Reprinted *from:* Journal of Forestry 75(8): 500, 505-506, August 1977.

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Stocking Percent And Seedlings Per Acre In Naturally Established Longleaf Pine

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*ABSTRACT-4 relationship between milacre stocking and number of longleaf pine seedlings (*Pinus palustris *Mill.) per acre was derived from observations of 128 populations naturally established under a wide range of site conditions. The nonlinear regression obtuined from the data was* $Y = 100 [1-(0.561)^X]$*, in which Y is the percentage of milacres stocked and X the average number of seedlings per milacre plot (seedlings per acre in thousands). This regression accounted for 85 percent of the observed variation in milacre stocking. The coefficient decreased when sample plot size was reduced to 0.5 and 0.25 milacre.*

Successful natural regeneration of longleaf pine (*Pinus palustris* Mill.) requires an even distribution of seedlings. In appraising stocking, the usual procedure is to set up sample plots or quadrats of one milacre (43.56 square feet), randomly or systematically distributed. Stocking is then expressed as the percentage of plots having at least one established seedling. A milacre value of 75 would thus represent a stocking estimate of 750 or more well-distributed seedlings per acre. The actual number of trees per acre would be considerably higher, as some plots will have more than one seedling. With a random (Poisson) distribution of seedlings, the expected number would be 1,386 per acre. A random distribution of naturally established seedlings is rare, however, because conditions such as seed source, seedbed characteristics, and seed predation may vary greatly within a regeneration area. This paper explores the relationship between the plot stocking values and the number of longleaf pine seedlings established under a wide range of geographic locations, sites, and stand conditions.

Procedures

Study data.-Data were compiled from five regeneration studies made in 1949 to 197.5 *(table 1)*. Studies one through four were in southwest Alabama and study five was at various locations throughout the South. All together, 128 seedling populations were sampled. Observations were confined to naturally established stands undisturbed by logging or fire. Seed source was reasonably uniform within all areas. About half of the areas had been prescribe-burned within 2 years before seedfall.

All milacre plots in studies two, three, and four were subdivided into one-half- and one-quarter-milacre subplots. All seedlings were then counted on one-quarter-milacre subplot per milacre plot in studies two and three; all seedlings on all plots were counted in study four.

The relationship between stocking percentage and seedlings per acre obtained from the five studies was

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Table 1. Information compiled from five longleaf pine regeneration studies made over a wide range of geographic locations.[1]

Study	Seedling populations sampled	Milacre plots per population	Milacre plots with seedling counts	Seedling ages
	——— Number ———			
1	6	30	30	2-5 months
2	7	50	12.5[2]	1-3 years
3	21	51[3]	2-18[2]	2-5 months
4	60	25	25	1-2 years
5	34	100	10	3 months-4 years

1 *Studies one, two, and three were at the Escambia* Experimental *Forest. Study four* was at *Escambia and on* the *Conecuh National Forest--both in* southwest Alabama. *Study* five was *at various locations in Alabama, Florida, Mississippi, Louisiana, and South Carolina.*

2 *All seedlings counted on one quarter-milacre subplot per milacre plot.*

3 *Range is from 8 to 72 milacres per population.*

tested with additional data taken from 21 separate regeneration areas of study five during the winter of 1973-74. For each of these areas, which ranged from 15 to 100 acres in size, 100 circular 1-milacre plots were established, each of which contained a quarter-milacre subplot. Stocking was recorded for each plot-subplot pair, and a complete seedling count was made for every tenth pair.

Model.—The strong curvilinear relationship that was found can be described by the equation

$$Y = 100\,(1-a^X)$$

in which Y is the percentage of sample plots stocked, X is the average number of seedlings per plot, and a is the coefficient that describes the curve. This model is a rewritten form of Gill's (1950) equation $p = 100\left[1-\left(\frac{hc-1}{hc}\right)^n\right]$, in which p is the percentage of stocked quadrats, c is the quadrat size in terms of number of quadrats to make up an acre, n is the number of trees per acre, and h is a "heterogeneity index"—equal to 1 when trees are randomly distributed. The model was derived from Gill's equation as follows:

$$Y = p = 100\left[1-\left(\frac{hc-1}{hc}\right)^n\right] = 100\left[1-\left(\left[1-\frac{1}{hc}\right]^c\right)^{n/c}\right] = 100\,(1-a^X).$$

The term $\left(1-\frac{1}{hc}\right)^c$ is a constant (a) for any individual curve. The exponent n/c is mean number of trees per plot (X). The model can be further reduced to $Y = 1-a^X$ if stocking (Y) is expressed as a proportion instead of a percentage. For the random model, when Gill's heterogeneity index h is 1, the constant a is 0.368.

The model was applied to all milacre stocking-seedling count data from the 128 populations by means of a nonlinear least squares regression. The same procedure was applied independently to each of the three plot sizes in the 88 populations with subplots and to both the milacre and quarter-milacre plots in the 21 population test series from study five.

The effect of plot size alone on the value of the coefficient a was tested at 0.05 level of significance according to the principle of conditional error (Swindel 1970).

Stocking Percentage and Trees Per Acre

Milacre plots.—The relationship between stocking percentage and average number of seedlings per milacre plot was $Y = 100(1-0.561^X)$ (*fig. 1*). Despite the broad range in geographic location, site conditions, and sampling methods, the model accounted for 85 percent of the variation in Y, based on the departure of the residuals from the regression. Confidence limits for the coefficient a were 0.547 to 0.575.

An important source of error was the fact that tree counts were made on only a subsample of plots in 62 of the 128 populations. Values for populations in which tree counts were made on all plots were usually closer to the regression curve (*fig. 1*). The curve of milacre stocking over average number of seedlings per plot, as derived from the test survey of 21 regeneration

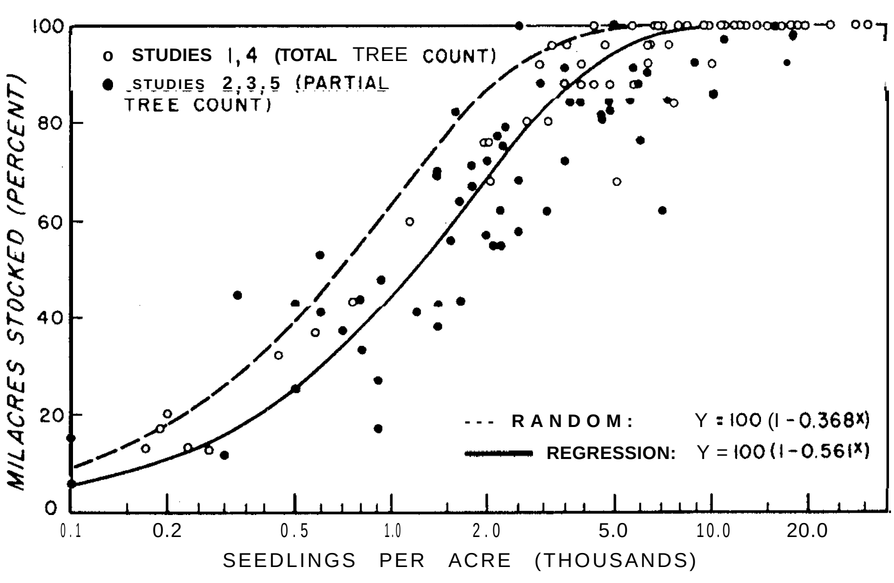

Figure 1. Relationship of milacre stocking to seedlings per acre in naturally established longleaf pine.

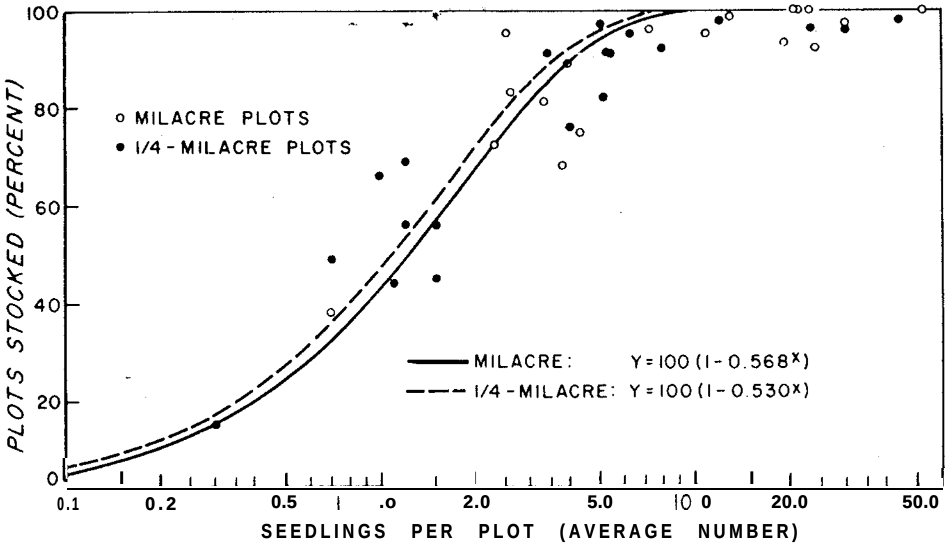

Figure 2. Relationship of plots stocked to seedlings per plot for nested 1- and quarter-milacre sample plots in naturally established longleaf pine.

areas, was $Y = 100(1\text{-}0.568^X)$ *(fig. 2)*—not significantly different from the original curve. Confidence limits for the coefficient *a* were 0.534 to 0.597.

Gill's index of heterogeneity was 1.73 ± 0.08 for all 128 populations and 1.77 ± 0.16 for the 21 test populations-a near random distribution. These values are much lower than those recorded for boreal forests (Gill 1950), where the heterogeneity index averaged about 5 for softwood species.

Subplots.—Regressions tor al! three plot sizes were significant. The coefficients (a) were 0.524. 0.503, and 0.477 for the 1-, half-, and quarter-milacre plots, respectively. As the plot size decreased, the curves were displaced left toward a more nearly random distribution. There was no explanation for this result.

Equations for both the quarter- and l-milacre plots differed significantly from a common curve derived from data for the two plot sizes combined; this result also occurred for the 21 test populations with quarter-milacre plots contained within milacre plots *(fig. 2)*.

The relationship between stocking percentage and the average number of seedlings per plot apparently changes with plot size. A reduction in plot size from l to a quarter milacre was associated with a decline in the coefficient *a* of 0.047 (88 population sample) and of 0.038 (21 population sample). These values indicate that probably the best coefficients to use for natural longleaf pine seedling populations such as these are 0.56 for l-milacre plots (as obtained from analysis of all milacre plot data), 0.52 (0.56-0.04) for quarter-milacre plots, and an intermediate value of 0.54 for half-milacre plots.

Application

The relationship between stocking percentage and the density of longleaf pine seedlings appeared to form a curve similar to that described for natural regeneration of other tree species (Wellner 1940, Gill 1950, Ghent 1969). The curve may represent naturally established longleaf pine seedling stands before disturbances such as logging or burning and may be a useful indicator of successful regeneration.

To evaluate regeneration success, one should first divide the regeneration area into sampling units of reasonably uniform seed source and seedbed conditions. Next, one should select the plot size most sensitive for the desired population density-the size that will provide the greatest range in stocking percentage for a fixed increase in trees per acre. At high stocking levels, a given increase in seedlings per acre produces a smaller increase in stocking than the same increase at intermediate levels. For example, an increase from 4,000 to 5,000 trees per acre is associated with a milwcre stocking increase of only 4 percentage points. whereas a change from 1,000 to 3,000 trees per acre represents an increase of 24 percentage points. Milacre plots are most effective for populations of 7.400 trees per acre or less; half-milacre plots are most effective for populations between 2.400 and 4.400 trees per acre; quarter-milacre plots are most effective for populations above 4,400 trees per acre. In terms of stocking, when 75 percent is exceeded. the next smaller plot size becomes more effective. When stocking falls below SO percent. the next larger plot size becomes more effective. Once a sample plot of appropriate size has been selected, the manager can then determine the plot stocking percentage associated with the desired number of seedlings per acre.

The usual standard for the natural regeneration of longleaf pine is about 6,000 established seedlings per acre before the parent overstory is cut. This amount allows for expected logging losses but still leaves a large enough residual population to ensure that the best 10 to 20 percent of the seedlings will adequately restock the regeneration area (Croker and Boyer 1975). If the coefficients described here are adopted. 6,000 seedlings per acre would be equivalent to a stocking of 63 percent for quarter-milacre. 84 percent for half-milacre. and 97 percent for milacre plots. In this case. the quarter-milacre sample plot would be the most sensitive index of successful regeneration. ■

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