Interplanting for bioenergy and riparian restoration in the southeastern USA

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1. ABSTRACT

More than 100,000 ha have been afforested in the Lower Mississippi Alluvial Valley (LMAV) of the southern USA Federal government incentives have underwritten this effort, focused on water quality improvement and wildlife habitat enhancement. Little attention has been given to possibilities for carbon sequestration or biofuels, but a flexible interplanting scheme utilizing eastern cottonwood (*Populus deltoides* var. *deltoides* Bartr. ex Marsh.) and oaks (*Quercus spp.*) could be used to co-produce fiber, fuels, and environmental benefits such as riparian area restoration. The interplanting technique became popular during the last decade; a total of 3,642 ha have been interplanted with cottonwood and oak in Arkansas, Louisiana, and Mississippi. Four possibilities are presented for producing fiber and biofuels with environmental benefits using cottonwood and interplanting techniques in the LMAV: plantations primarily for fiber production or restoration, and buffer strips with coppice for biofuels production or primarily restoration plantings.

2. INTRODUCTION

Programmes to restore riparian forests to former agricultural land in the southern United States have reversed decades of deforestation (Stanturf *et al*., 2000; Gardiner *et al.,* 2002). More than 100,000 ha have been afforested in three states in the Lower Mississippi Alluvial Valley (LMAV): Louisiana, Arkansas, and Mississippi (Gardiner *et al*., 2002). Federal government incentives have underwritten this effort by defraying establishment costs and paying private landowners for long-term conservation easements (King and Keeland, 1999). Policy goals to date have focused on water quality improvement and wildlife habitat enhancement, with little attention given to effects on carbon sequestration or biofuels (Stanturf *et al.,* 2000).

Scientists and land managers in the LMAV of the southeastern United States have developed an interplanting scheme utilizing the early successional eastern cottonwood (*Populus deltoides* var. *deltoides* Bartr. ex Marsh.) as a nurse species for the slower growing, disturbance-dependent Nuttall oak (*Quercus nuttallii* Palm.). Eastern cottonwood is a viable candidate as a nurse species due to specific traits of very fast early growth, sparse crown mass, and its suitability for intensive management (Stanturf *et al*., 2001). On sites suitable for cottonwood, the interplanting scheme appears to establish a diverse stand (Schweitzer *et al*., 1997; Twedt and Portwood, 1997) and quickly achieves a closed canopy, without greatly affecting the development of Nuttall oak (Gardiner *et al.,* 2001). The interplanting technique appears to mimic natural successional processes of riverfront hardwoods, but within a compressed time frame. The Nuttall oak, along with the diverse understory that typically develops in cottonwood plantations, can be released to become a natural bottomland hardwood forest.

A flexible management system for the interplanting scheme is being developed that includes harvesting one or two cottonwood rotations for pulpwood, managing the cottonwood for sawlogs, or both. This scheme is being applied to restoring riparian areas and presents opportunities for other conservation uses such as forested buffer strips, and other production possibilities such as bioenergy. Our objectives in this paper are to describe the interplanting scheme and its implementation to date, and assess its potential application for co-production of riparian restoration benefits and biofuels.

3. INTERPLANTING COTTONWOOD AND OAK

The critical step in the interplanting system is establishing the cottonwood nurse crop, using proven techniques based on years of research and practice (Stanturf *et al.*, 2001). Timing of weed control is the most important requirement, as weed competition must be minimized until the cottonwood is at least 2.4 m tall, which should occur in one growing season. A summary of the establishment activities is presented in Table 1; a more detailed explanation follows.

Table 1. Sequence of activities used to establish a cottonwood-oak interplanting useful for riparian restoration and biofuels production in the Lower Mississippi Alluvial Valley (Source: Stanturf *et al.*, 2001)

Year 1 October	Two-pass site preparation disking Row establishment and liquid nitrogen applied in trenches @ 112 kg N ha^{-1}
March	Plant cottonwood Spray herbicide in band over dormant cuttings (oxyfluorfen @ 0.26 kg active ingredient ha^{-1}+ glyphosate @ 1.4 active ingredient kg ha^{-1})
May	One pass disking between planting rows, followed 2 weeks later by second pass at right angle to first
June or July	Banded spray of oxyfluorfen @ 0.7 kg active ingredient ha^{-1}
August	One pass disking between planting rows, followed 2 weeks later by second pass at right angle to first
Summer	Insect control for cottonwood leaf beetles (carbaryl @ 0.92 kg active ingredient ha^{-1})
Year 2 June	Insect control for cottonwood leaf beetles (carbaryl @ 0.92 kg active ingredient ha^{-1})
June and July	One pass disking between rows; optional if cottonwood is taller than 2.4 m
Year 3 March	Plant Nuttall oak seedlings at offset position from cottonwood, either between every row or every other row of cottonwood
Year 10 Winter or Summer	Cottonwood harvest (Winter harvest if coppice rotation is desired, Summer if conversion to oak forest is desired)

3.1 Site Preparation

Land undergoing afforestation generally has been converted from soybeans (*Glycine max* (L.) Merrill). Ideally, site preparation begins immediately following soybean harvest. If soybeans are combined with chopping and shredding, plant residues are a fine-textured debris and pose no problems for afforestation plantings. The first step in site preparation is double disking. Next, the soil is ripped with a straight shank in order to break up the subsoil. If a traffic pan has developed, subsoiling must be done in the year previous to tree planting. Ripping is conducted along planting rows spaced 3.66 m apart. A bar pulled perpendicular to the ripped row sets out a grid marking the planting spots. This treatment is necessary to insure uniform spacing within and between rows to allow effective cultivation during the growing season. Liquid nitrogen fertilizer is added to the planting slit made by the ripping shank in the same pass. This requires specialized equipment to place the fertilizer 46 cm to 51 cm deep in the slit. Site preparation should be completed in the Fall. On expanding clay soils (smectitic mineralogy), it is essential for the slit to undergo several wetting and drying cycles (from precipitation) in order for fine particles to fill in the slit. Otherwise, soil drying in the spring and summer will cause the soil to crack along the planting slit, exposing tree roots to desiccation.

3.2 Planting

Cottonwood cuttings of 41 cm to 46 cm length are planted by hand from December through March. Spacing for pulpwood rotations of 3.66 m by 3.66 m provides a density of 746 stems per ha. Oak seedlings are 1-0 bareroot nursery stock, ≥ 1 cm root collar diameter and 46 cm to 91 cm stem length; root systems can be pruned to ≥ 20 cm and should have ≥ 3 or 4 first-order lateral roots pruned ≥ 10 to 15 cm in length.

3.3 Cultural treatments

Cottonwood is extremely intolerant of shading and control of competing vegetation is critical during the first growing season. A pre-emergent herbicide is sprayed in a 1 m band centered on the planting row. This should be done over the top of dormant cuttings, between December and mid-February. Chemicals presently used are oxyfluorfen (0.26 kg a.i.ha^{-1}) and glyphosate (1.4 kg a.i.ha^{-1}). Chemicals can be applied in a tank mix with an 80-20 nonionic surfactant, 1 percent solution. This is applied with ground equipment, most often a rubber-tired, 90 horsepower farm tractor. Readiness to spray is critical, as sufficient dry periods for maximum efficacy are scarce at this time of year.

Beginning in early May, mechanical competition control via disking begins. A treatment consists of two passes perpendicular to each other. Two treatments (i.e., four passes) in the first growing season are likely to be needed, but as many as four treatments could be required in conditions of severe weed competition. Johnson grass (*Sorghum halepense* (L.) Pers.) is a particularly vigorous competitor and additional steps may be needed for its control. Cottonwood leaf beetle (*Chrysomela scripta* F.) may defoliate young plants and cause mortality. Spot applications for both these pests may be all that is required during the first year. For control of Johnson grass, a basal spray of oxyfluorfen is used. Foliar spray of carbaryl at 0.92 kg a.i.ha^{-1} is effective for control of cottonwood leaf beetle.

In the second growing season, mechanical competition control by cross disking will be needed if cottonwood plants are < 1.8 m tall. If cottonwood is > 2.4 m tall, then disking may be unnecessary. Plants intermediate between these heights may benefit on some sites from disking once or twice.

3.4 Interplanting

The primary objective in afforestation for many non-industrial private landowners is enhancing wildlife habitat, particularly for game animals and waterfowl. We believe it is possible to accomplish this quickly by interplanting suitable oak species between every other row of cottonwood. Because of the need for mechanical weed control for one or two years to establish the cottonwood, we delay planting the oak until the beginning of the second or third growing season. Interplanting between every other row of cottonwood allows directional felling of the cottonwood at the end of the pulpwood rotation and avoids damage to the oak seedlings.

4. INCENTIVES PROGRAMS

Planting trees on former agricultural land is seldom attractive without the cost sharing available through the federally financed Wetlands Reserve Program (WRP) and Conservation Reserve Program (CRP) because of the initial capital costs, lack of an annual return, and greater perceived risk. Because the WRP is aimed at restoration, emphasis has been on planting oaks and few cottonwood plantings have been funded under the WRP (King and Keeland, 1999). The CRP has been managed with more flexibility and has funded cottonwood-oak interplanting. Although CRP is federally financed, reimbursement rates and allowable practices are set by individual states. All states customarily reimburse a landowner up to 50 percent of establishment costs. In Mississippi, rates have been as much as \$106 ha^{-1} for site preparation and planting, with an annual soil rent payment of \$109 ha^{-1}. Continuous Sign-Up/CRP is a variation on the basic CRP program that provides an incentive payment and cost sharing to private landowners for establishing forested buffer strips along water bodies. Additional incentives are offered because participation rates have fallen short of federal program goals under the 8 million km Conservation Buffer Initiative and the 10 million ha goal announced in the Clean Water Action Plan.

Cottonwood plantations have been established in the LMAV since the 1960s. Through the mid-1970s, approximately 123,000 ha of cottonwood were planted by industry for pulpwood (Burkhart and Krinard, 1976). The interplanting technique became popular during the last decade. A total of 3,642 ha have been interplanted with cottonwood and oak: 1,012 ha in Arkansas, 202 ha in Louisiana, and 2,428 ha in Mississippi (Jackie Henne-Kerr, Tembec, personal communication, 2003).

5. POTENTIAL COTTONWOOD PRODUCTIVITY

Cottonwood establishment and productivity will be low on poorly drained soils or when flooding persists into the growing season (Stanturf *et al*., 2001). However, productivity limitations caused by competition can be overcome through advances in chemical weed control that make it possible to grow trees even on heavy clay soils, at least to pulpwood rotations. Cottonwood can be productive on a range of sites. The poorest site on which to attempt cottonwood production would be Vertisols with 46 cm or less of clay at the surface, well drained (no standing water), with at least a 1 % slope.

Average yields for cottonwood plantations were estimated using data from the Fitler Managed Forest in Issaquena County, MS (Table 2). Three typical stands were used, representing soils with varying suitability for growing cottonwood. These stands were all on old-field sites, protected from overbank flooding by a river levee, with good survival (83% to 91%). All were planted with technology described in Table 1: improved planting stock, fertilized at site preparation, and treated with the new herbicide technology. Yields ranged from 47 to 77 tons ha^{-1} (oven dry weight to a 7.6 cm diameter merchantable top) at harvest, age 10.

Table 2. Characteristics of stands selected to represent soil productivity classes and yield potential of cottonwood under management (Source: Stanturf and Portwood, 1999)

	Commerce*	**Tunica-Bowdre***	**Sharkey***
Site Index (base age 10), m	24.4	22.3	20.1
Basal Area, m^2 ha^{-1}	6.7	3.9	3.4
Stems ha^{-1}	682	622	642
Survival, %	91	83	86
Tons ha^{-1}, age 10	76.7	56.3	47.1
Mean annual increment, OD Tons ha^{-1} at age 10	7.7	5.6	4.7
Cumulative annual increments, OD Tons ha^{-1} at age 10	8.4	7.0	6.0

* Soils are Commerce (Aeric Fluvaquents), Tunica-Bowdre (Vertic Haplaquepts-Fluvaquentic Hapludolls) and Sharkey (Chromic Epiaquerts).

6. ECONOMIC BENEFITS

A positive return can be expected for cottonwood plantations on former agricultural land by meeting the following conditions: plant only sites where cottonwood is adapted, apply appropriate cultural treatments when they are needed, obtain financial help to offset the initial establishment costs, and if current markets for cottonwood pulpwood persist and stumpage prices increase at least as much as inflation.

Cottonwood will not tolerate shading; therefore control of competing vegetation is critical during the first growing season. Commercial plantations in the LMAV can be established using the system summarized in Table 1. Cottonwood production costs are estimated for a typical farm operation (Table 3), where suitable equipment is available as well as surplus labor. Costs would be significantly higher if contracted. If a grower lacks the commitment or resources to provide needed treatments at critical times, then something other than cottonwood should be planted.

Table 3. Cost for establishing and tending cottonwood plantations on former agricultural land in the Lower Mississippi Alluvial Valley (Source: Stanturf and Portwood, 1999)

Dates	Activity	Cost per ha
Year 0	Site preparation	$99
Year 1	Plant cottonwood	$194
	Herbicide	$86
	Disk	$49
	Insecticide	$22
Year 2	Insect control for cottonwood leaf beetles	$22
	Two-pass disking (if needed)	$25

Stumpage prices for pulpwood vary considerably over time but generally they have kept pace with inflation. Most national and regional forecasts of timber supply suggest that stumpage prices will be higher in the future (Adams, 2002). Stanturf and Portwood (1999) evaluated the economics of cottonwood using a stumpage value of $9 per green ton (metric), the average price paid by Crown Vantage (now Tembec) in 1998. They looked at the effect of varying stumpage price at $8, $10, and $12 per green ton. For short-term investment analysis, they assumed a base case with real discount rate of 4% and no inflation and a 10% cost of capital. Several scenarios were examined, including rising costs and stumpage and adjusting for higher risk using a discount rate of 8%.

Cottonwood production was profitable under most conditions. Including federal cost-share payments greatly increased profitability, especially on lower productivity Sharkey soils. Stumpage, volume yields, and taxes all influence profitability in the short and long terms. Long-term management for cottonwood pulpwood (going beyond one rotation) was profitable if coppice was included. On lower productivity sites, coppice is probably necessary to make long-term (i.e., multiple rotations) timber management profitable. Coppice yields are lower than first-rotation yields by 50% to 75%, depending on how well multiple sprouting is controlled. It has been customary to thin stumps back to two sprouts in the winter after the third growing season, removing up to ten sprouts from each stump. Managers have shown that harvesting every other row during the winter, which encourages sprouting, can be an effective alternative. After it is clear that sprouting has been successful, usually one or two growing seasons, the residual trees are harvested in the summer to discourage sprouting.

Long-term timber management for pulpwood can be profitable if coppice is included. On lower productivity sites, coppice is probably necessary. A landowner has more options, however, on the higher productivity sites. Sawtimber management is a possibility on the best sites (for example, Commerce soils) although stumpage probably needs to increase at a rate greater than inflation to make this profitable.

Two potential sources of income were omitted from the analysis. Annual payments for hunting leases could more than offset annual costs for taxes and administration. Fees for hunting leases average approximately \$12 to \$17 ha^{-1} yr^{-1}. A more speculative income stream is from carbon-offset payments. Industries that produce greenhouse gases, anticipating markets for carbon credits, have paid some landowners for carbon sequestration in plantations. Industry in the U.S. has paid an average of \$1.81 to \$4.54 per ton of carbon sequestered, and companies in Europe are willing to pay up to \$9 per ton. Cottonwood plantations in the LMAV could sequester an estimated 135 tons ha^{-1} of carbon in 10 years (based on estimated biomass production). If an industry paid \$1 per ton for carbon credits, a landowner could earn almost \$14 ha^{-1} yr^{-1} from a cottonwood plantation.

7. OPPORTUNITIES FOR BIOENERGY

Populus species are usually considered in any discussion of short-rotation woody crops for fiber or energy and there are numerous production and utilization scenarios to consider. Recent efforts have examined standard woody biomass production systems with non-standard utilization scenarios. For example, Strauss and Grado (1997) developed a general model of *Populus* production and its use in ethanol manufacturing. Other efforts are beginning to examine the joint production of biomass and environmental benefits. For example, De La Torre Ugarte *et al.* (2003) analyzed the effect on agriculture of biofuels production, including *Populus* biomass and wildlife benefits under the CRP. A general approach is needed to examine the economics of standard and novel production systems such as the cottonwood-oak interplanting, novel and standard utilization scenarios, with co-production of environmental benefits such as wildlife habitat (Wesley *et al*., 1981; Hamel, 2003) and water quality improvement (Thornton et al. 1998). Although such a synthesis is beyond the scope of this paper, the following scenarios highlight some of the possibilities of producing fiber and biofuels along with environmental benefits using cottonwood and interplanting techniques in the LMAV.

1. *Fiber production*. One scenario would be expansion of the cottonwood fiber plantations in the LMAV, with utilization of the unmerchantable biomass for biofuels. This can be profitable under some conditions (Stanturf and Portwood, 1999), especially with establishment costs offset by incentive payments under CRP. Profitability beyond the first rotation would be enhanced, especially for small landowners, by coppicing. Although yields for pulp are reduced by 67% to 75% of first rotation yields (Jackie Henne-Kerr, Tembec, Personal communication 2003), this is mostly due to fewer merchantable stems from coppice. With bioenergy markets for the remaining material, effective production would be almost as much biomass as is produced in the first rotation.
2. *Restoration.* Fiber and biofuels could be a secondary product if restoration is the primary goal, using the interplanting technique with the incentives available under the CRP. The current prescription for planting oak is between every other row of cottonwood; thus, the oak is on a 3.66 m by 7.32 m spacing. This is done, in conjunction with direction felling of the cottonwood into the non-oak row and removal, in order to minimize damage to the oak seedlings. We believe that it is possible to double the oak stocking (to 3.66 by 3.66 m spacing) without suffering significant loss of seedlings in a careful harvesting operation. We would still recommend directional felling and removal of the cottonwood by trafficking every other row. Oak seedlings

broken off during logging will probably re-sprout with only minimal mortality. Under this alternative, a single rotation of pulpwood and biofuels would be produced. Alternatively, co-production of biofuels with or without pulpwood could continue for a coppice rotation.

3. *Buffer strip coppice.* Cottonwood buffer strips established under the Continuous signup/CRP would meet water quality goals and provide fiber and biofuels using continuous coppice rotations. For fiber production, the buffer strip would be established as a linear cottonwood plantation (spacing of 3.66 m by 3.66 m). In a typical buffer strip planting of 30 m width, this results in 8 rows of cottonwood. One km of buffer strip is approximately 3 ha of plantings. A buffer trip managed strictly for biofuels could be established at narrower spacing.
4. *Buffer strip restoration.* Buffer strips established strictly for restoration purposes using the interplanting technique could probably be managed for several rotations of coppice due to the increased sidelight, which would maintain the oak in the understory.

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