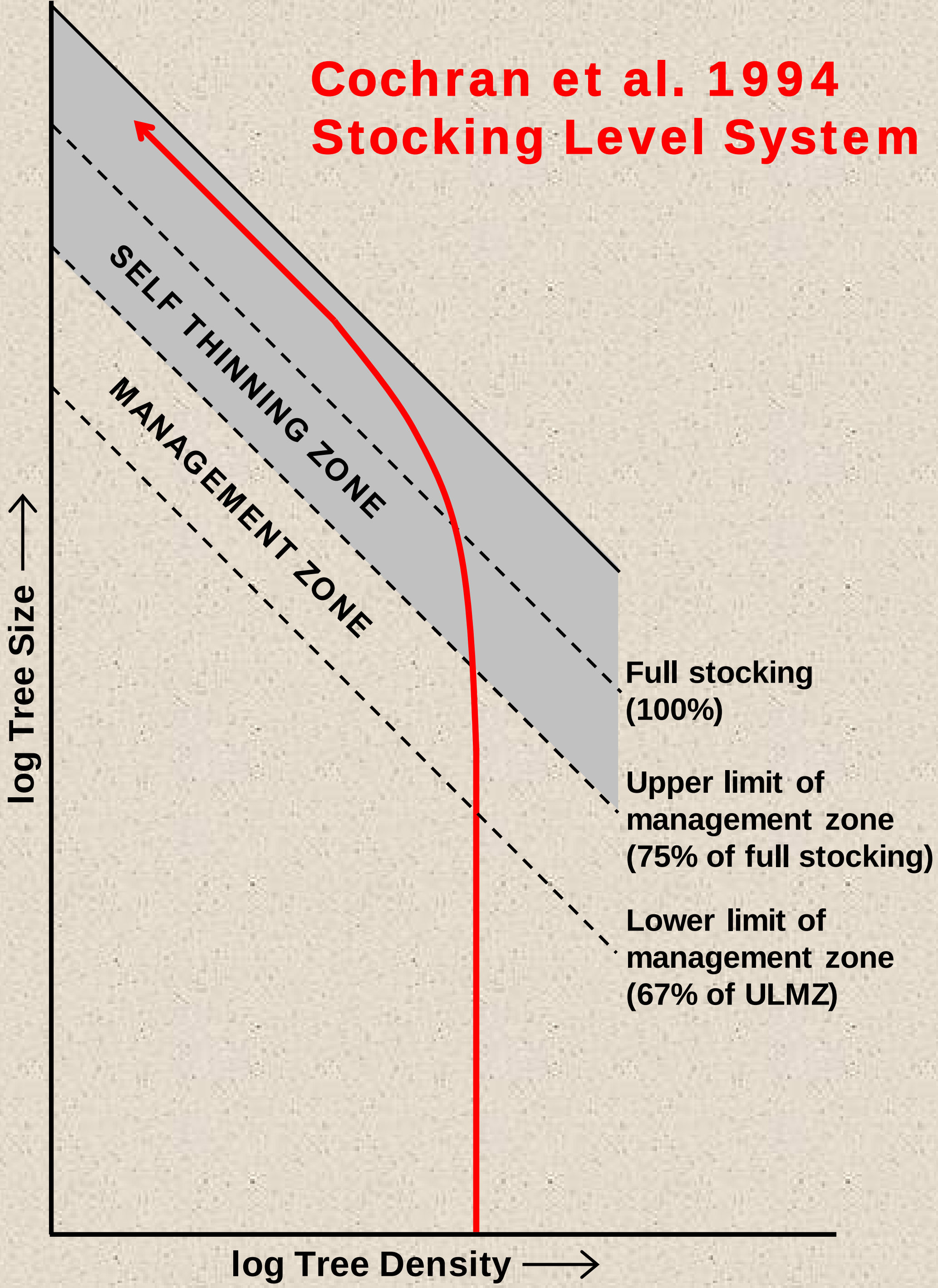
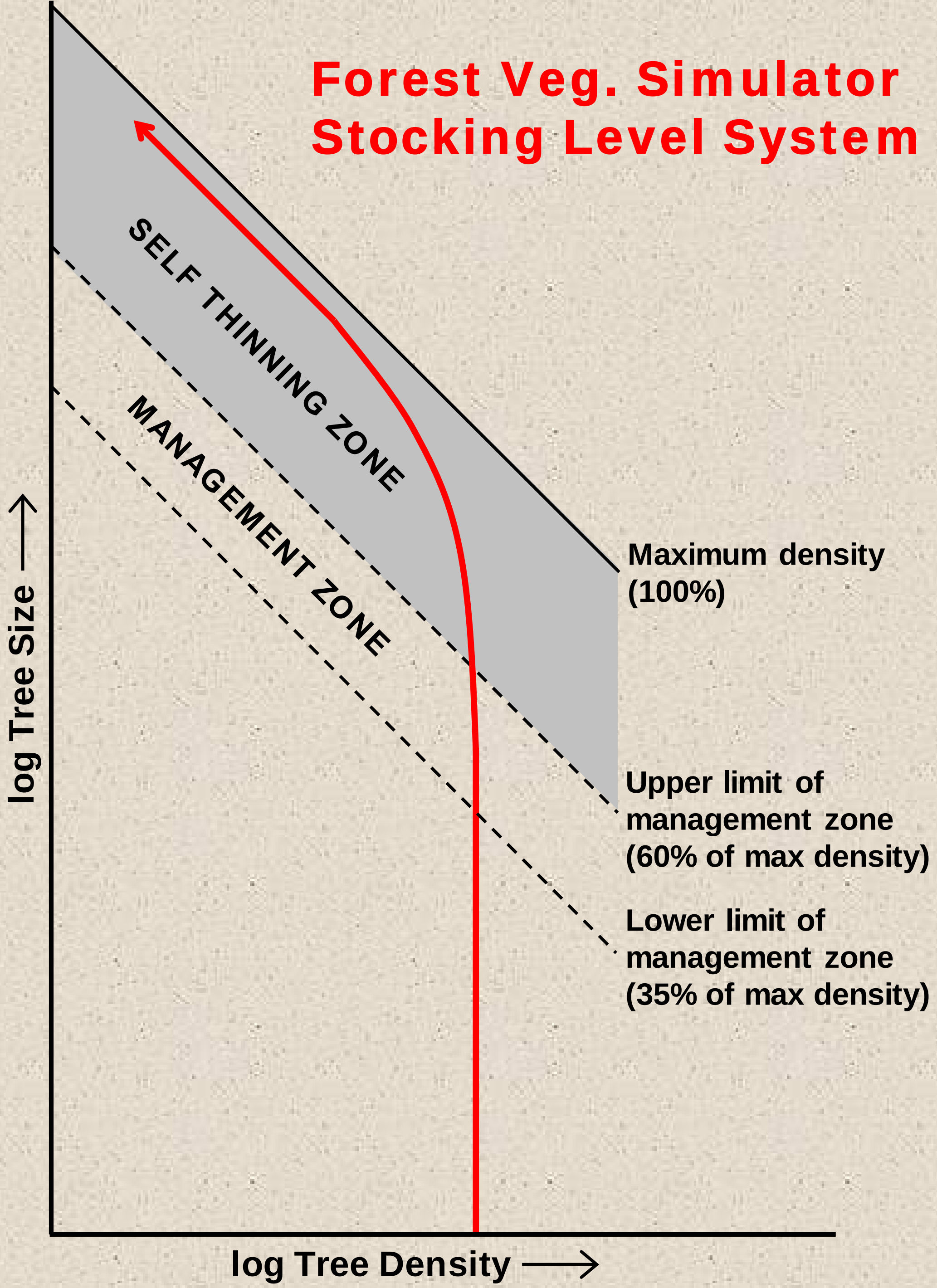
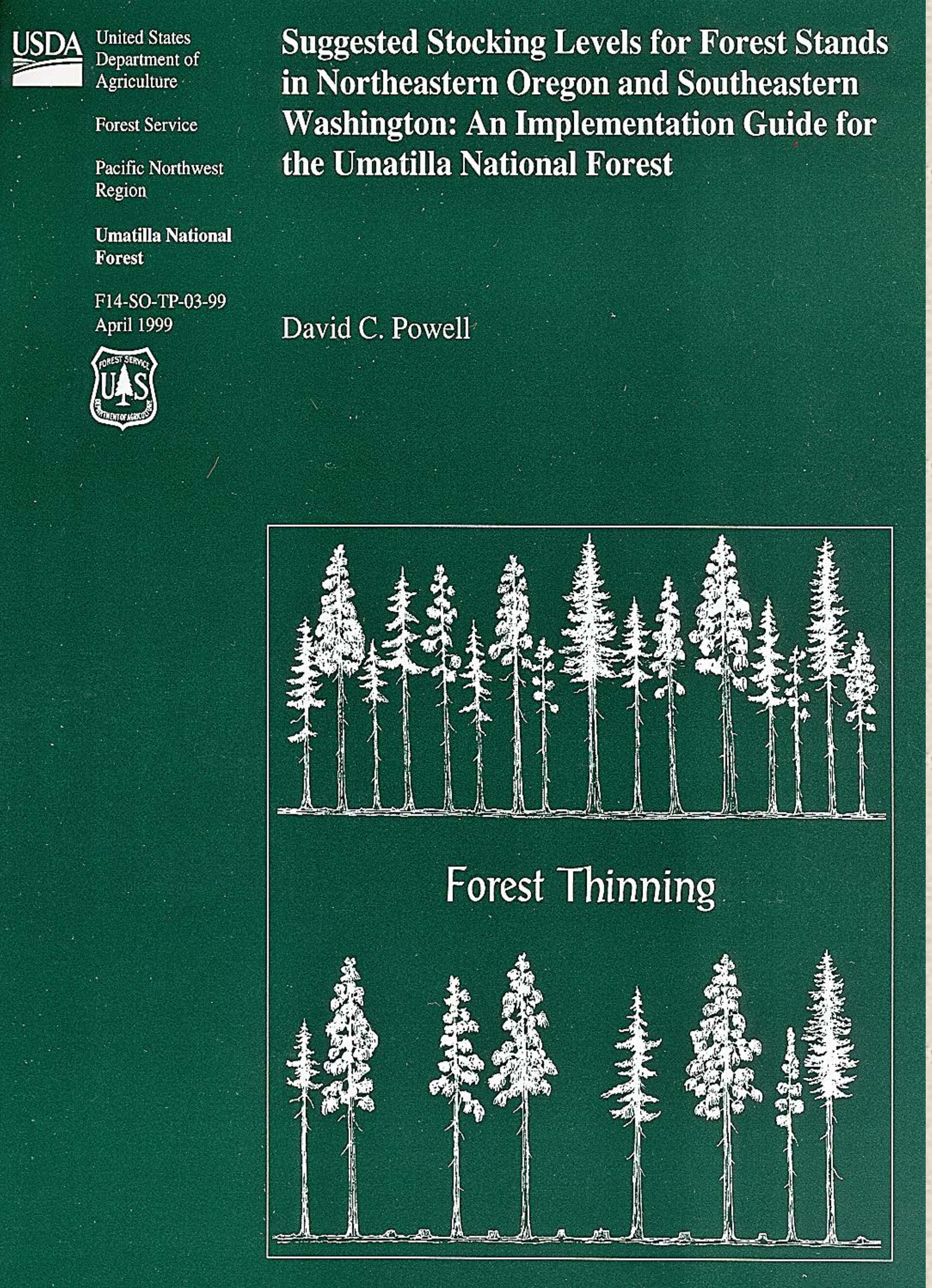
Suggested stocking levels for Blue Mountains are presented in a Research Note from April 1994. It provides site-specific stocking levels for 7 species and 66 plant associations – a total of 462 possible combinations. I am not aware that this level of detail has been developed elsewhere.



In Cochran et al. 1994, a goal is to avoid the self-thinning zone. A management zone was defined, and its upper limit (ULMZ) was set at the lower limit of the self-thinning zone: any stand maintained below the ULMZ would avoid self-thinning mortality. For all species except ponderosa and lodgepole pines, the **ULMZ is 75% of full stocking**. The ULMZ for pines was adjusted for bark-beetle risk. The lower limit of the management zone or **LLMZ is 67% of the ULMZ** for all 7 tree species.



The Forest Vegetation Simulator bases density management regimes on maximum density, not on full stocking (normal density). When using FVS, the **ULMZ is 60% of max density**. (The ULMZ for pines must still be adjusted for bark-beetle risk, so it won't be a straight 60% of max density, as for other tree species.) The lower limit of the management zone or **LLMZ is 35% of maximum density** (this would also vary for pines due to bark-beetle risk).


USDA United States Department of Agriculture

Forest Service

Pacific Northwest Region

Umatilla National Forest

F14-SO-TP-03-99
April 1999

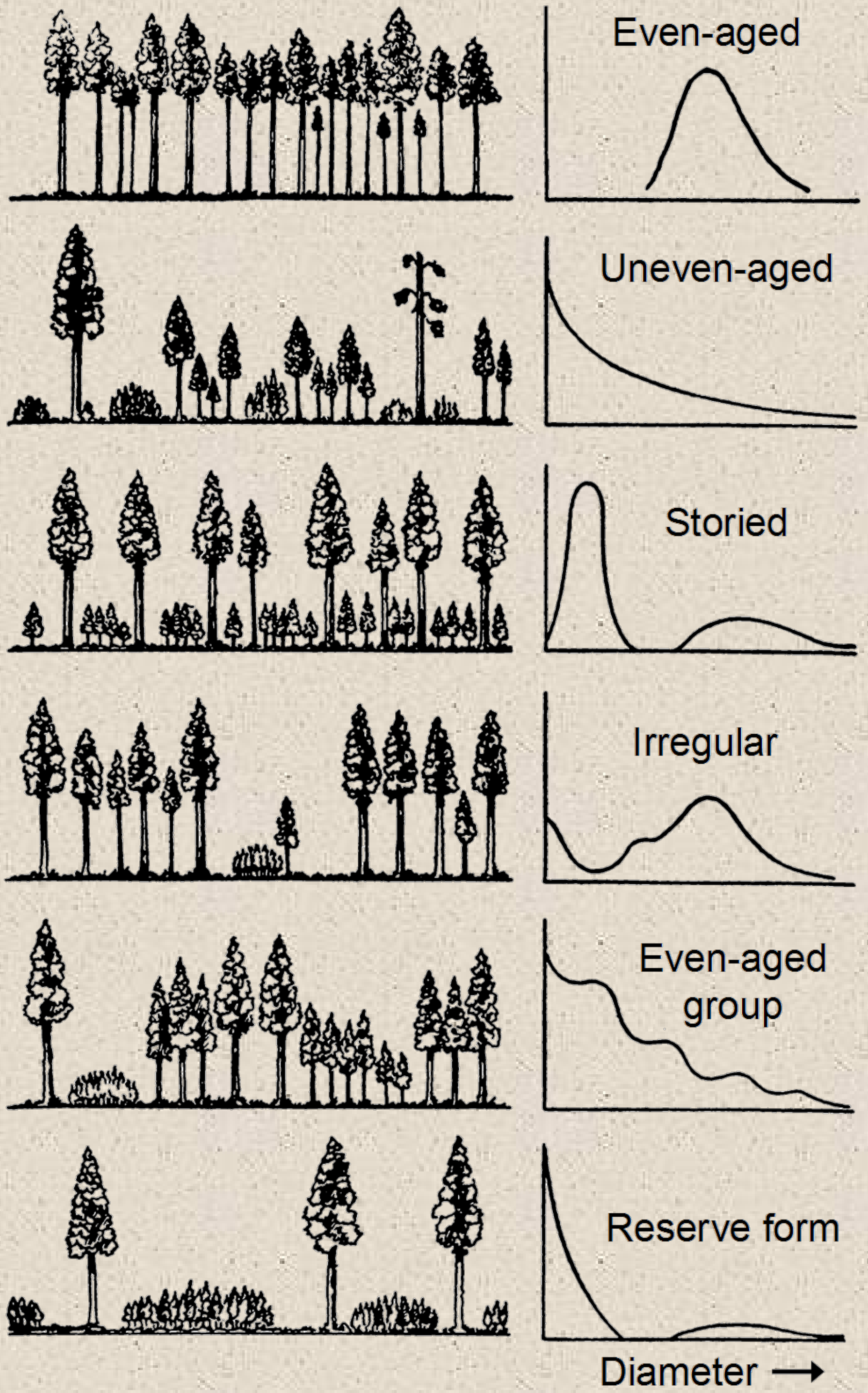
Suggested Stocking Levels for Forest Stands in Northeastern Oregon and Southeastern Washington: An Implementation Guide for the Umatilla National Forest

David C. Powell

After the Cochran research note was published in 1994, Umatilla NF silviculturists began asking for additional stocking information to help apply the Cochran results:

- SDI values for the ULMZ
- SDI values for the LLMZ
- Basal area for all levels
- Data for irregular stands
- Data for uneven-aged stands
- Data for range of QMDs
- Canopy cover information
- Intertree spacing information

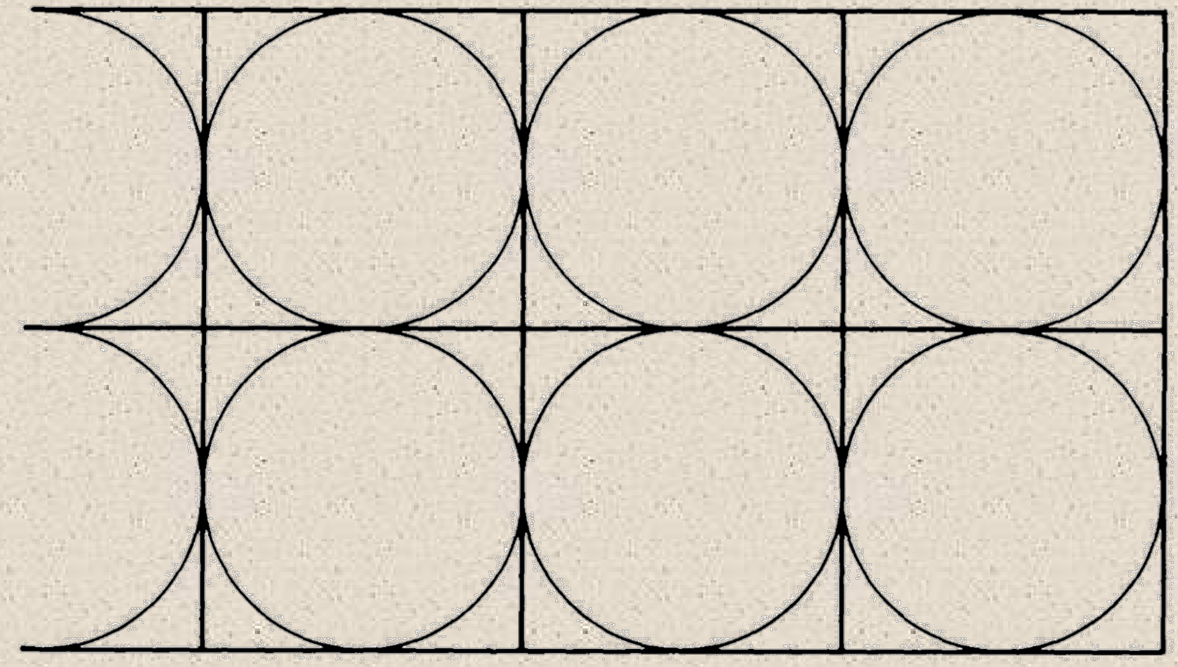
So in 1999, I developed an implementation guide to provide this information and help **users apply the Cochran stocking results**.

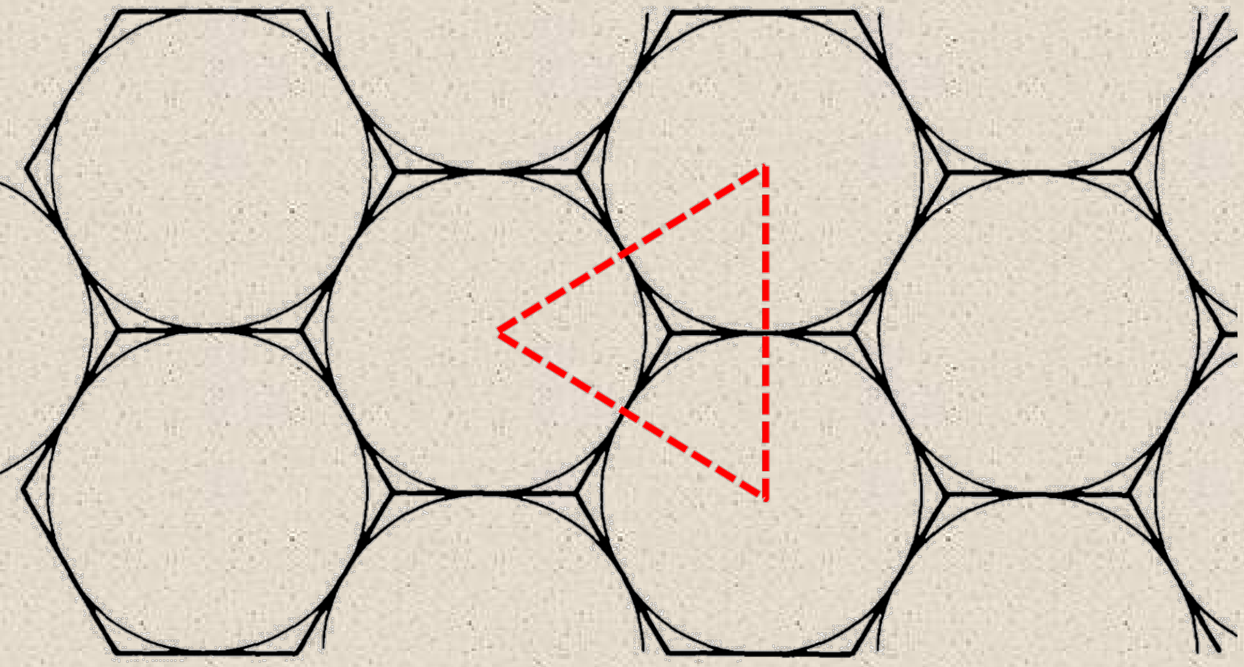


Forest stands have a variety of diameter distributions and six of them are shown here (from Daniel et al. 1979). Even-aged stands have a normal, bell-shaped diameter distribution.

CAUTION: Reineke developed stand density index using even-aged stands: “This stand-density index, based on the relationship between number of trees per acre and their average diameter, is premised on the characteristic distribution of tree sizes in even-aged stands” (Reineke 1933, pg. 627, first paragraph).

NOTE: The Dsum SDI method (Diameter-summation) calculates SDI by diameter class; it is used with stand structures that are not even-aged.



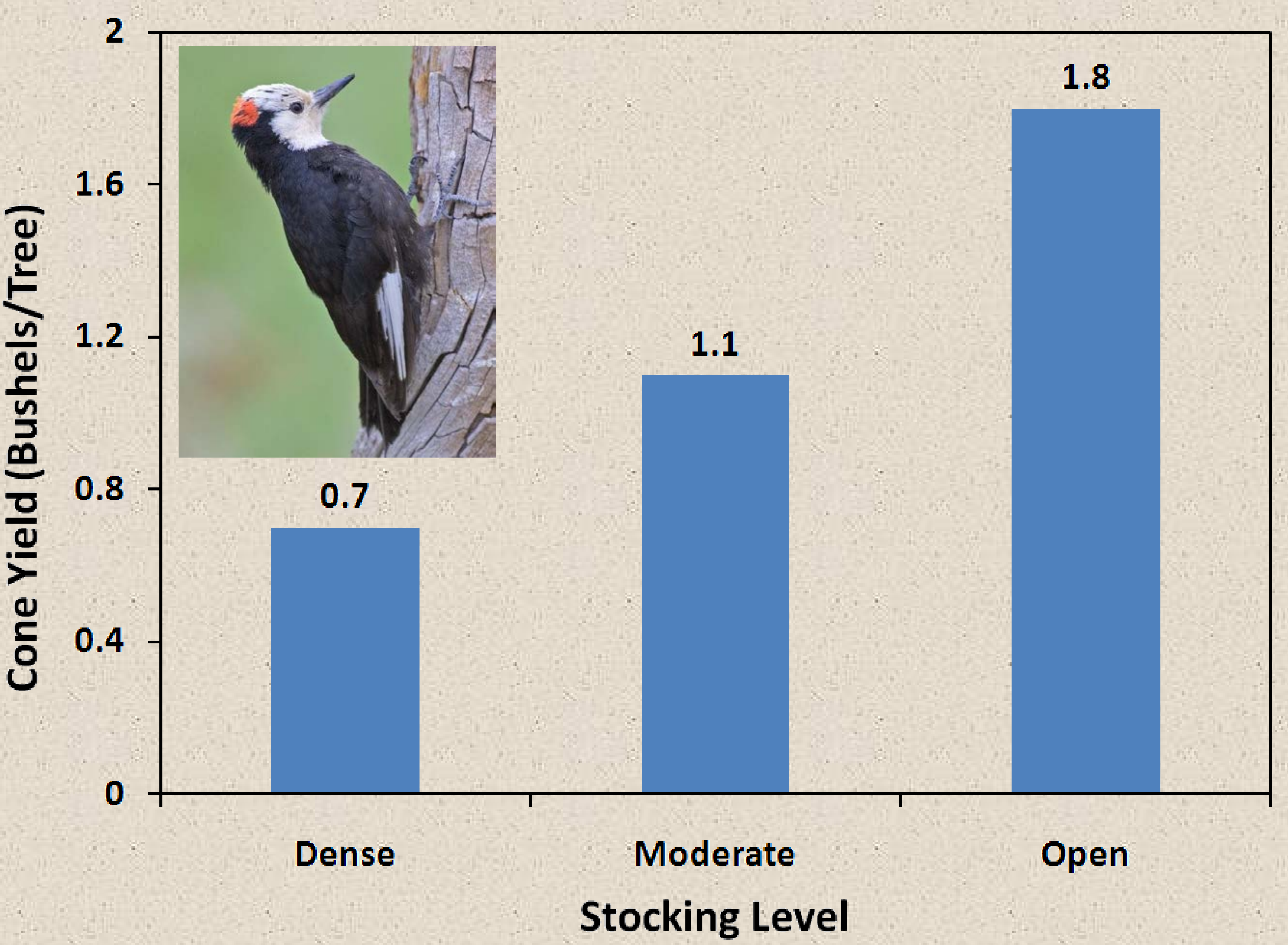


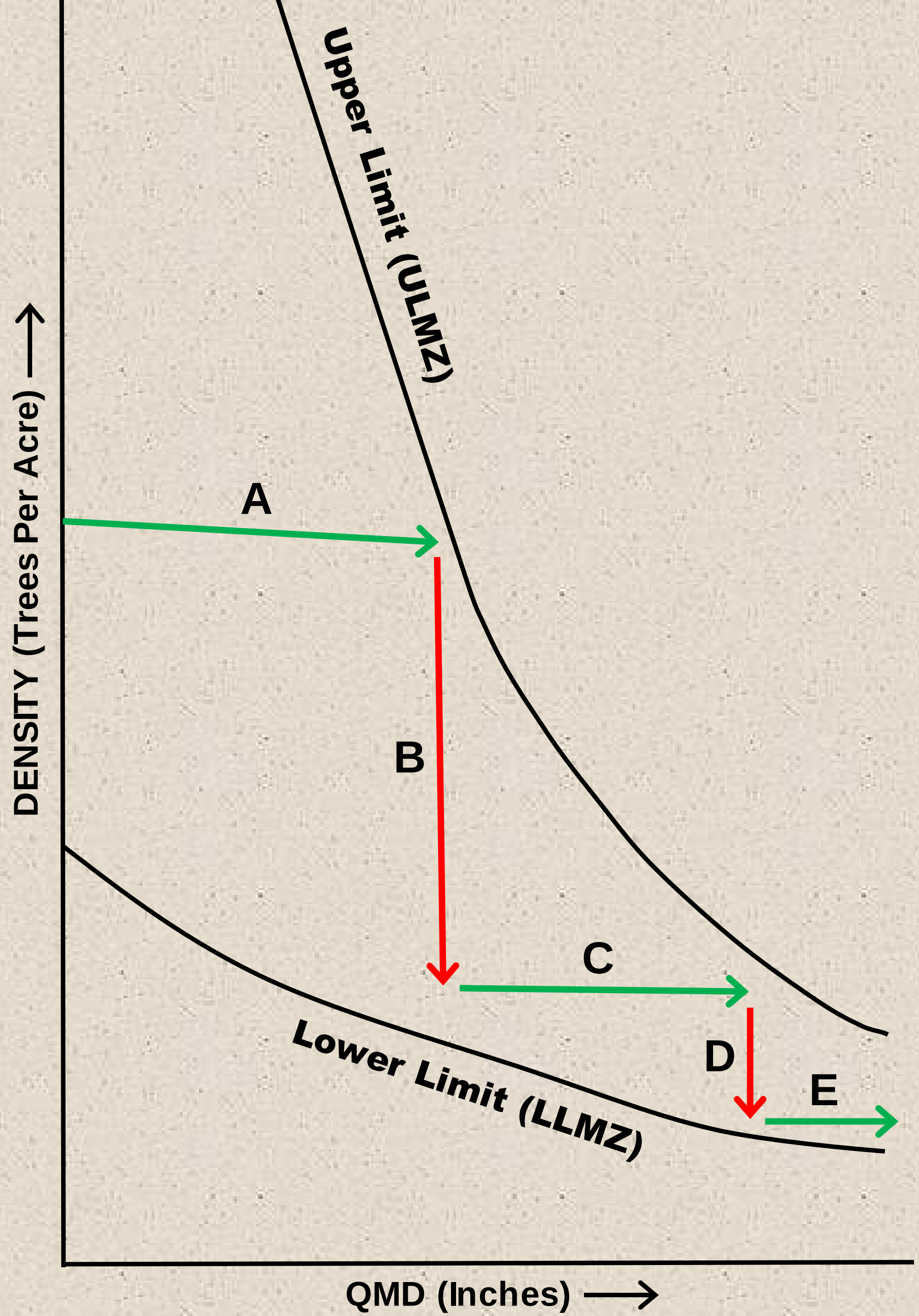
Density can also be expressed as intertree spacing:

Square spacing, where crowns (circles) occupy the center of an adjacent square.

Equilateral spacing, where crowns occupy adjacent hexagons. Known as equilateral spacing because an equilateral triangle is formed by connecting the centers of three adjacent hexagons.

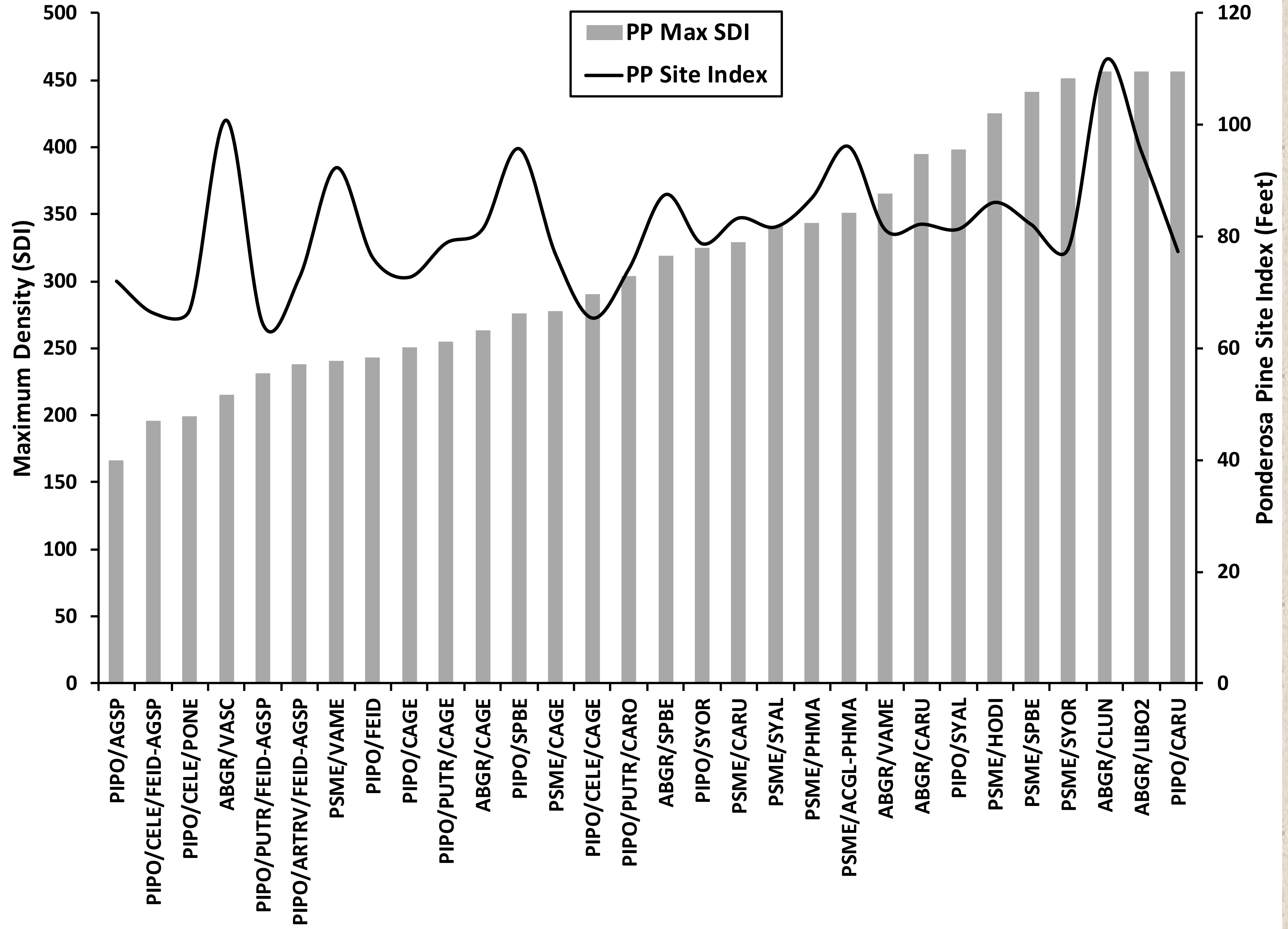
Low Stand Density = More PP Seed = Better White-Headed Woodpecker Habitat (Pearson 1912, Krannitz & Duralia 2004)

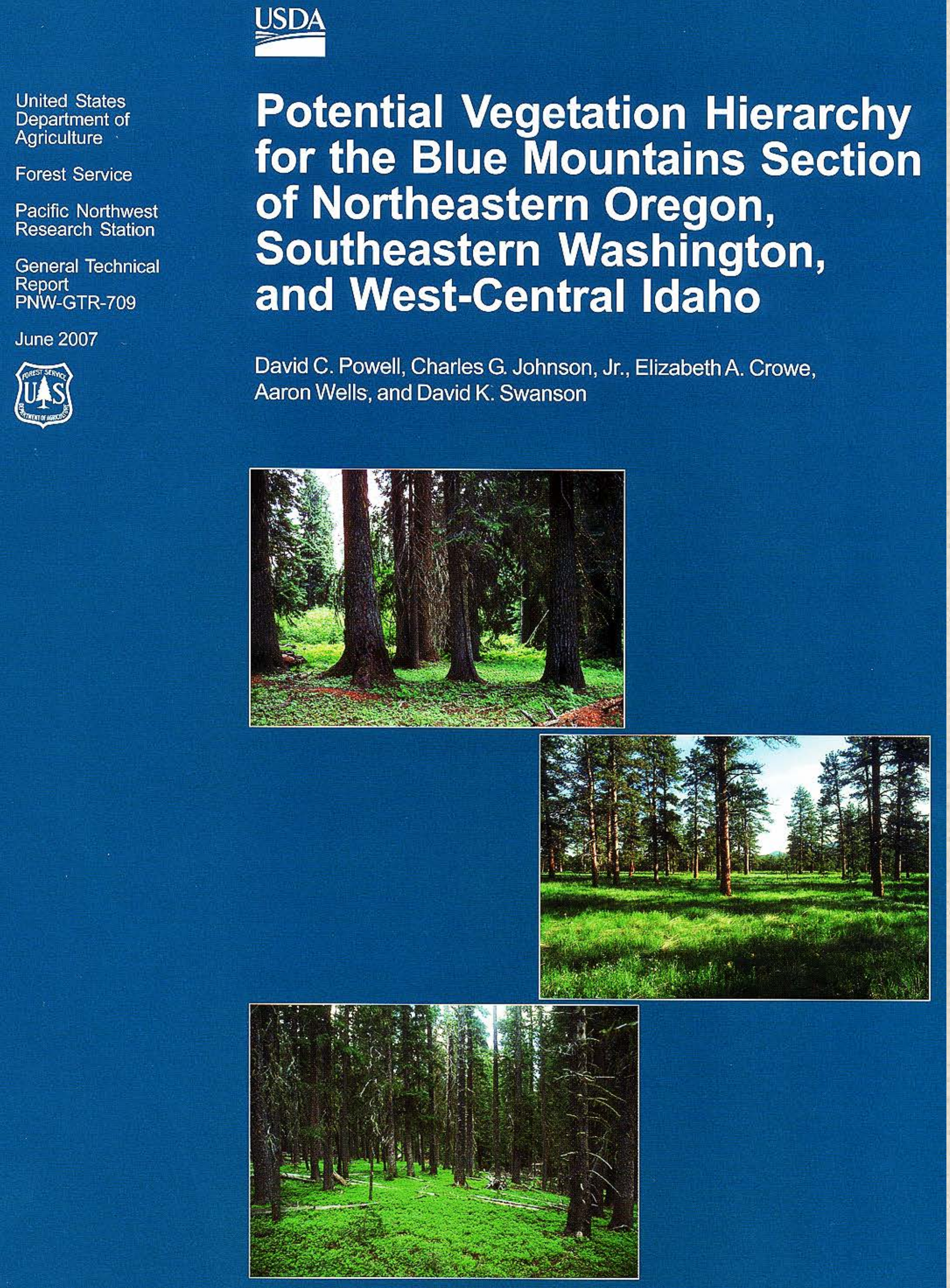




A hypothetical thinning regime using the upper and lower limits of a management zone. In this example, initial density begins in the management zone and growth causes stand QMD to move toward the upper limit (segment A); a thinning then drops the trajectory back into the management zone (segment B is the thinning). Same process for other segments (green is growth; red is thinning).

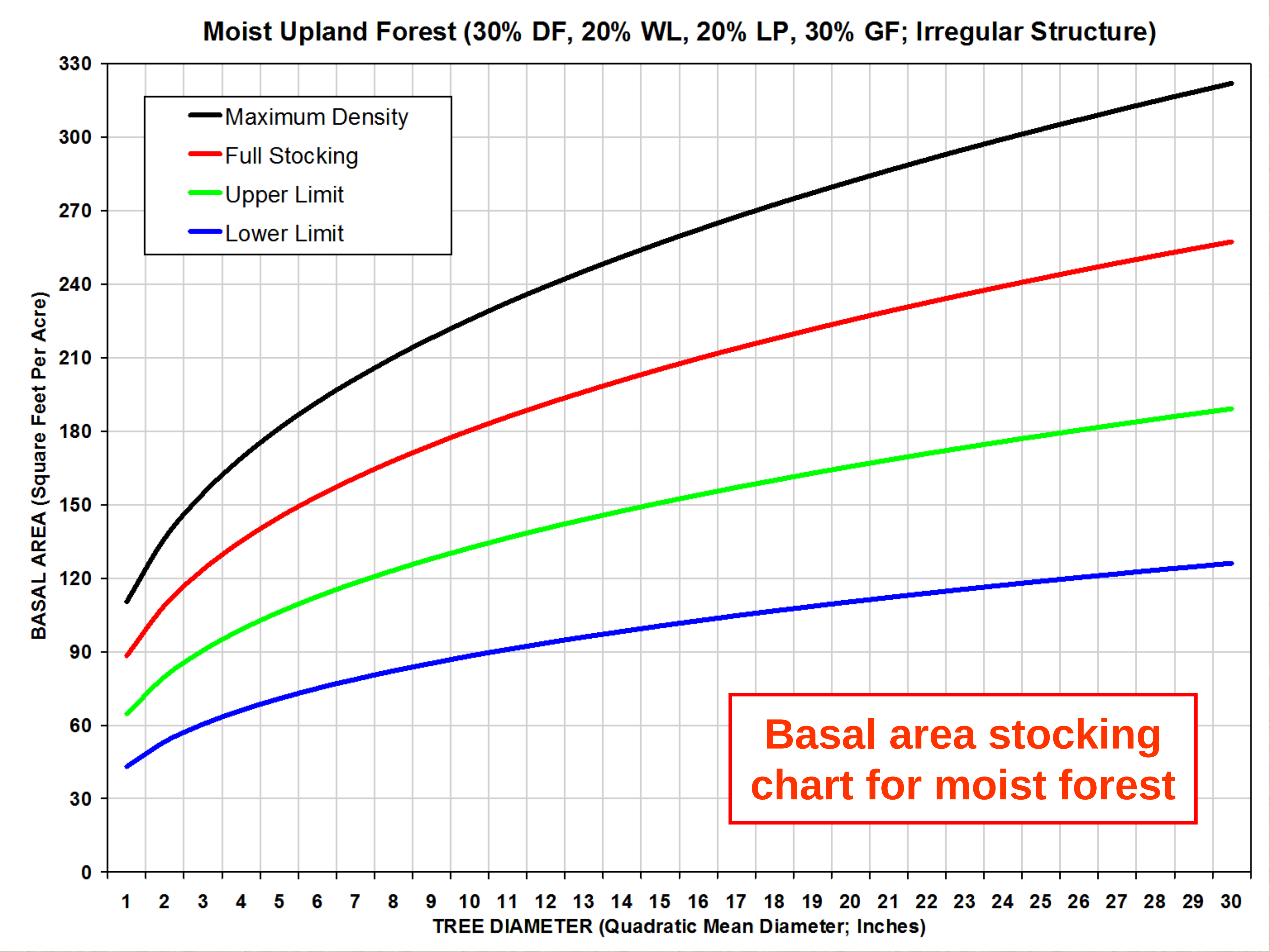
Max SDI better reflects site quality than site index!





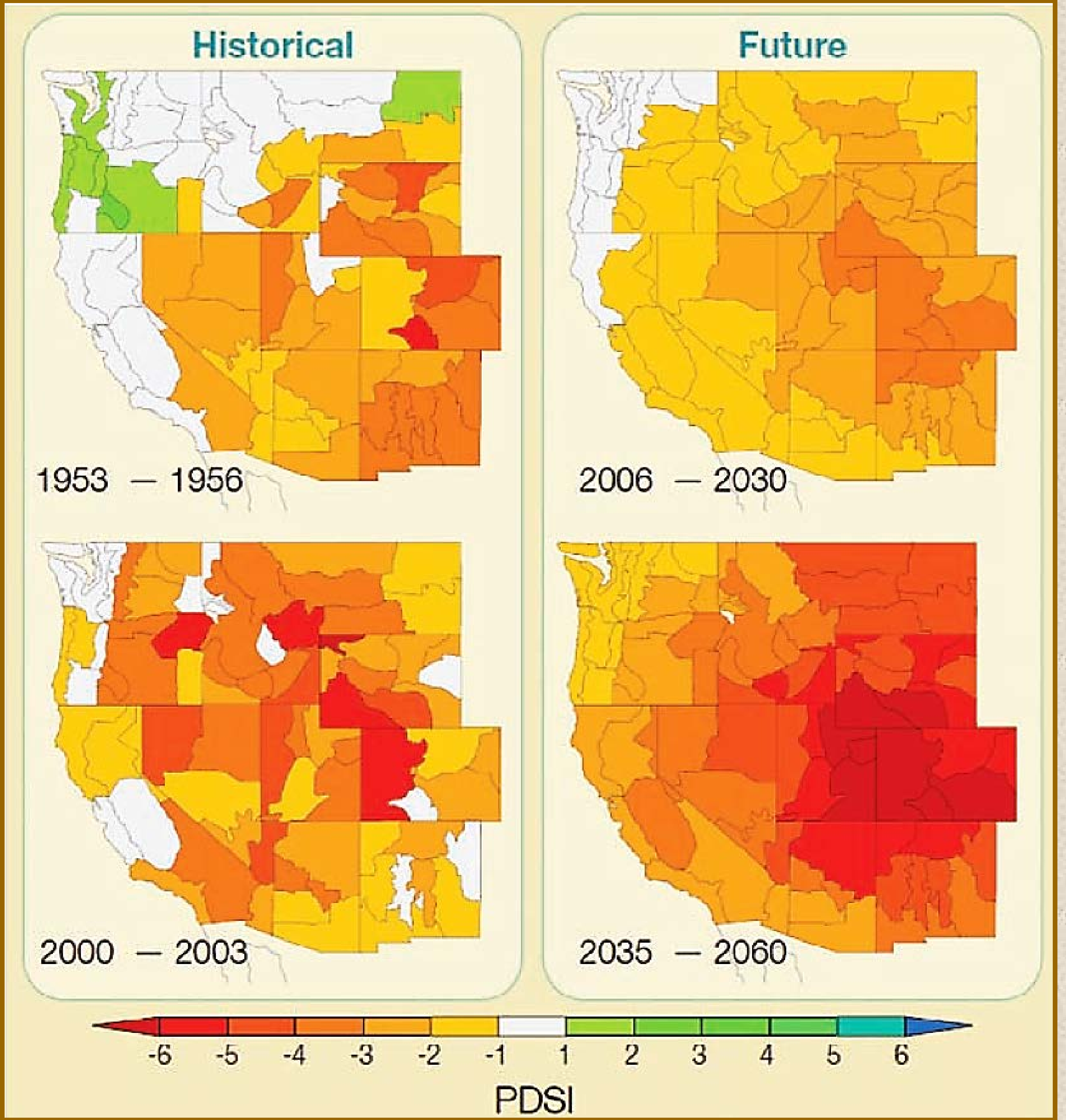
Mid-Scale Stocking Data

The Blue Mountain national forests spent more than a decade working with our area ecologists to develop a system for assigning the 507 potential vegetation types (plant associations, plant community types, and plant communities) to plant association groups (PAGs) and potential vegetation groups (PVGs). **This GTR provides tables showing how 507 ecoclass codes for the Blues were assigned to PAGs and PVGs.**



Moist Upland Forest (30% DF, 20% WL, 20% LP, 30% GF; Irregular Structure)
Maximum Density
Full Stocking
Upper Limit
Lower Limit
BASAL AREA (Square Feet Per Acre)
330
300
270
240
210
180
150
120
90
60
30
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
TREE DIAMETER (Quadratic Mean Diameter; Inches)
Basal area stocking chart for moist forest

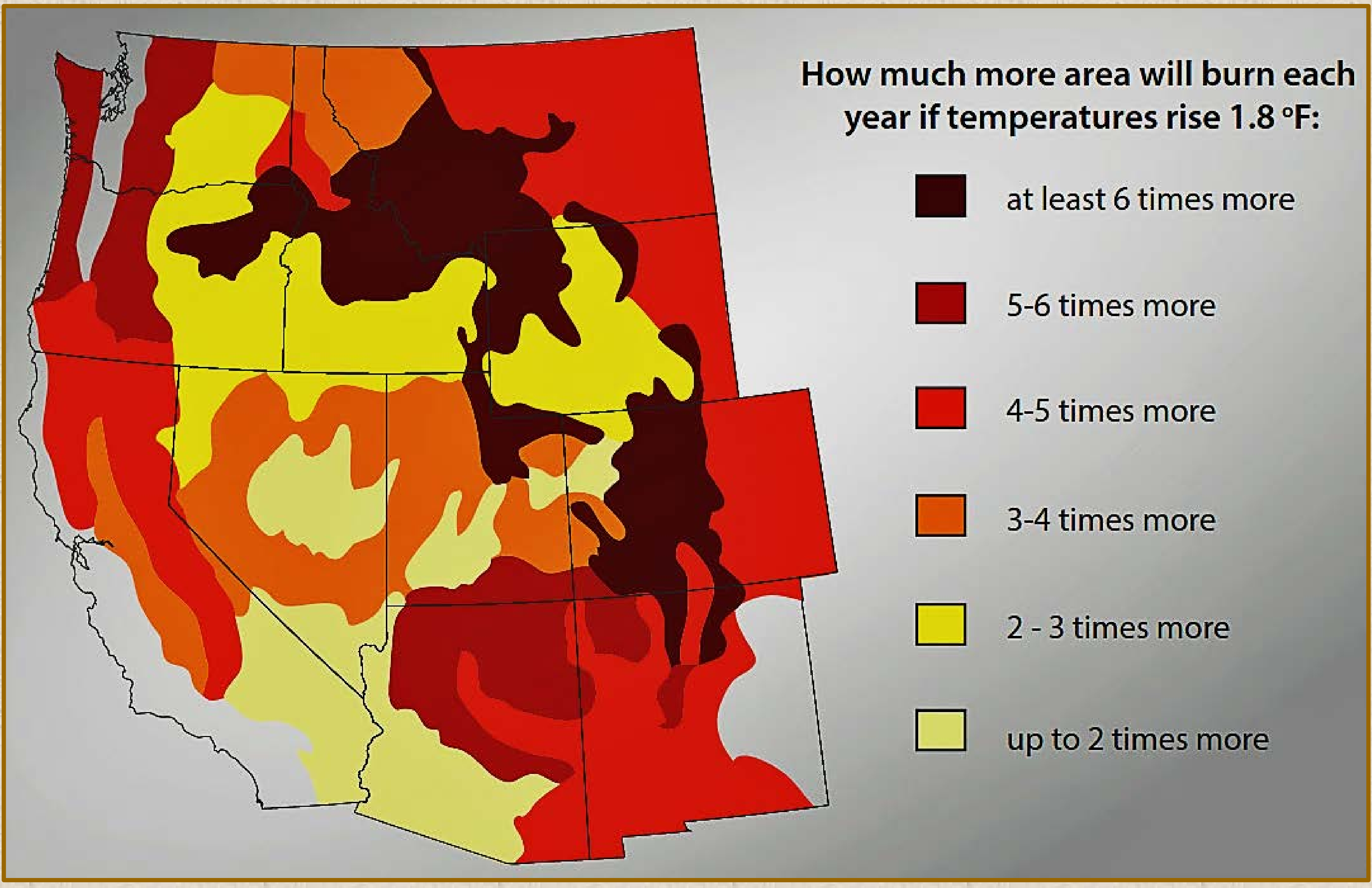
Density Mgmt. and Climate Change



An important factor affecting future forest distribution is drought, which integrates temperature and precipitation (PDSI: Palmer Drought Severity Index).

Research suggests that forests won't just 'waste away' from drought; they will be driven past tipping points by wildfire or another disturbance process acting with uncharacteristic severity or frequency.

Often, fire acts as a driving force, pushing forests into places they haven't been, or at least not recently.



Source: The Age of Western Wildfires report (September 2012 by Climate Central); derived from a National Research Council study in 2011

Estimating Crown Fire Susceptibility for Project Planning

David C. Powell

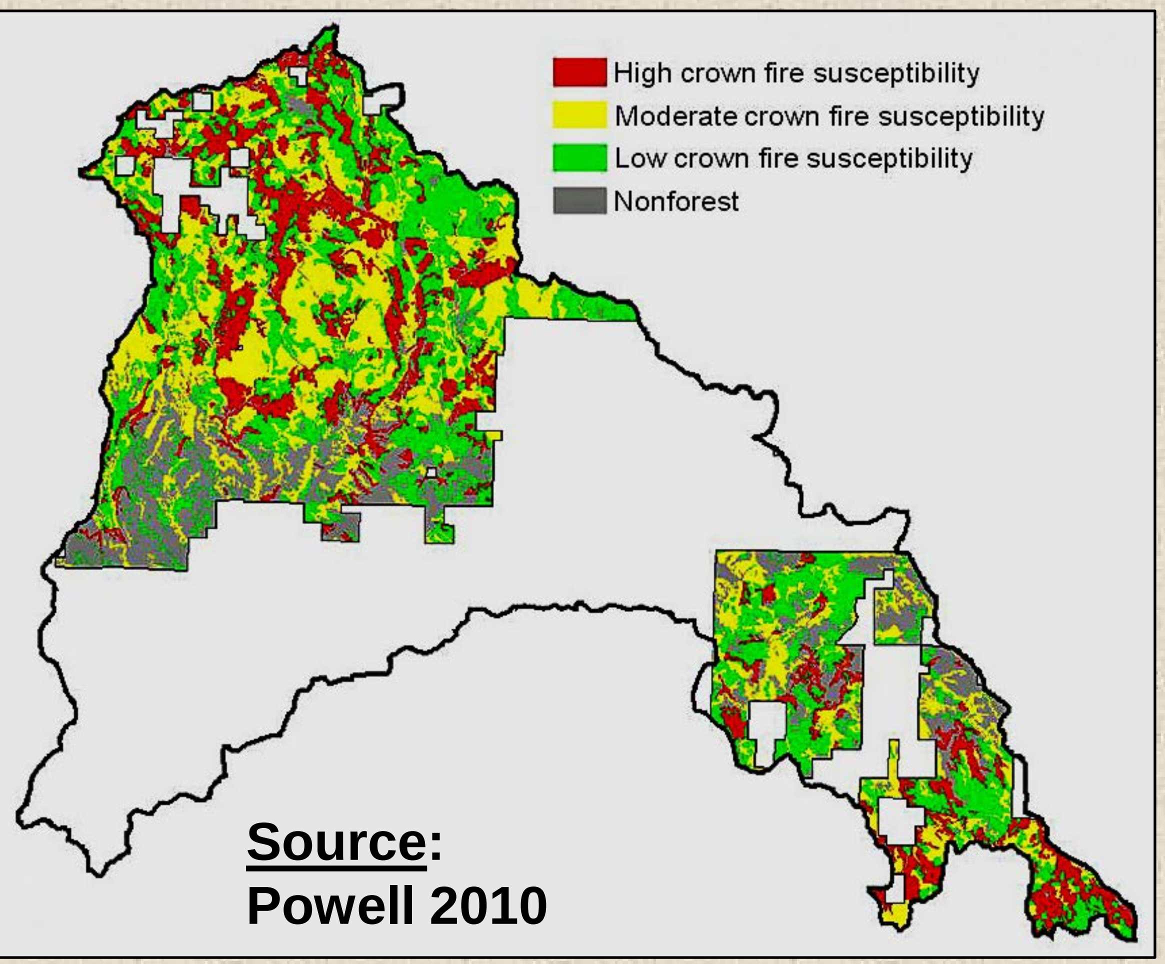
Fire managers traditionally recognize three types of fire (Pyne and others 1996):

- Ground fires burning in organic materials such as peat;
- Surface fires burning in herbs and other fuels lying on or near the ground surface; and
- Crown fires burning in elevated canopy fuels.

When considering fire effects on vegetation and other ecosystem components, crown fire is acknowledged to be the most severe of the three fire types. Although crown fire is normal and expected for fire regimes III, IV, and V (Schmidt and others 2002), a large amount of crown fire is neither normal nor expected for the dry forests of fire regime I (Agee 1993). (See box on

Crown fire in the Blue Mountains, OR, showing the long flame lengths and high fireline intensity typically produced by crown fire. Photo: David Powell, Umatilla National Forest.

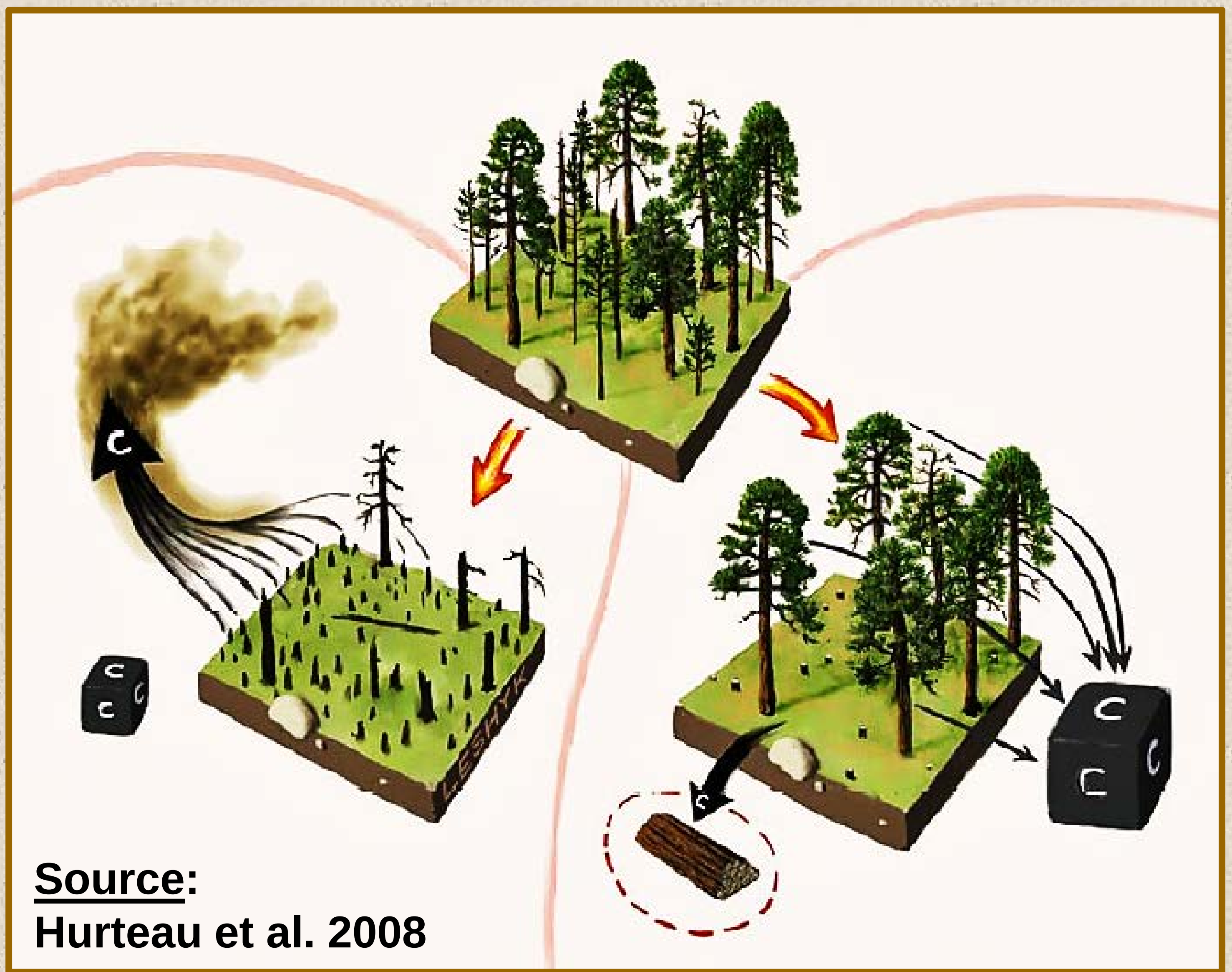
COVER TYPE GROUPS[1]	CROWN FIRE SUSCEPTIBILITY: STAND DENSITY INDEX LOW (≤.05 kg/m^3 CBD)	MODERATE (.06−.09 kg/m^3 CBD)	HIGH (≥.10 kg/m^3 CBD)
Ponderosa pine	≤ 140	141-364	≥ 365
Douglas-fir	≤ 100	101-249	≥ 250
Grand fir	≤ 70	71-199	≥ 200



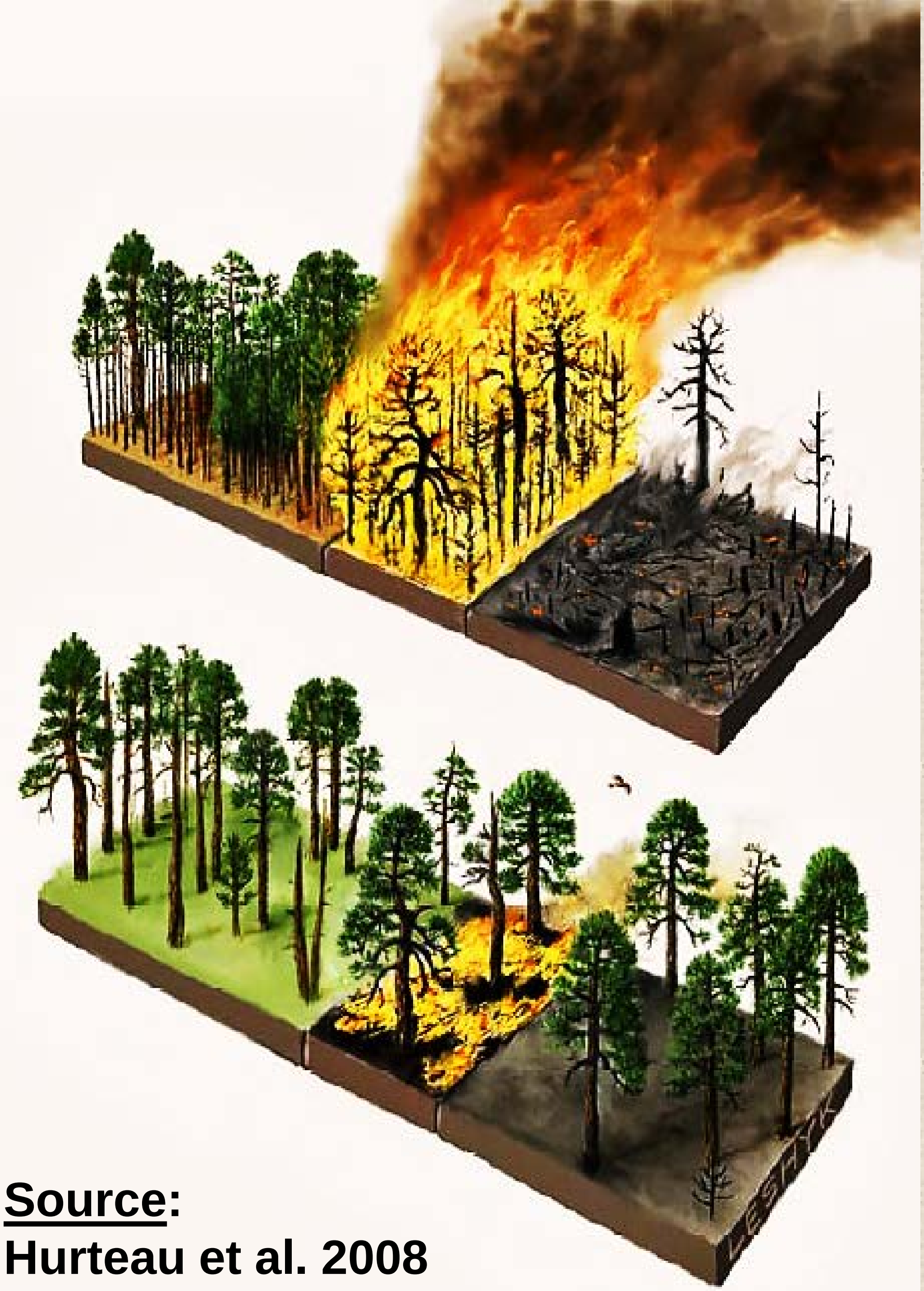
<u>Source</u>:
Powell 2010

I quantified 3 categories of crown fire suscep-tibility (high, moderate, low) for 5 stand density metrics (stand density index, trees per acre, basal area per acre, canopy cover, and equilateral tree spacing).

When starting with an intact forest, management (thinning) sequesters more carbon than allowing it to burn, while maintaining a fully functional forest.



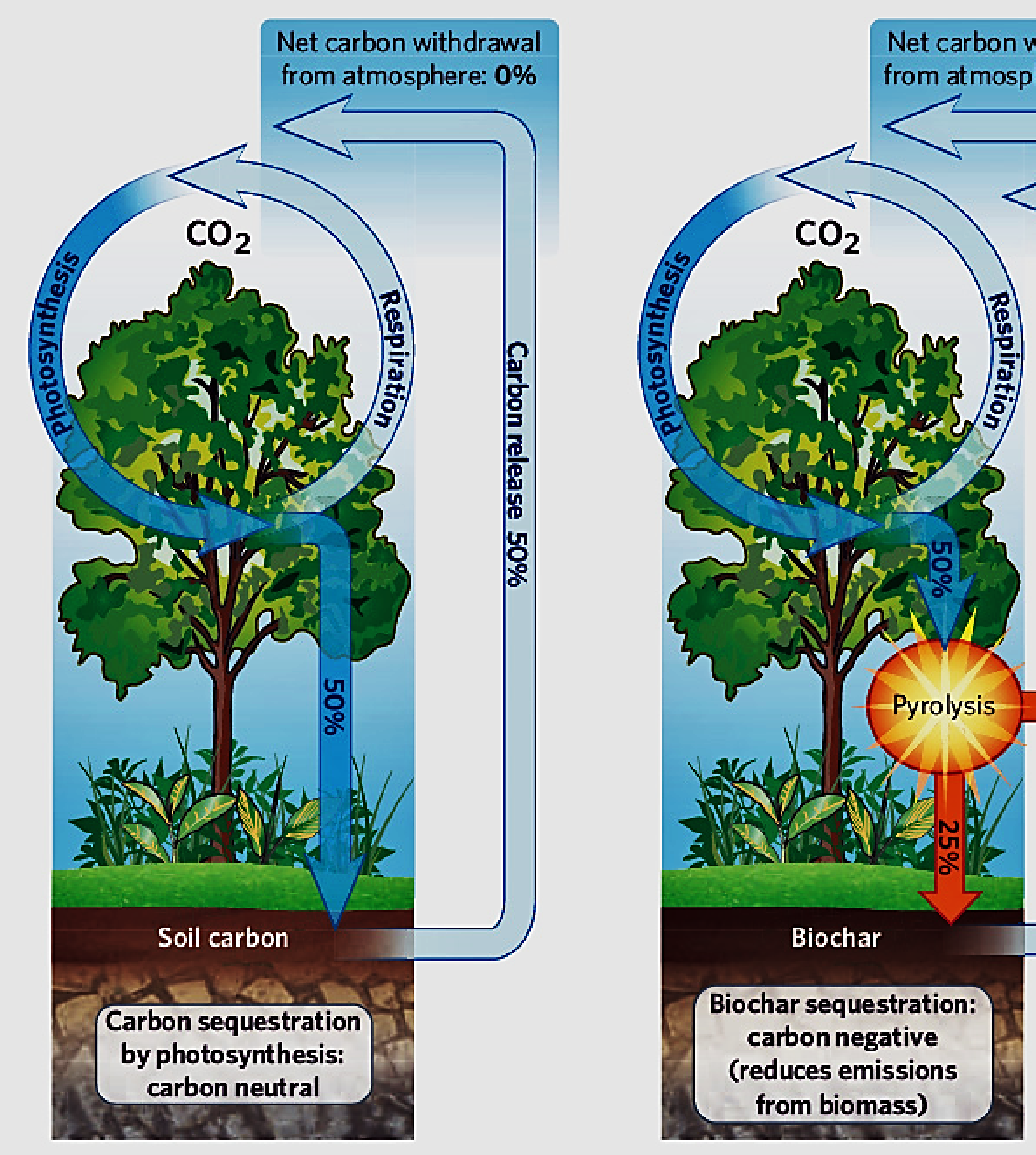
Source:
Hurteau et al. 2008



Source:
Hurteau et al. 2008

Not all fire is created equal. High-severity fire (top) kills most trees (including large ones), releases lots of greenhouse gas, and has little sequestration value. Low-severity fire (bottom) lets large trees survive, reduces fire risk, thins small trees, and also provides carbon sequestration benefit.

Note that charcoal (from pyrolysis) is C negative



Source: Lehmann 2007

Fossil fuels: C positive

Live plants: C neutral

Biochar: C negative

Our ability to manage density will control whether future forests are resilient to climate change