Forage Utilization Work Group

LOBLOLLY PINE-BASED FORAGE PRODUCTION: WHAT WE'RE LEARNING IN ARKANSAS

David M. Burner
Dale Bumpers Small Farms Research Center
USDA-ARS
Booneville, AR

The mission of the Dale Bumpers Small Farms Research Center (DBSFRC) is to develop scientific principles and technologies that enhance the profitability and sustainability of small farms in the mid-South region. These farmers are at particular risk from increased costs of production, declining receipts, and potential loss of a way of life. We are studying agroforestry as a means to ameliorate this risk through commodity diversification.

Crop monoculture has been a paradigm of modern U.S. agriculture. Unlike tropical or semi-arid regions, where agroforestry is widely practiced, the U.S. has been very slow in adopting agroforestry practices because of the lack of scientific, socio-economic, and traditional support systems associated with conventional agriculture. Further, conventional agriculture has a large database that may not apply to agroforestry systems because of unforeseen competitive interactions for soil water, nutrients, and light. The design of agroforestry systems is complex, governed by species, site conditions, spatial and temporal factors, and producer budget and objectives. Poor understanding of these factors constrains the design, establishment, management, and adoption of agroforestry systems. It might be appropriate to say that livestock producers are as uneasy with the prospect of tree farming as tree farmers are with cattle production.

Despite these deficiencies, the conversion of marginal crop and pasture land to tree crops is becoming increasingly attractive as an economically rational use of land resources (Grado et al., 2001; Harwell and Dangerfield, 1991). Profitability (gross value of production less cash expenses) of cow-calf production in the southern U.S. was positive only seven of 17 years from 1982 through 1999 (USDA-ERS, 2001), while the U.S. softwood timber supply situation appears to be entering a growth phase with pine stumpage prices in the South projected to increase 1.5% annually for the next several years. About 22 million acres in the South, much of it marginal crop and pastureland, could yield a greater economic return when planted with pine to create silvopastures (Haynes, 1990). Loblolly pine is well suited for agroforestry because it grows rapidly on sites with low inherent soil fertility and minimal fertilizer inputs (Schultz, 1997).

Overstory trees can simultaneously complement or constrain understory forage production and quality. Trees can favorably alter the understory microclimate (Feldhake, 2001) and protect forage by reducing evapotranspiration during drought (Frost and McDougald, 1989), minimizing deleterious interactions of heat stress and high light intensity on photosynthesis of C_3 species (Lin et al., 1999), and reducing radiation frost damage (Feldhake, 2002) compared to unshaded forage. Conversely, trees can reduce forage production through shade, competition for soil water and nutrients, and allelopathy (Clason and Sharrow, 2000; Garrett and McGraw, 2000). The objective of this paper is to highlight selected studies at the DBSFRC on physiological constraints and growth dynamics of loblolly pine-based agroforestry, including research limitations, concerns, and research needs.

Forage responses to spacing early in the tree rotation

We conducted a study to determine if row spacing affected yield, quality, and botanical composition of minimally managed forage in loblolly pine early (5-6 yr after planting) in the tree rotation (Burner and Brauer, 2003). Plots were located in alley middles in each of eight tree spacing configurations: 4 x 8’, 4 x 12’, 4 x 16’, 2 row (4 x 8)’ + 24’, 3 row (4 x 8’) + 32’, 4 row (4 x 8’) + 40’, 5 row (4 x 8’) + 48’ wide, and control (no trees). The first three configurations were ‘rectangular’ configurations, and the last four were ‘multiple-row’ configurations. Tree rows were planted in an east-west orientation. As expected, forage yield was low (880 lb/acre/yr) with no fertilizer inputs. Row spacing affected the yield, quality, and botanical composition of pasture five to six years in the rotation especially at densities exceeding 340 trees per acre (TPA). Botanical composition shifted from predominantly cool-season (tall fescue) to warm-season (bermudagrass and *Panicum*) grasses between annual spring and fall harvests, respectively, which caused seasonal differences in several yield and quality traits. Forage yield generally increased, but quality and minerals (crude protein, IVDMD, Ca, and P) tended to decrease with alley spacing. Forage minerals, except for Cu and Na, met or exceeded needs of growing and finishing beef cattle, while crude protein concentration (8.4%) was marginally adequate. The tendency for increased forage quality in pine-shaded alleys would be offset by low yield, necessitating rotational grazing.

Trees should be planted in rows no closer than 16’ for best forage yield, quality, and equipment access. Minimal management will limit forage productivity, animal stocking rate, and possibly tree growth, and might require that livestock be supplemented with protein and minerals. Further, tall fescue might not be sustainable with minimal management. While we do not necessarily recommend a no-input approach as a best management practice, resource-limited producers may be unable to impose high-input strategies on marginal sites.

Another study was conducted in separate plots of the same pine stand to assess the effects of tree density and configuration (multiple-row vs. rectangular) on forage yield with fertilizer inputs (Brauer et al., 2004). Forage in May and September averaged about 7,000 and 4,000 lb/acre in the control, respectively. Forage yields were lower in pine alleys than the control. At comparable TPA, forage yield tended to be greater in multiple-row configurations with wide (40 to 48’) alleys than rectangular configurations (8 x 8’ or 12 x 12’). Tall fescue was the dominant species in all configurations in May, and in 4 x 8’ and 8 x 8’ configurations in September. Bermudagrass was the dominant species in September in the control. Tall fescue and bermudagrass were co-dominant in September in 12 x 12’, 4 row (4 x 8’) + 40’ and 5 row (4 x 8’) + 48’ configurations. Forage yield was inversely related to tree canopy cover in May (r^2 = 0.96) and September (r^2 = 0.90). Forage yield in summer (i.e., June to September) was related to productivity of the bermudagrass. Annual forage production in this study was 22 and 81% greater for multiple-row than rectangular configurations at tree densities of 300 and 680 TPA, respectively. The differences in forage production suggest that multiple-row configurations are preferable to rectangular configurations for forage production. Other research also has shown that the 2-row multiple-row configuration is practical for producing sawtimber without sacrificing the area allocated for forage production (Ares and Brauer, 2003).

Influence of alley crop environment on orchardgrass and tall fescue forage

A study was conducted to determine whether the alley environment differentially affected persistence, forage yield, and quality of two shade tolerant forage grasses (Burner, 2003). The experiment was conducted for 3 yr on orchardgrass, tall fescue, and a 1:1 orchardgrass - tall fescue mixture in 16'-wide alleys of 10-yr-old loblolly pine and shortleaf pine, and an unshaded control at Booneville, AR. Loblolly pine was 5' taller and had twice the canopy cover as shortleaf pine (52 and 25% canopy cover, respectively). Averaged across harvests, orchardgrass persisted better in loblolly pine alleys (72% stand) than in the control (44% stand), while tall fescue persisted better in the control (30% stand) than in loblolly pine (13% stand). Persistence in shortleaf pine alleys was intermediate for both grasses. Yields of orchardgrass and the mixture did not differ in pine alleys (1150 lb/acre), and were usually greater than tall fescue yields ($\leq$ 620 lb/acre). Across treatments, forage yield in pine alleys was about 70% of that in the open. Crude protein was higher in loblolly pine alleys (17.2%) than in the control (14.1%). In a related study, orchardgrass had a lower concentration of total nonstructural carbohydrate in alley cropped than control forage, while water soluble carbohydrate and digestibility did not differ (Burner and Belesky, 2004). The introduction of livestock into this system could affect species persistence due to preferential grazing of orchardgrass. For example, orchardgrass did not persist well in conifer-shaded swards grazed by sheep in West Virginia (Belesky et al., 2001). Producers should consider using orchardgrass monocultures or mixtures with tall fescue for pine alleys in the mid-south U.S.

Forage nitrogen recovery in a meadow and loblolly pine alley

Forage should be managed differently in conventional and agroforestry systems, but managers have scarce data on which to base their decisions. We conducted experiments to measured forage N fertilizer recovery at two sites: an unshaded meadow and a shaded alley in 10-yr-old loblolly pine (Burner and MacKown, 2005; Burner and MacKown, 20XX). Tall fescue was the predominant forage species. Fertilizer N was broadcast as split-applications at six rates (90 lb/acre increments from 0 to 450 lb/acre/yr). The meadow and pine alley had sufficient forage yield for rotational livestock production. Cumulative forage yield in the meadow was much more responsive to added N than pine alley forage, but average cumulative fertilizer N recoveries were only 38% and 12%, respectively. The proportion of total forage as tall fescue was favored at rates $\geq$ 180 lb/acre, but these rates increased concentrations of forage nitrate in the pine alley to potentially harmful levels for grazing ruminants (> 2300 ppm nitrate-N). Cumulative forage N use efficiency (CNUE) was 23 and 10 lb dry weight per lb supplied N for the meadow and pine alley, respectively. Cumulative N acquisition efficiency, not cumulative N conversion efficiency, appeared to be the primary driver of low CNUE in the pine alley. Low CNUE could be caused by low energy levels in alley cropped forage (Burner and Belesky, 2004). The apparent increase in crude protein in pine alley vs. meadow forage appeared to be a mechanistic response to decreased specific leaf weight. A shallow fragipan, low available soil P (≤ 6 ppm), and depletion of soil water in July to September (both sites), and low solar irradiance (pine alley), were likely contributors to low fertilizer N recovery and forage productivity. Because of poor forage yield response, low CNUE, risk of nitrate toxicity to ruminant livestock, and substantial accumulation of soil mineral N (55 to 210 lb/acre) in pine alleys fertilized with ≥ 180 lb N/acre/yr, only maintenance levels of fertilizer N (≤ 90 lb/acre/yr) should be applied to similar sites. For these same reasons, yearly applications of fertilizer N > 270 lb/acre/yr are not recommended for meadows similar to the study site.

Conclusions

Pine alleys can be used for rotational livestock grazing, but management and planning are needed to assure there is an adequate supply of quality forage. Loblolly pine grows well on poor sites as long as there is no standing water, and trees will respond to fertilization when soil nutrients are deficient. Growers should select suitable sites and plant trees at appropriate stocking levels to maximize the grazing potential until the first thinning, while at the same time assuring that tree density meets long term production objectives.

Orchardgrass appears to be at least as competitive, if not more so, than tall fescue in pine alleys despite being at its extreme southwestern range limit in western Arkansas. Tall fescue may not be a sustainable alley crop except under minimal tree competition in wide alleys, but it may be possible to develop tall fescue cultivars with enhanced shade or drought tolerance. Producers using orchardgrass in pine alleys should consider establishing the sward after three to five seasons of tree growth to take advantage of protective shade. It is not clear whether these two forages differ in shade or drought tolerance. We are conducting research to try to separate relative impacts of shade and soil water on tall fescue because one or both of these factors decrease concentrations of forage energy levels needed to drive nutrient accumulation and assimilation. Alley cropped forage can have roughly the same yield and quality as conventional pasture if the level of tree competition is regulated through appropriate planting design, periodic pruning and thinning, and control of animal stocking rates. Special attention should be paid to forage nitrate because N fertilization of shaded forage can foster nitrate accumulation. We are currently studying N recovery of grass and tree components to better understand the competitive interactions between these system components.

The integration of pines, forage, and livestock on the same land unit requires more management and thought than monoculture production. Are the benefits of commodity diversification through agroforestry sufficient to offset management costs? Can a farm be more economically and biologically sustainable if agroforestry methods are implemented? We believe the answer to both questions is “yes”.

References

Ares, A. and D. Brauer. 2003. Carbon partitioning and growth in a loblolly pine agroforestry plantation: stand configuration and pruning effects. p. 337-338. Proc. 8th North Amer. Agrofor. Conf., 23-25 June 2003. Corvallis, OR.

Belesky, D.P., C.M. Feldhake, and J.P.S. Neel. 2001. Production and botanical composition of a grass-legume sward as a function of conifer tree canopy density. Proc. Am. Forage Grassld. Counc. 10:285-289.

Brauer, D., D. Burner, and M. Looper. 2004. Effects of tree configuration on the understory productivity of a loblolly pine-forage agroforestry practice. K.A. Cassida et al. (eds.) Proc. Amer. For. Grasslnd. Conf. 13:412-416. Roanoke, VA.

Burner, D.M. 2003. Influence of alley crop environment on orchardgrass and tall fescue herbage. Crop Sci. 95:1163-1171.

Burner, D.M. and D.P. Belesky. 2004. Diurnal effects on nutritive value of alley-cropped orchardgrass herbage. Crop Sci. 44:1776-1780.

Burner, D.M. and D.K. Brauer. 2003. Herbage response to spacing of loblolly pine trees in a minimal management silvopasture in southeastern USA. Agrofor. Syst. 57:67-75.

Burner, D.M. and C.T. MacKown. 2005. Herbage nitrogen recovery in a meadow and loblolly pine alley. Crop Sci. 45:1817-1825.

Burner, D.M. and C.T. MacKown. 20XX. Nitrogen effects on herbage nitrogen use and nutritive value in a meadow and loblolly pine alley. Crop Sci. (In press).

Clason, T.R. and S.H. Sharrow. 2000. Silvopastoral practices. p. 119-147. *In* H.E. Garrett et al. (ed.) North American agroforestry: an integrated science and practice. ASA, Madison, WI.

Feldhake, C.M. 2001. Microclimate of a natural pasture under planted *Robinia pseudoacacia* in central Appalachia, West Virginia. Agrofor. Syst. 53:297-303.

Feldhake, C.M. 2002. Forage frost protection potential of conifer silvopastures. Agric. For. Meteor. 112:123-130.

Frost, W.E. and N.K. McDougald. 1989. Tree canopy effects on herbaceous production of annual rangeland during drought. J. Range Manage. 42:281-283.

Garrett, H.E. and R.L. McGraw. 2000. Alley cropping practices. p. 149-188. *In* H.E. Garrett et al. (ed.) North American agroforestry: an integrated science and practice. ASA, Madison, WI.

Grado, S.C., C.H. Hovermale, and D.G. St. Louis. 2001. A financial analysis of a silvopasture in southern Mississippi. Agrofor. Syst. 53:313-322..

Harwell, R.L. and C.W. Dangerfield, Jr. 1991. Multiple use on marginal land: a case for cattle and loblolly pine. For. Chron. 67:249-253.

Haynes, R.W. 1990. An analysis of the timber situation in the United States: 1989-2040. Gen. Tech. Rep. RM-199. USDA/FS, Fort Collins, CO.

Lin, C.H., R.L. McGraw, M.F. George, and H.E. Garrett. 1999. Shade effects on forage crops with potential in temperate agroforestry practices. Agrofor. Syst. 44:109-119.

Schultz, R.P. 1997. Loblolly pine. U.S. Dept. Agric., For. Serv. Agric. Hndbk. 713. U.S. Govt. Print. Off., Washington, DC.

U.S. Dept. Agric., Econ. Res. Serv. 2001. [On-line] http://www.ers.usda.gov/data/costsandreturns/. Verified 15 March 2006.