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Center for Research on Sustainable Forests

Silviculture for Acadian Spruce-Fir Forests

A New Stocking Guide & Density Management Diagram for Acadian Spruce-fir Forests

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BACKGROUND

Accurate determination of stand stocking is crucial in making rigorous silvicultural prescriptions that optimally utilize available growing space over the rotation. Recent research (Ray et al. 2023) has demonstrated that both commonly used stocking-assessment tools—density management diagrams and stocking guides—can be developed using a common, consistent, and biologically based reference that can be adapted to specific regions and/or forest types. Maximum attainable density at a given average tree size (i.e., quadratic mean diameter, QMD) is estimated by regression analysis from a large sample of fully stocked stands, and then stocking is quantified using the concept of relative density (RD; the actual density relative to this maximum at the same QMD). This paper presents diagrams of both kinds adapted from Ray et al. (2023), intended for practical and theoretical use in the Acadian spruce-fir region.

The ***Density Management Diagram*** (DMD; Figure 4.1) follows Reineke's (1933) Stand Density Index (SDI) model with QMD and trees per acre (TPA) as the main axes, both transformed logarithmically. SDI is defined as the number of 10-inch dbh trees per acre at 100% relative density. The maximum SDI for this diagram was set at 548 based on the state- and forest-type–level summaries of Woodall and Weiskittel (2021) weighted by the areas in each state and ecoregion (Table 4.1).

The ***Stocking Guide*** (SG; Figure 4.2) follows the Gingrich (1967) format, with basal area (BA) and TPA as the main axes, and QMD lines radiating from the origin. Instead of the historical A, B, and C lines, management zones are defined by relative density levels as described in Ray et al (2023).

Both charts are meant to apply to stands dominated (>75% BA+) by northern conifer species with a QMD of at least 4 inches. Stocking of single- and multi-aged stands can be assessed, although the prescription process will differ. If trees under 3 inches dbh are tallied (for example, to assess sapling regeneration in multi-aged stands), do not include them in the calculations of BA and TPA for reasons explained by Curtis (2010).

These charts represent a range-wide average depiction of size-density relationships for eastern spruce-fir that update earlier work by Wilson et al. (1999) on the basis of an expanded dataset and updated analytical methods. Different range-wide SDIMAX values have been used (e.g., Ray et al. 2023); this one is based on a weighted average. Users interested in deriving location-specific estimates of RD and stocking can make use of the SDIMAX values presented in Table 4.1.

Density Management Zones

Both charts show four density management zones defined by RD, as described by Ray et al. (2023):

Zone of Imminent Competition-caused Mortality (ZICM, in orange): stands in this zone will begin self-thinning at RD = 55% and grow along the upper boundary (RD = 67%).

Zone of Optimal Density Management (ZODM, green): stands in this zone fully occupy the growing space but do not experience self-thinning. To maximize timber yields, formulate thinning schedules to keep stands within this zone bounded by RD = 30% (lower limit) to RD = 55% (upper limit).

Zone of Low-density Management (ZLDM, light green): stands in this zone will exhibit rapid growth of individual trees but somewhat lower stand growth rates than those in the ZODM. The lower limit (RD = 15%) approximates the lower limit of crown closure if trees are released early and heavily.

Understocked: Insufficient density to achieve full crown closure, even if thinned early in stand development.

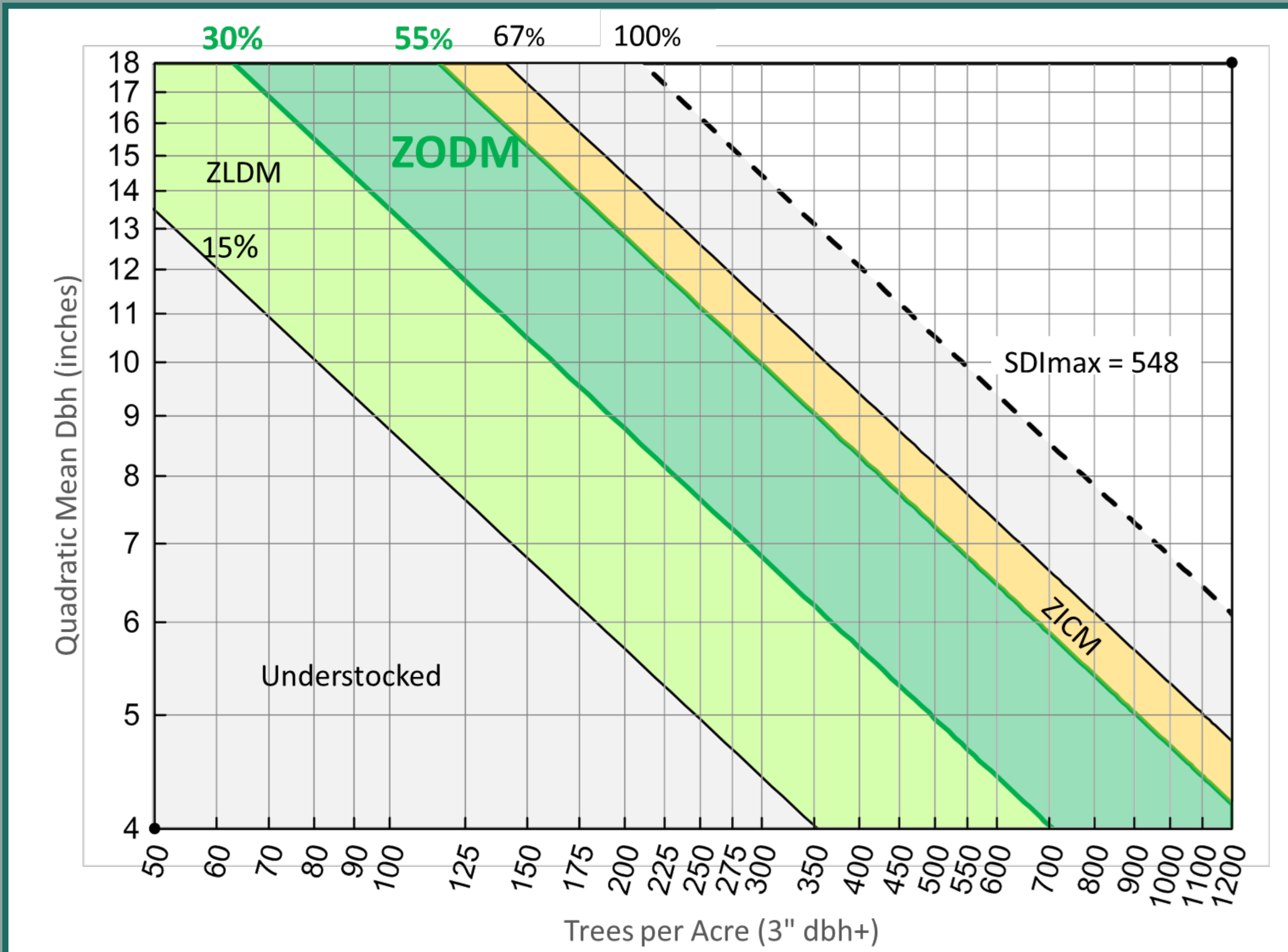

Figure 4.1. Density management diagram for Acadian spruce-fir forests based on a maximum stand density index of 548. Density management zones are defined in the text.

Application

To assess stocking, users must estimate basal area (BA) and trees per acre (TPA). Basal area is readily measured with a prism, angle gauge, or Relasksop, or with fixed-area plots. If using variable radius plots, count the "in" trees at each sample point and multiply by the Basal Area Factor (BAF) to determine BA. Dbh must also be recorded for all "in" trees to obtain TPA.

To calculate TPA from a variable-radius point sample, use the formula:

TPA = BAF/BA, where BAF = the prism basal area factor and BA = the basal area in square feet of each tallied tree, computed as [.00545 * Dbh^2] where Dbh is measured in inches. For example, a 9-inch dbh tree tallied with a 15-BAF prism would equal:

$$15 / [.005454 * 9 * 9] = 33.95 \text{ TPA.}$$

To calculate QMD for the DMD, compute the basal area per tree by dividing the stand BA by the TPA. Then, divide this BA by .005454 and take the square root. For example, the QMD of a stand with BA = 120, TPA = 350 would equal:

$$[(120/350)/0.05454]^{0.5} = 7.93 \text{ inches.}$$

One could also plot the BA-TPA pair on the SG and estimate the QMD graphically in reference to the QMD isolines.

To compute the RD of a stand, first calculate the TPA corresponding to a RD = 100% for a given QMD (the TPAMAX), as follows:

$$TPAMAX = 548 / [(QMD/10)^{1.6}]$$

In the example above,

$TPAMAX = 548/ [(7.93/10)^{1.6}] = 794$ TPA. This is the value at the 100% RD line on either chart for this specific QMD.

The RD is the ratio of the actual TPA to this maximum value, holding QMD constant:

RD = 350/794 = 44%, which would fall within the ZODM.

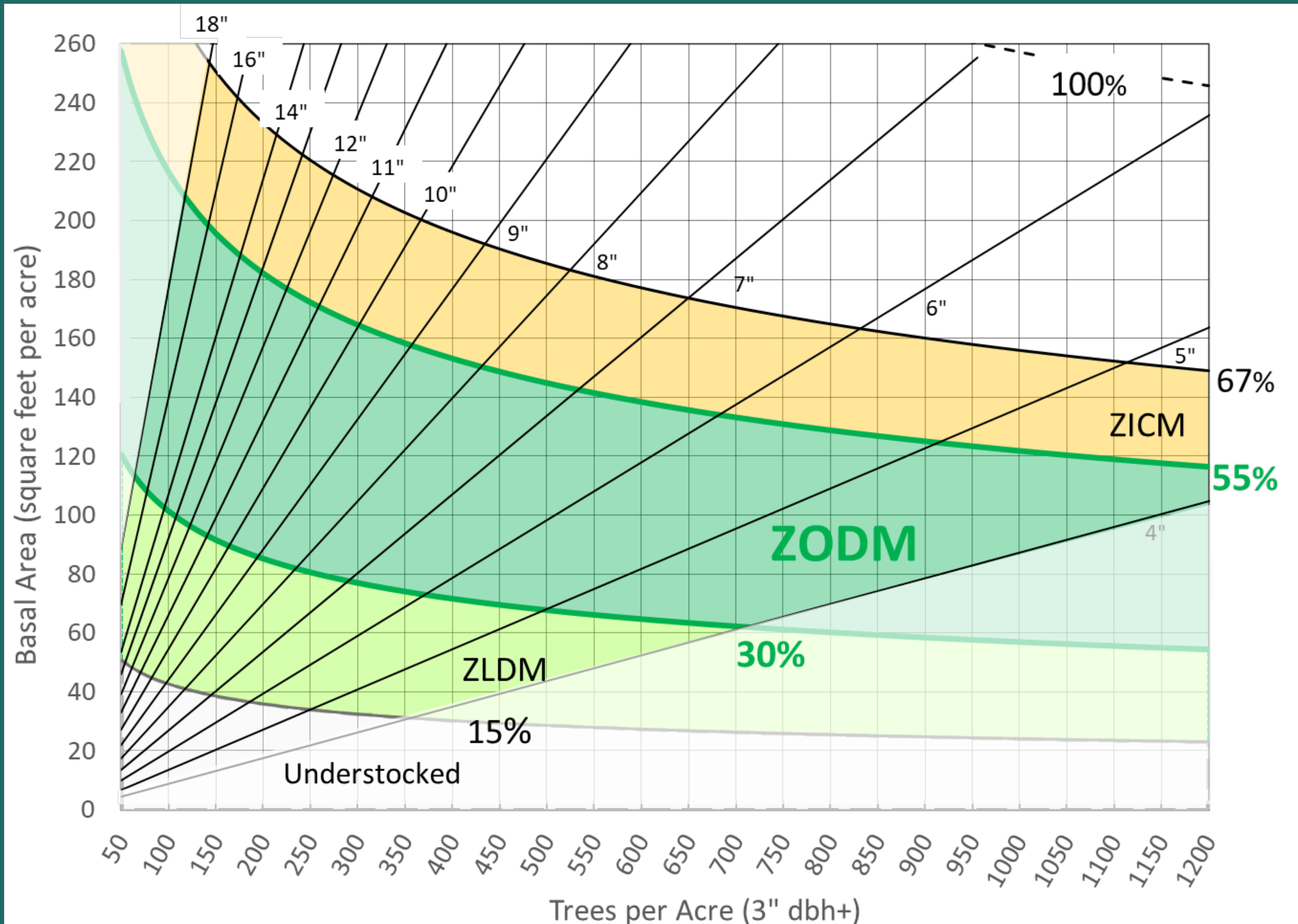

Figure 4.2. Stocking guide for Acadian spruce-fir forests based on a maximum stand density index of 548. Density management zones are defined in the text.

Table 4.1. Estimates maximum stand density index (SDImax) by state, forest type, and ecoregion. Additional states, forest type, and ecoregions can be found online at: https://doi.org/10.6084/m9.figshare.24412246.v1

State	Ecoregion	SDImax
	Spruce-Fir	
Maine	Acadian Plains and Hills	542
	Northern Appalachian and Atlantic Maritime Highlands	527
New Hampshire	Northern Appalachian and Atlantic Maritime Highlands	636
New York	Eastern Great Lakes Lowlands	323
	Northern Appalachian and Atlantic Maritime Highlands	640
Vermont	Northern Appalachian and Atlantic Maritime Highlands	613
	Spruce	
Maine	Acadian Plains and Hills	547
	Northern Appalachian and Atlantic Maritime Highlands	564
New Hampshire	Northern Appalachian and Atlantic Maritime Highlands	597
New York	Eastern Great Lakes Lowlands	575
	Northeastern Coastal Zone	655
	Northern Allegheny Plateau	430
	Northern Appalachian and Atlantic Maritime Highlands	564
Vermont	Northern Appalachian and Atlantic Maritime Highlands	608

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Acknowledgments

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