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Stand Density Management Charts for Eastern Spruce-Fir Forests

Eastern spruce-fir forests, characterized by red spruce (*Picea rubens*) and balsam fir (*Abies balsamea*), cover millions of acres in the northeastern United States and southeastern Canada. Many spruce-fir forests are managed for wood production and wildlife habitat. To best manage these forests for the resources they provide, it is important to determine the stocking, that is, the size and number of trees in a given stand. The stocking provides different levels of growth and canopy closure, which informs managers when and how to thin the stand.

Researchers from the U.S. Department of Agriculture, Forest Service, Northern Research Station collaborated with partners at the University of Maine and Humboldt University to produce updated stand density management charts for eastern spruce-fir forests. The new decision-support tools provide updated guidance, and results from their use suggest that these forests can maintain a much higher stocking level than was previously recognized.

KEY FINDINGS

- New stand density management charts for eastern spruce-fir forests show that much higher stocking can be maintained than was previously recognized.
- A new stand density management diagram and a stocking guide ensure that more land managers will be able to use the relationships defined in the charts.
- Tools, like the R software package Stand View, make creating density management diagrams and stocking guides that correspond to each other easier.

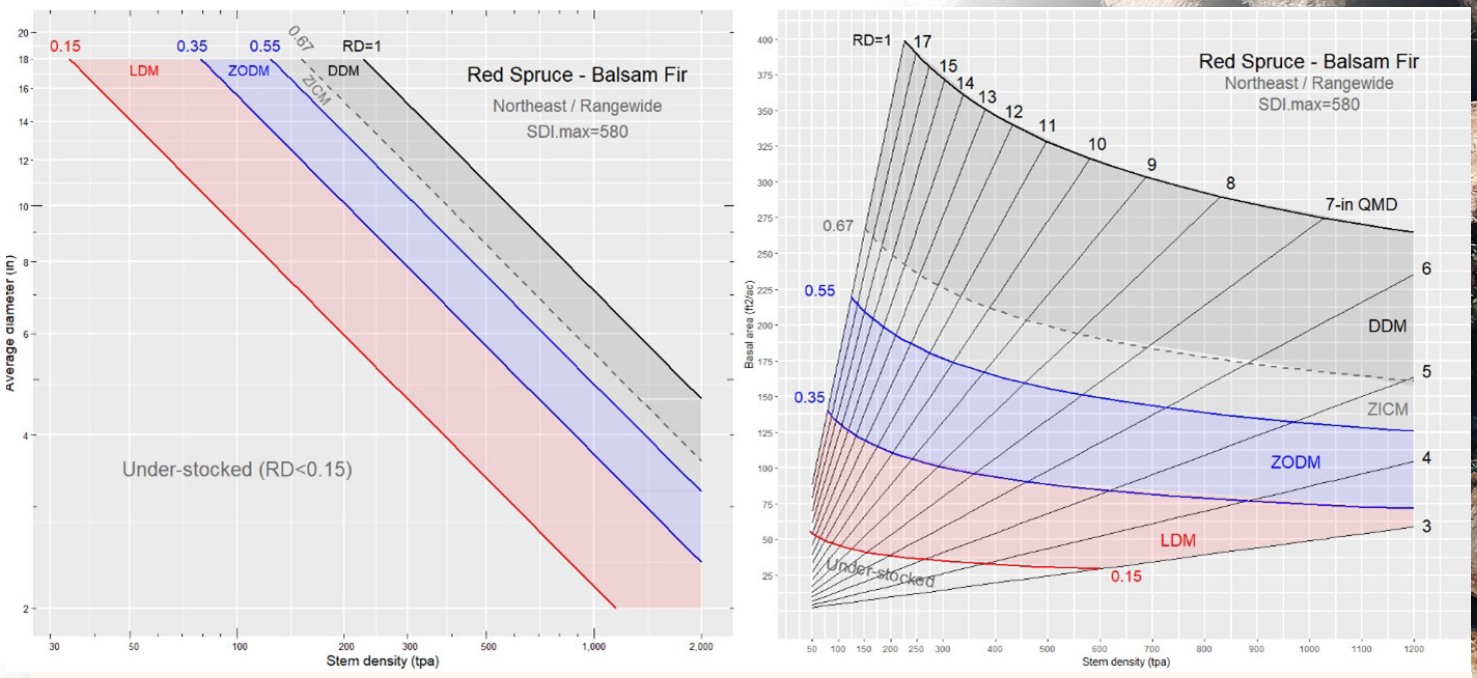

Figure 1.—Updated quantitative silviculture tools for the spruce-fir forest type in the Northeast. Panel A is a density management diagram showing combinations of stem density (x-axis) and average stand diameter (y-axis) in five zones of density management space. Panel B presents the same information as a stocking guide, with basal area on the y-axis and average stand diameter rendered as isolines (3 to 17 inches). These graphs are based on work by Ray et al. (2023).

Two Types of Charts

Stand density management charts, which display the relationships between size and density of trees in a stand, come in two formats: density management diagrams and stocking guides (Fig. 1). Density management diagrams (Fig. 1A) originated in the western United States. These diagrams display the quadratic mean diameter on the y-axis and trees per acre on the x-axis. Diagonal lines on these charts represent the stand density index, which is the relative stand density. Management zones on density management diagrams include understocked, density management zones, and density-dependent mortality.

Stocking guides (Fig. 1B) are more common in the eastern United States. These diagrams show the relationship between basal area on the y-axis and trees per acre on the x-axis for stands with different quadratic mean diameters, which appear as diagonal lines on the graph. These threshold lines define management zones based on stocking levels, with stocking lowest in the bottom corner of the guide and highest in the top. Traditionally, management zones defined by the lines help managers determine whether forest stands are understocked, fully stocked, or overstocked.

Revised Stocking Guidance

The research team produced equivalent density management diagrams and stocking guides by ensuring that the maximum size density relationship was the same for both charts. They used a maximum stand density index of 580 to define this relationship, which corresponds to the average of red spruce and balsam fir being used to predict density dependent mortality in the Northeast Variant of the FVS model (Dixon and Keyser 2021) and is consistent with more recent work on relative density by forest type and ecoregion (ranging from 542 to 640 trees per acre; Woodall and Weiskittel 2021). In doing so, the research team was able to plot the same relative density on both charts, thereby producing two comparable resources.

Both diagrams use the convention of relative density (maximum stand density index divided by observed stand density index) to define the upper and lower bounds of the color-coded management zones, where

- DDM (relative density ranges from 1.0 to 0.67) corresponds to an expectation of high density dependent mortality,
- ZICM (relative density ranges from 0.67 to 0.55) is the average stand self-thinning trajectory or the zone of imminent competition mortality,
- ZODM (relative density ranges from 0.55 to 0.35) is the zone of optimal density management where net stand level production is expected to be highest,
- LDM (relative density ranges from 0.35 to 0.15) is a zone of low density management where the growth rates of individual trees is optimized, and
- relative density less than 0.15 is considered understocked in relation to wood production objectives.

The new stand density management charts represent a significant advance from the version published decades earlier. For example, the new charts draw on more comprehensive datasets and reveal that much higher stocking can be maintained in eastern spruce-fir forests than previously thought. The new charts also use zones that convey different conditions, rather than threshold lines that indicate overstocked versus understocked conditions.

Do-It-Yourself Stand Density Management Charts

In addition to creating the new charts, the research team created instructions for how managers can make their own stand density management charts. With published maximum stand density index available and with R software packages like Stand View that are free and designed to help managers produce stand density management charts, anyone can create new charts. Instructions for constructing stand density management charts can be found in the supplemental material of the research team's publication.

FURTHER READING

Ray, David; Seymour, Robert; Fraver, Shawn; Berrill, John-Pascal; Kenefic, Laura; Rogers, Nicole; Weiskittel, Aaron. 2023. Relative density as a standardizing metric for the development of size-density management charts. Journal of Forestry. 121(5-6): 443–456. https://doi.org/10.1093/jofore/fvad029.

Dixon, G.; Keyser, C. 2021. Northeast (NE) Variant Overview of the Forest Vegetation Simulator. Fort Collins, CO: USDA Forest Service, Forest Management Service Center.

Woodall, Christopher; Weiskittel, Aaron. 2021. Relative density of United States forests has shifted to higher levels over last two decades with important implications for future dynamics. Scientific Reports. 11:18848. https://doi.org/10.1038/s41598-021-98244-w.

PROJECT LEADS

Laura Kenefic is a research forester with the Northern Forest Science and Applications research work unit of the Northern Research Station. Kenefic's interests include ecology and silviculture of mixed-species stands, carbon storage and climate adaptation, and diversity and inclusion science.

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Forest Service Research and Development works with partners to deliver the knowledge and tools that land managers need to sustain the health, diversity, and productivity of our Nation's forests and grasslands for present and future generations. The Northern Research Station (NRS), one of seven FS R&D units, is rooted in the geography of the Northeast and Midwest. NRS science supports a sustainable future.

For questions on Rooted in Research, please contact Andrea Brandon-Hennig. Technical editing by Carol Hollar-Zwick. Design and layout by Jeremy Siegrist.