Adapting Gingrich Stocking Guides for Managing Oak Woodlands and Savannas

John M. Kabrick, Brice B. Hanberry, Daniel C. Dey, Benjamin O. Knapp, David R. Larsen, Lauren S. Pile Knapp

Overview:

- Gingrich's stocking guide is a stand density diagram based on the minimum tree-area ratio equation for oaks and hickories that incorporates information about the number of trees, the basal area, and the quadratic mean diameter of a stand relative to the maximum that can be sustained according to the principle of self-thinning.
- Because Gingrich's stocking guide identifies the maximum and minimum stand density for full growing space occupancy, the chart identifies the optimal stand densities for maximizing diameter growth of individual trees while maintaining a high stand-level volume for sawtimber production.
- However, stocking guides also can be used to manage oak woodlands, savannas, and other open forests where density and structure are manipulated to create understory light levels and other conditions favorable for the growth of native graminoids, forbs, and legumes.
- To make Gingrich's stocking chart more useful for woodland and savanna management, additional stocking thresholds were needed. We proposed that closed-canopy woodland stocking ranges from the B-level up to about 75%, open-canopy woodland stocking ranges from 30% to the B-level, and savannas have stocking < 30%.
- These stocking thresholds can be used for planning savanna and woodland thinning or for evaluating stand density reductions from prescribed fire treatments.

Summary:

Management problem: Despite growing interest in restoring and managing oak woodlands and savannas, few silvicultural guidelines and tools are available, particularly for evaluating or adjusting woodland or savanna stand density and overall structure. Gingrich's Stocking Guide has been used for managing oak-hickory forests for several decades, but important density thresholds are intended for use in forests where maintaining full growing space occupancy is the goal during thinning.

Management need: Stocking guides modified to identify important density thresholds will inform the management of the more open structures of oak woodlands and savannas. Woodlands and savannas are managed at lower stocking levels than oak forests and therefore have unique stocking thresholds that are tailored to biodiversity goals rather than timber production objectives.

Research purpose: We present stocking thresholds for oak woodlands and savannas and discuss how they were derived through empirical measurements.

Silvicultural Concepts:

- Growing space availability strongly affects the growth rate and form of trees. Trees grown under lower stand densities grow at faster rates and develop larger, fuller crowns than trees grown under higher stand densities. For oak-hickory forests, Gingrich's has been the most widely used stocking guide for managing stand density.
- Key thresholds on Gingrich's guide include the average maximum density (the A-line, 100% stocking) and the minimum density of full growing space utilization (the B-line, 55 to 58% stocking). The A-line indicates average maximum growing space occupancy (stocking) occurring in undisturbed oak-hickory stands originally derived from the minimum tree area equation. The B-line indicates the average minimum growing space occupancy that would occur with open-grown trees where all the growing space is fully occupied; this was originally derived from the maximum tree area equation but also has been found to be at 57 to 59% stocking for trees 4 to 20 inches d.b.h. A third line, the C-line, is the stocking level on an average site that will grow to the B-line in 10 years.
- We propose that Gingrich's Stocking Guide can be used for managing savannas, woodlands, and other similar open forests where timber management is not the primary goal. To do this, stocking thresholds were identified to define the growing space for savannas and woodlands. Thresholds were identified empirically using witness tree data from the General Land Office and data from contemporary experiments (table 1).
- **Closed-canopy woodlands** have stocking ranging from the B-line to 75% (fig. 1). The upper bound corresponds to the stocking of a closed-canopy forest that has had the mid-story and understory trees removed through thinning or repeated prescribed fire (Knapp et al. 2017). The lower boundary is defined by the B-line because, by definition, all growing space is occupied, and crown closure occurs at this stocking level. **Open-canopy woodlands** have stocking below the B-line, and therefore below the point of crown closure. The lower boundary of open woodlands—30% stocking—is somewhat arbitrary but is the stocking level where woodlands transition into **Savannas**, as supported by density estimates made with witness tree data from the General Land Office surveys (Hanberry et al. 2014).

- Stocking levels can also be used to estimate crown closure and understory light levels, two important factors for managing ground layer vegetation in oak woodlands and savannas (fig. 2).

Management Applications:
- Stocking thresholds can be used for evaluating the density of unmanaged savannas and woodlands to determine the stocking adjustments that are needed for their restoration. They can also be used for evaluating stand density reductions from prescribed fire treatments or for planning thinning treatments to meet savanna or woodland stocking goals.
- Because canopy closure and light transmission can be predicted with stocking, woodland and savanna stocking goals can be identified for meeting the physiologic needs of specific understory plants.
- Marking guides can be prepared where stocking goals are translated into target basal area thresholds to facilitate tree marking with a prism.
- These thresholds provide a more objective way for defining savannas and woodlands using structural attributes, for identifying the stand density adjustments that are needed, and for explicitly communicating how to thin stands to meet restoration goals.
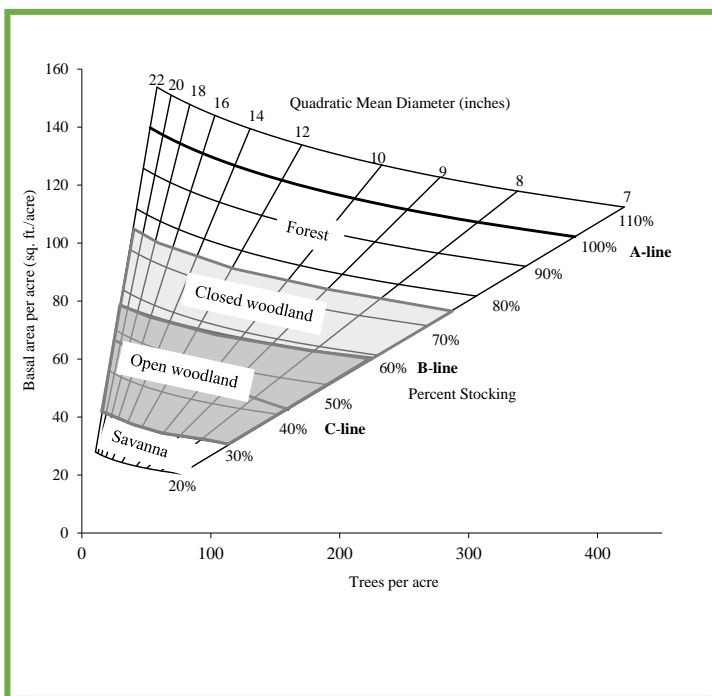
Figure 1—Stocking thresholds used for managing savannas and woodlands compared to forests. Woodlands can be further divided into those with closed (light grey shading) or open (dark grey shading) canopies.
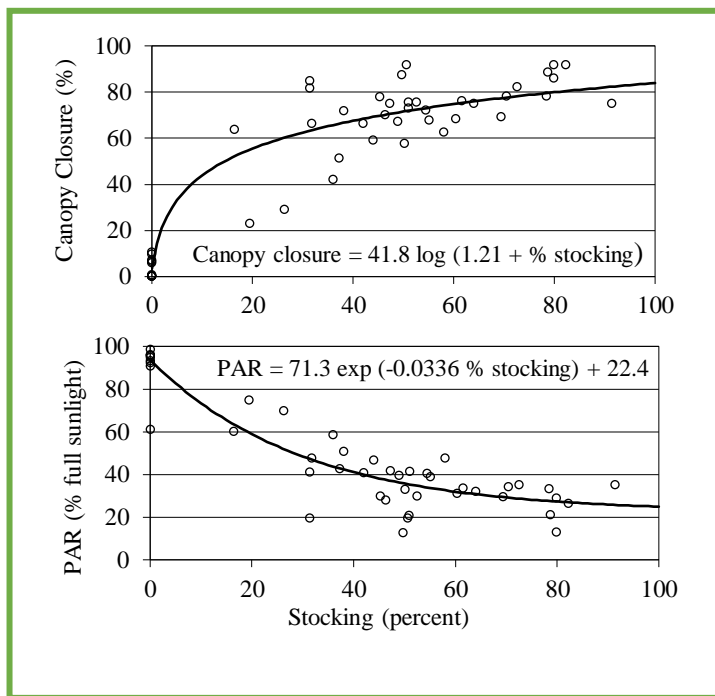
Figure 2—Relationship between percent stocking and canopy closure and photosynthetically active radiation (PAR) in recently thinned unmanaged stands (adapted from Blizzard et al. 2013).

Table 1—Stocking and density thresholds for oaks and pines (> 5 inches d.b.h.) using witness tree data from General Land Office records from the Missouri Ozark Highlands (adapted from Hanberry et al. 2014).

Vegetation type	Stocking (%)	Density (per acre)	Oak (%)	Pine (%)
Prairie	< 10	< 20	--	--
Oak savanna	< 30	< 40	≥ 30	--
Open oak woodland	< 55	< 70	≥ 30	--
Closed oak woodland	< 75	< 100	≥ 30	--
Oak forest	≥ 75	≥ 100	≥ 30	--
Oak-pine savanna	< 30	< 40	≥ 30	≥ 30
Open oak-pine woodland	< 55	< 70	≥ 30	≥ 30
Closed oak-pine woodland	< 75	< 100	≥ 30	≥ 30
Oak-pine forest	≥ 75	≥ 100	≥ 30	≥ 30
Pine savanna	< 30	< 40	--	≥ 30
Open pine woodland	< 55	< 70	--	≥ 30
Closed pine woodland	< 75	< 100	--	≥ 30
Pine forest	≥ 75	≥ 100	--	≥ 30
Other forest	≥ 75	≥ 100	< 30	< 30

References

Blizzard, E.M.; Kabrick, J.M.; Dey, D.C.; Larsen, D.R.; Pallardy, S.G.; Gwaze, D.P. 2013. Light, canopy closure, and overstory retention in upland Ozark forests. In: Guldin, James M., ed. 2013. Proceedings of the 15th biennial southern silvicultural research conference. e-Gen. Tech. Rep. SRS-GTR-175. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 73–79.

Hanberry, B.B.; Jones-Farrand, D.T.; Kabrick, J.M. 2014. Historical open forest ecosystems in the Missouri Ozarks: Reconstruction and restoration targets. Ecological Restoration. 32: 407–416.

Knapp, B.O.; Hullinger, M.A.; Kabrick, J.M. 2017. Effects of fire frequency on long-term development of an oak-hickory forest in Missouri, U.S.A. Forest Ecology and Management. 387: 19–29.