MAXIMIZING HARDWOOD PLANTATION PRODUCTIVITY IN THE SOUTHEASTERN UNITED STATES—LESSONS LEARNED FROM LOBLOLLY PINE

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ABSTRACT.—To maximize the benefits from Union Camp's timberland investment, the company has been involved in pine plantation management for nearly 50 years. During this time, the approach has been to progressively remove non-climatic barriers to growth through a combination of site preparation, silviculture, planting stock improvement, and genetics. The result has been that pine plantation productivity at Union Camp has increased 500% over that of natural stands. The principles developed from pine management have been extended to hardwoods with similar increases in productivity. These principles identify a path to maximum hardwood plantation productivity including the integration of biotechnology to provide further gains.

New economic drivers are emerging in plantation forestry in the United States. First, for U.S. forest products companies to remain globally competitive with producers in sub-tropical and tropical locales, they must match the wood costs of those regions. Ostensibly, this means increasing the productivity of U.S. plantation forests to equal those in areas of the world that have a climate more conducive to tree growth. Second, the lackluster performance of forest products company stocks in the 1990's has been perceived by some in the investment community as due to the poor return on capital that characterizes the forest products industry. Forest productivity comes under scrutiny because forest land represents capital, and corporations are increasingly demanding an attractive rate of return on that capital. Thus, profitability, not cost minimization, is becoming the operative term in plantation forestry. Increased productivity can increase profitability in plantation forestry as a reduction in the rotation age will produce a greater rate of return by reducing the investment "lifetime."

Plantation forestry in southern pines has a rich tradition dating back more than 50 years. Throughout this period, industry-wide pine plantation productivity has steadily risen to a level 200% greater than that of natural pine stands of the 1950's, transforming the southeastern U.S. into the world's largest producer of industrial wood. Through intensive culture, Union Camp has increased pine plantation productivity by 500% over this period. During this time, important lessons in pine cultivation have been learned that are just now being applied to southern hardwoods. Below are some of these lessons.

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BRIEF HISTORY OF SOUTHERN PINE CULTIVATION

The history of yield increase in southern pines from the 1950's until today is depicted in table 1. The first major development was an understanding of what constituted a fully stocked pine stand along with the realization that loblolly outperformed slash pine on most sites in the Atlantic and Gulf Coastal Plain. The next significant developments were silvicultural. Both the practice of bedding and the discovery that most southeastern soils were phosphorus deficient led to major increases in pine productivity that were achieved for very little cost. In time, the development of nursery practices and the incorporation of improved seed from genetics programs have also contributed significantly to the yield. The sum of the contributions to yield of the steps in table 1 were such that by the early 1990's, a mean annual increment of about 6 tons of wood per acre per year was the industry standard.

About that time, at Union Camp we realized that significant increases in productivity could yet be made above the industry average yield of 6 tons per acre per year. Our basic tenet was the removal of barriers to growth. The processes that convert light energy into stem biomass are all relatively inefficient and are further attenuated by climate. Our lack of control over most of the factors that reduce yield dictates that we aggressively pursue the factors that we can control.

Examples of the steps we took to remove some of the remaining barriers to growth include:

•Σ Increased competition control. In part through membership in research cooperatives at Auburn University and the University of Florida, we began to realize that some herbaceous weeds (especially

Table 1.—*The history of yield development in southern pine plantations in the United States.*

Decade	Key developments	Yield, wet tons/acre/year
1950's	Natural slash pine stands	2
1960's	Fully stocked slash pine plantations	3
1970's	Phosphorus fertilization at time of planting; bedding	4
1980's	Competition control; mid-rotation nitrogen fertilization; single-family planting	6 (Industry average yield)
1990's	Intensive culture	12 (Union Camp yield)

grasses) were strong competitors at levels we would have previously considered innocuous. The same was true for hardwood competition in the understory of older stands. These findings led us to pursue competition control with greater intelligence.

- Optimum fertilization regimes. In part through membership in the North Carolina State University Forest Fertilization Co-op, we came to appreciate that "leaves grow trees." Foliar nitrogen content was found to be directly proportional to leaf area index, which in turn was directly proportional to yield. This led us to develop fertilization regimes that optimized foliar nutrient content.

- Tip moth control. Partly through participation in the University of Georgia Tip Moth Consortium, growth impact studies indicated that damage from Nantucket pine tip moth seriously reduced yield. This led to a control program based on the moth's life cycle.

- Increased seedling size. We have not yet found that point at which the gain in wood volume at rotation no longer improves with increased seedling size. That is, the larger the seedling at the time of planting the more wood at rotation. Although there are practical limits to just how large a seedling can be grown, lifted, and planted, the observation that big seedlings grow more wood has led us to plant seedlings that are larger than the largest grade in the industry.

The combination of the above practices, along with single family planting of improved seed, has led us to double the biomass yield of loblolly pine to twice that of the industry average, or a mean annual increment of 12 tons per acre per year. These are the highest operational pine plantation yields reported in the U.S., and are comparable to loblolly pine yields in Brazil.

APPLICATIONS TO HARDWOODS

The application of these principles to hardwoods (most notably sweetgum and sycamore) has lead to results similar to those of pine: namely, yield increases on the order of 500% over that of natural hardwood stands. However, hardwoods pose their own unique set of problems. The major differences between hardwoods and pine that have to be taken into account are:

- Competition control. This is a crucial factor in successful hardwood plantation management. Successful control of competition begins with site selection, harvesting, and site preparation. Relatively flat sites are preferred. Harvesting must be done in such a way as to leave a clean site with low stumps because this facilitates ground application of herbicides. Excessive land clearing and heavy mechanical site preparation should be avoided to minimize soil compaction and the removal of topsoil. Pre-emergent herbicides and shielded application of post-emergent herbicides in the first and second seasons are mandatory.

- Fertilization. In general, optimum foliar nutrient concentrations are higher for hardwoods than for pine. Hardwoods are also more sensitive to soil texture and pH. All these will influence fertilization prescriptions. Establishing target foliar nutrient levels and a regular program to monitor them is imperative to providing optimal fertilization regimes.

- Planting stock. If increased planting stock size is important for pine, it is even more so for hardwoods. Large seedlings (root collar diameter > 10 mm) are needed to provide adequate root regeneration in bareroot seedlings.

- Genetics. Given the intense competition with regard to product pricing, genetic improvement in the form of increased growth rate needs to be delivered to the field now. We simply do not have 50 years to develop improved types as in southern pines. Fortunately for hardwoods, the ability to vegetatively propagate selection-age trees is possible. Clonal selection and testing offers the opportunity to deliver up to a 50% gain in volume growth in a just a few years. Tissue culture can be an important part of vegetative propagation, either as a means to lower the production cost of vegetatively propagated planting stock or for genetic transformation. When a clonal program is in place, this provides the entrée for the vegetative propagation of genetically engineered trees as well. Union Camp is in the process of field testing hardwood clones that have been engineered for herbicide resistance, increased growth rate, and improved wood quality. The first two traits could have a direct impact on wood costs from hardwood plantations.

CONCLUSION

To put it bluntly, intensive culture exemplifies the dictum, "it takes money to make money." Investments in fertilization, competition control, and planting stock are all substantially higher than those of conventional stand management, but the investments pay off in reduced wood cost due to greater yields and shorter rotations. Our experience with intensive culture of pine and hardwoods has brought us to the following conclusions:

- Remove the barriers to growth first and worry about the cost of removing those barriers later. To determine the biological potential of a species, barriers to growth need to be initially eliminated despite the cost associated with doing so. Once the biological potential is measured, then the costs and benefits of a treatment can be fairly ascertained. A good indication that site-related barriers to growth have been removed is that plantation yields become equal across a region regardless of soil type and vegetation cover.

- If you don't manage trees intensively, don't bother with genetics. When the Brazilians first started to grow loblolly pine, they used unimproved seed purchased from state agencies in the U.S. Their first plantations grew at three times the rate as those in the U.S. that had been established from improved seed. At the outset, gains from site prep, silviculture, and improved planting stock will far exceed gains from genetics. However, at some point when optimum fertilization regimes are in place and all the competition is controlled, the opposite becomes true and genetic gain will be the only means left to improve productivity. Until that point is reached, genetic potential will not be fully realized under non-intensive culture conditions because some other factor will be holding it back. Conversely, organizations that will be in a position to exploit clonal forestry and biotechnology will be those that have already mastered intensive culture. Biotechnology will mean an increase in the cost of planting stock, and only organizations that allow the full potential of the increased investment to be realized will be able to justify the increased cost.