GROWTH OF SOUTHERN PINES AT DIFFERENT STAND CONFIGURATIONS IN SILVOPASTORAL PRACTICES

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ABSTRACT

Predictions of economic outputs from silvopastoral practices in the southern United States remain uncertain because of scarce baseline information. Silvopastoral trials have mainly included single- or multiple-tree rows separated by alleys with (1) constant stand density or (2) constant alley width. For constant density trials, (a) basal area of 18-yr-old slash pine (*Pinus ellioti* Engelm.) in northern Florida was similar in single- and double-row configurations, and decreased 44% with a 3.6-fold increase in alley width for the double-row configuration; (b) basal area of 32-yr-old slash pine in double-row configuration in central Florida decreased 46% for a 2.1-fold increase in alley width; (c) basal area of 18-yr-old slash pine and loblolly pine (*Pinus taeda* L.) in single-row configurations in central Louisiana was 37-41% greater than in triple-row configuration with a 2.3-fold increase in alley width, and (d) basal area of 11-yr-old loblolly pine in a double-row configuration in western Arkansas was 20% greater than in a quadruple-row arrangement. For a constant alley width of 14.6 m in central Arkansas, basal areas of 18-yr-old loblolly pine in single, double and quadruple-row configurations were 20, 27, and 46 m^2/ha. In this study, basal areas in the silvopastures were similar or greater than those of an adjacent spacing trial for similar stand densities but bole biomass for a given tree diameter was likely 26-53% lower in the silvopasture because of differences in allometric relationships. Decisions on tree spatial arrangements in silvopastures should consider the combined effects of basal area accumulation, biomass partitioning and wood quality.

Keywords: agroforestry, tree spatial arrangements, biomass, *Pinus*

INTRODUCTION

The combination of pastures and trees can be a productive and sustainable land use in temperate regions of North America. Silvopastures often have greater overall productivity per unit land area than forests (Clason 1995; Sharrow et al. 1996). They can also conserve C and N (Sharrow and Ismail 2004), and expand benefits to landowners by increasing wildlife habitat and hunting (Grado et al. 2001; Husak and Grado 2002). Landowners have identified aesthetic enhancement, soil fertility improving, preservation of biodiversity, integration of conservation and production goals, and economic diversification as potential reasons to adopt agroforestry (Lawrence et al. 1992), and most of them apply to silvopastures.

In the United States, however, adoption of silvopastoral practices with planted trees and tame pastures has been slow. Possible causes that may explain restricted adoption are absentee landownership, lack of financial assistance, high establishment costs, increased management complexity, and ample land availability that may discourage sharing production activities on a common land area. Adoption can also be hindered by limited data on wood yields and quality for different tree spatial arrangements that are needed to predict economic outcomes.

Silvopastoral trials have mainly followed two approaches: (1) constant initial stocking with varied configuration (single- or multiple-tree rows), alley width, distance between rows or between trees within rows, and (2) constant alley width with varied configuration, initial stocking, and distance between rows or between trees within row. These experiments demand ample resources, and are costly to establish. As a result, there have been few long-term silvopastoral experiments in the United Sates. Because of the lack of an experimental network systematically testing tree growth for matrix combinations of tree density and alley widths on different sites, existing silvopastoral studies can be considered cases studies providing needed information for prediction and planning purposes until comprehensive data sets become available.

In this study, we examine basal area in silvopastoral stands with loblolly and slash pine corresponding to the two types of experiments outlined above in Arkansas, Florida, and Louisiana. Stand basal area at a given age is a reflection of bole diameter growth, and has been proposed as a suitable index of tree competition on crops growing on alleys in agroforestry practices (Nissen and Midmore 2002). Yet, in silvopastoral configurations, allometric shifts can significantly alter the relationships between tree bole diameter and woody biomass or volume. Therefore, we present data on allometric changes in loblolly pine silvopastures in central Arkansas. We also estimate differences in timber and biomass yields between silvopastures and forests. These analyses would facilitate decision-making regarding appropriate spatial configurations in silvopastoral practices in the southern United States.

MATERIALS AND METHODS

Stands With Constant Initial Stocking

In 2002, we measured bole diameter at 1.35 m aboveground (DBH) and total tree height in stands with (1) 32-yr-old slash pine in single- and double-row configurations at 1,135 trees/ha in Avon Park, central Florida (mean annual rainfall = 1,400 mm, soil type = Spodic Psammaquent of the Basinger soil series); (2) 18-yr-old slash pine in double-row configuration at 1,135 trees/ha in Withlacooche, northern Florida (mean annual rainfall = 1,346 mm, soil type = sands over marine clay); (3) 18-yr-old loblolly and slash pine in single- and triple-row configurations at 1,165 trees/ha in the Palustris Experimental Field in central Louisiana (mean annual rainfall = 1,470 mm, soil type = Plinthic Paleudult of the Beauregard-Guyton association); and (4) 11-yr-old loblolly pine in double- and quadruple-row configuration at 1,541 trees/ha in Booneville, western Arkansas (mean annual rainfall = 1,214 mm, soil type = Typic Fragiudult of the Leadvale series). Tree measurements for some previous years were available for most of these stands.

Stands With Constant Alley Width

We measured DBH and total tree height in stands with 18-yr-old loblolly pine in single-, double- and quadruple-row configurations with 14.6-m alleys and initial densities of 308, 568 and 932 trees/ha in Winrock Farm, central Arkansas (mean annual precipitation = 1,232 mm; soil = Typic Hapludult of the Linker series).

Biomass Partitioning at Different Configurations

At the study site in Winrock Farm, we felled 66 loblolly pine trees from single-, double- and quadruple-row configurations, and from an adjacent stand of the same age and on the same soil series than the silvopastoral stands. Trees were randomly chosen from the 25-29 cm DBH class and separated into bole, branches, and foliage as previously described (Ares and Brauer 2005).

For all studies, treatment effects were analyzed as mixed models with block as a random effect (Littel et al. 1996). Procedure MIXED in SAS 8.2 (SAS Institute 1999) that estimates variance components using restricted maximum likelihood methods was used for the statistical analyses. An $\alpha = 0.05$ was used for determining significance. In general, mean total height did not differ among configurations and data were not included in this study.

RESULTS
Stands With Constant Initial Density

Basal area of 18-yr-old slash pine in northern Florida was similar in single- and double-row configurations with 7.3-m alley widths (P = 0.67).

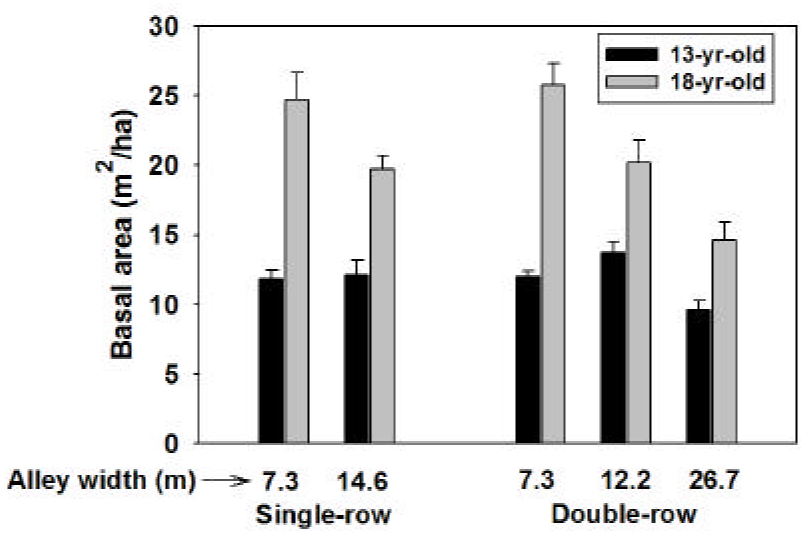

Figure 1. Stand basal area of slash pine in single- and double-row configurations at initial stand density of 1,135 trees/ha in central Florida. Values are means ± one standard error.

In the single-row configuration, basal area decreased 25% as alley width doubled from 7.3 to 14.6 m but differences were not statistically significant (P = 0.15). In the double-row configuration, basal area dropped 44% with a 3.6-fold increase in alley width (P = 0.03). Differences in basal area with alley width were noticeably more marked at age 18 than at age 13.

In central Florida, basal area of 32-yr-old slash pine in double-row configuration decreased 46% when alley width approximately doubled and tree distance within rows halved but differences were not statistically significant (P = 0.17).

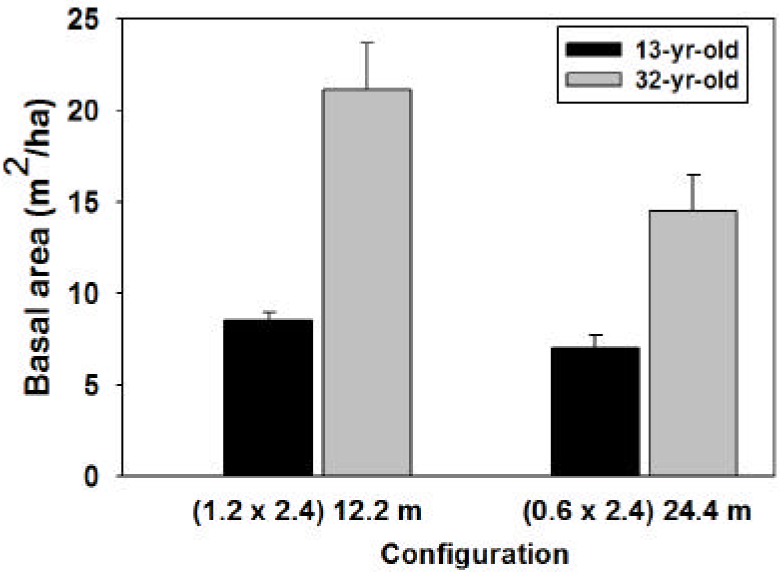

Figure 2. Stand basal area of slash pine in double-row configuration with varied alley widths planted at initial stand density of 1,135 trees/ha in northern Florida. Values are means ± one standard error.

At age 13, basal areas in the two arrangements did not differ (P = 0.21).

Basal area of 18-yr-old slash pine and loblolly pine in single-row configuration in central Louisiana was 37-41% greater than in triple-row configuration with a 2.3-fold increase in alley width (P = 0.03).

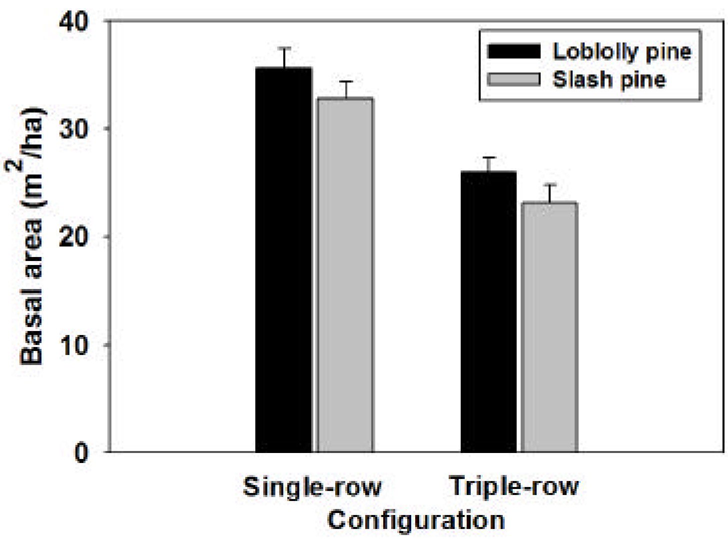

Figure 3. Stand basal area of loblolly and slash pine in single- and triple-row configurations planted at initial stand density of 1,165 trees/ha in central Louisiana. Values are means ± one standard error.

At both configurations and ages, basal areas of loblolly and slash pine were not significantly different (P > 0.29).

In western Arkansas, basal area of 11-yr-old loblolly pine in double-row configuration was 20% greater than in the quadruple-row arrangement ($P < 0.001$).

Relative differences in basal area between configurations appeared rather constant from 2002 to 2004.

Table 1. Stand basal area of loblolly pine in double- and quadruple-row configurations at initial stand density of 1541 trees/ha in western Arkansas. Values are means ± one standard error. The stands were 11-yr-old in 2004.

Configuration	Spacing	2002	2003	2004
Double-row	(1.20 x 2.40) 7.20 m	22.9 (0.33)	28.4 (0.39)	33.4 (0.46)
Quadruple-row	(1.20 x 2.40) 16.0 m	19.1 (0.29)	23.3 (0.36)	27.5 (0.44)

Stands With Constant Alley Width

In central Arkansas, for a constant alley width of 14.6 m, basal area of 18-yr-old loblolly pine in single-, double-, and quadruple-row configurations averaged 20, 27 and 46 m^2/ha. Therefore, basal area increased 2.3 fold from single- to quadruple-row arrangements at the expense of about 33% reduction in alley pasture area.

Comparisons Between Silvopastoral and Forest Stands

Existing plantations on similar soils in close proximity allowed comparisons of loblolly pine basal areas in forests and silvopastoral arrangements. In central Arkansas, for a given stand density at age 18, basal areas in single-, double-, and quadruple-row configurations in the silvopasture were on average 11, 19 and 34% greater than the projected basal areas for loblolly pine forest stands with similar stand density (Figure 4a). In western Arkansas at age 11, stand densities for forest and silvopastoral configurations did not overlap but data suggested that basal areas in double and quadruple-row configurations would be approximately similar to a projected trend for rectangular, forest-type arrangements (Figure 4b).

Biomass Partitioning at Different Configurations

Configuration affected biomass partitioning to boles ($P < 0.01$), which ranged from approximately 58-62% of total tree biomass in quadruple rows to 51% in single rows, and foliage ($P < 0.001$), which varied from 13% in single rows to 9% in internal quadruple rows.

Position within the row affected biomass partitioned to boles ($P < 0.01$) and branches ($P < 0.02$). Bole and total tree biomass for a given tree diameter were 26-53% and 6-10% lower in the silvopastures than in the adjacent forest because of differences in allometric relationships.

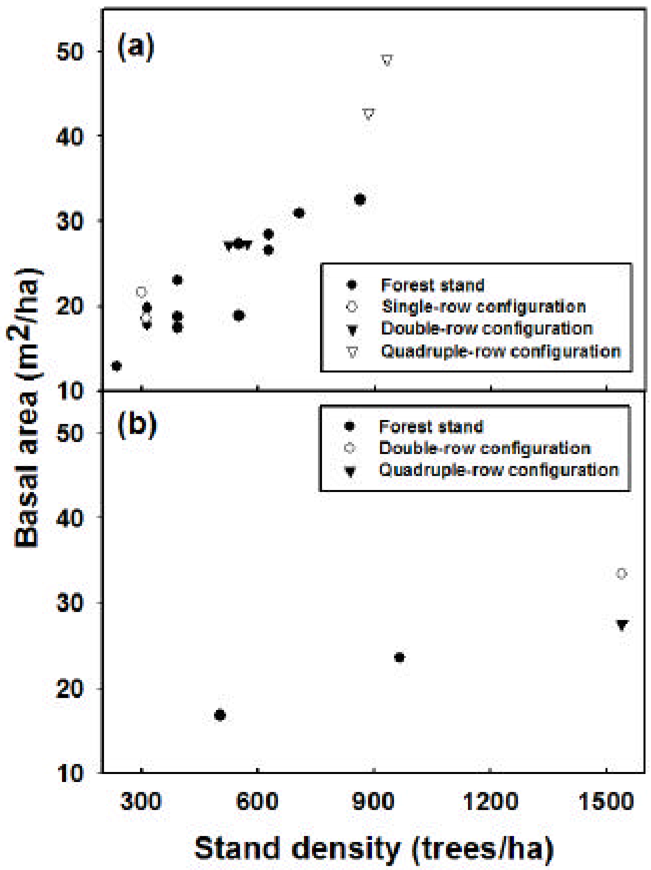

Figure 4. Stand density versus basal area in loblolly pine silvopastoral and forest configurations (a) at age 18 in central Arkansas, and (b) at age 11 in western Arkansas.

Table 2. Biomass partitioning to tree components of loblolly pine in silvopastoral configurations and adjacent forest in Winrock Farm, central Arkansas, and from a published study in Arkansas.

Configuration	Row	Age yrs	Stocking trees/ha	Percent partitioning to Bole	Branches	Foliage
Single-row		18	308	51.5	35.8	12.7
Double-row	1	18	568	54.0	36.1	9.9
	2			59.1	29.4	11.5
Quadruple-row	1[a]	18	932	58.2	32.3	9.5
	2[b]			62.5	28.9	8.6
Adjacent forest		19	983	79.0	18.8	2.2
Ku and Burton (1973)		18	n/a	83.1	13.5	3.4
Ku and Burton (1973)		18		81.6	14.9	3.5

[a] external east-row, [b] internal east-row

DISCUSSION

Early silvopastoral studies with southern pines (Lewis et al. 1983, 1985) appeared to indicate that double-row arrangements were the best configurations to maximize tree growth for common alley widths (e.g., 12-14 m). Our measurements of some of these studies later in the rotation and of other trials, indicated that basal areas were similar in single- and double-row configurations but tend to decrease as the number of rows increased over two. In addition, reducing distance between trees within rows coupled to increased alley widths in general reduced stand basal area accumulation with time.

In central Arkansas, basal area of loblolly pine in the silvopasture configurations was greater than that of a nearby thinned forest stand even though the thinned stand was two years older than the silvopasture. That could have been caused by improved understory vegetation control in the silvopasture, and/or increased nutrient supply from fertilizers applied to the herbage.

Increased basal area did not necessarily translate into increased woody biomass or timber volume per unit ground area. In central Arkansas, loblolly pine trees had gradual changes in biomass partitioning from single- to quadruple-row configurations. As expected, trees in the single-row configuration partitioned less biomass to boles and more to foliage than trees in double-row and quadruple-row configurations. Although statistical tests were not possible, data indicated that biomass partitioned to boles in the silvopasture was 26-53% less than bole biomass fractions observed in an adjacent forest. The reduction, however, was only 6-10% for total aboveground woody biomass because greater partitioning to branches in silvopastoral stands partially compensate for decreasing partitioning to boles. Thus, the reduction in yield in the silvopasture caused by the decreased partitioning to boles should be accounted for when comparing timber yields between silvopastoral configurations and forest stands. Results suggest that after correcting for biomass partitioning, woody biomass production in single- and double-row configurations would be less than in forest stands of comparable basal area but similar in quadruple row-configurations. Trees in double rows separated by 2.4 m distance, exhibited appreciable bole sweep and visual characteristics suggesting considerable presence of tension wood. A tree-row arrangement with thinning could be an alternative to single and double-row configurations as greater biomass partitioning to boles and improved wood quality would compensate for the decrease in stand basal area accumulation.

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