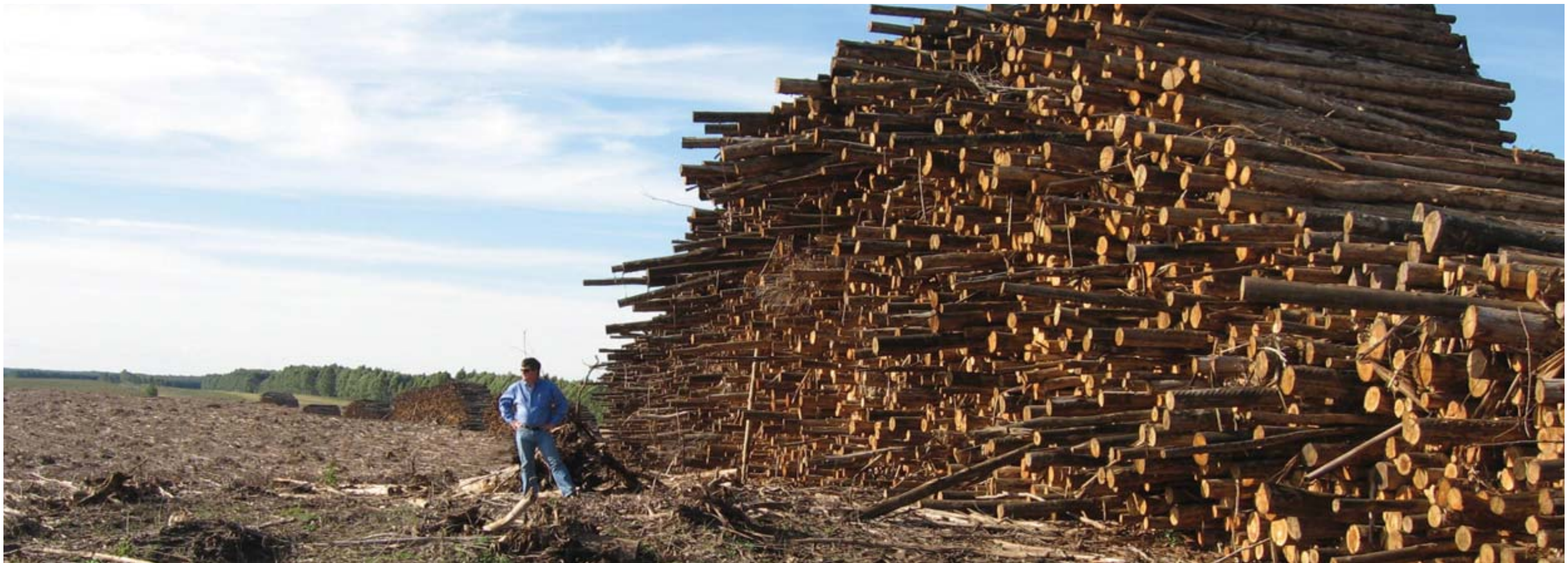

Financial Evaluation of Eucalypt Bioenergy Plantations in the Southeastern United States

Developments in the bioenergy field are emerging rapidly in many parts of the world. Potential bioenergy "products" currently include biodiesel; wood pellets; cellulosic ethanol; advanced biofuels; torrefaction; and electricity generated from wood products or from co-firing with coal or other alternative fuel sources. Annual agriculture-based crops will have a large role to play in biomass for bioenergy at the national level. However, in the southern U.S., the majority of biomass has and will be derived from forest resources.

A number of forest species will be considered for bioenergy plantations. Candidate forest bioenergy species include pine, cottonwood, sweetgum, and other hardwood species. One genus with tremendous bioenergy potential is Eucalyptus, commonly called eucalypts. The eucalypts are comprised of over 700 species and are amongst the most frequently planted species in the world. Eucalypts have high BTU (British thermal unit) and energy value, rapid growth rate, and stump-sprouting capability (coppice) following harvest. These traits and others make it a desirable bioenergy forest plantation choice in specific parts of the southern U.S.

—Derek Dougherty and Jeff Wright

While the U.S. Forest Service has records of eucalypts being planted in California and Florida beginning in the 1870s, historically the use of eucalypts in the southern U.S. has been limited by their freeze tolerance. Recent species test indicate that E. benthamii (Eben) and E. macarthurii (Emac) appear to have enough cold tolerance to be considered for use in biomass plantations in the southeastern U.S. Plantings of these two species at locations ranging from southern Texas to lower South Carolina survived well through the hard 2010 winter freeze. Adoption of these two species for bioenergy feedstock production in the southeastern U.S. now depends on quantifying biomass production rates, costs, necessary returns, and the resulting delivery cost per BTU. The purpose of this article is to discuss establishment requirements and production economics of these two eucalypts species for use as a bioenergy crop in the southeastern U.S.

Eucalyptus Plantation Establishment and Management

Given intensive culture, eucalypt production can be some of the highest in the world. In contrast, when low intensive culture is applied, production of eucalypt is similar to conventional southeastern U.S. pine and hardwoods. Thus, to fully benefit from deploying eucalypts, the appropriate growth culture (silviculture) to attain high production rates is important. Proper silviculture for Emac and Eben includes site preparation tillage, weed control, and fertilization. When appropriate silviculture is implemented, rotation ages (period from planting to harvest) are in the six to eight year range. Wood production rates of 9 to 16 green tons per acre per year of total biomass are reasonable for the Lower Gulf Coast region of the U.S. Table 1 is an example of a standard silvicultural management regime for establishing a stand of Eben or Emac.

Mechanical site preparation treatments may include disking and ripping to promote root growth. These must be done early enough for soils to have resettled after mechanical site disturbance. Chemical site preparation, using chemicals with no soil or very limited residue potential, can be completed with conventional ground or aerial operators.

Eucalypt seedlings are currently

available in containerized stock. Most seedlings are produced from open-pollinated seed. Planting is completed with contract crews using planting tools, similar to those used for Southern yellow pine seedlings. Planting can be done in the fall (September through November) when moisture is adequate or in early spring after the last expected freeze date, but fall planting is preferred. Usually about 600 trees per acre are planted for biomass production.

After planting, follow-up herbaceous weed control is a must. Weed control should begin early and control must be maintained near complete. Two weed control treatments may be needed in the first year on some sites. An early year two herbaceous weed control may also be necessary. Once the trees have captured the site, no additional weed control is necessary

Nutrient management is also essential. A soil analysis should be completed to determine if any macronutrient or micronutrient deficiencies exist. Fertilization regimes may include an application before planting to take care of any identified deficient elements and to provide starter nutrients and may also include an individual tree fertilization within year one after seedlings have become established. This can be accomplished by spreading a balanced fertilizer with micronutrients evenly around each tree being careful not to concentrate too much fertilizer near the young seedling. Fertilization should be completed in year two. Once the stand is fully established and the site fully captured, no additional fertilization is usually required.

Eucalypt Coppice Management

Eucalypts, depending on species and seed source, generally coppice vigorously. When the tree is harvested, multiple shoots sprout from the cut stump to recapture the site and fuel new post-harvest growth. With access to the stored resources present in the advanced root system, this initial growth can be greater than that of a newly planted seedling. For this reason, follow-up coppice rotations, if managed well, can be more productive than the initial planted rotation. Exceptions to this would include instances when coppice success is poor, i.e., some of the trees from the initial rotation fail to coppice and die, resulting in a secondary stand that has less surviving stems or stocking than the initial stand. Other exceptions might include occurrences of low coppice vigor or poor management. Coppice survival and vigor varies based on many factors, including season of harvest, stump size, and the vitality of the tree prior to harvest.

Another major benefit of a coppice rotation is that the up-front costs of successive plantations are dramatically decreased as compared to the initial rotation directly from seedlings. Lesser up-front cost means greater returns from similar harvest values. Alternatively, it could also mean that lower stumpage prices are required to provide the same rate of return to the investor. Success through coppice is not free. Like the original planted stand, site resources need to be guarded through herbaceous weed control treatments and potentially amended

Year	Management Activity Description	Cost	Cost NPV
0	Mechanical site preparation	–$100	–$100
0	Seedlings	–$150	–$150
0	Planting labor	–$54	–$54
0	Chemical site preparation	–$47	–$47
1	Herbaceous weed control	–$50	–$46
2	Herbaceous weed control	–$50	–$43
2	Fertilization	–$100	–$86
	Totals	–$551	–$525

▲**TABLE 1** Costs incurred in eucalypt case study regime (600 seedlings per acre, 7-year rotation).

through fertilization treatments to reach strong productivity. However, the high costs of initial mechanical tillage, chemical site preparation, seedlings, and planting labor, are avoided. Amending the management regime and costs in the base case study used above moved the net present value investment cost of $525 from the planting rotation, to a coppice rotation discounted investment cost of $215 per acre.

Motivated by the cost savings and increased early growth of coppice, the number of coppice rotations following the initial plantation establishment rotation may be substantial. Willow plantation managers interested in energy production, for instance, may establish an initial plantation and follow it with six or more coppice rotations of three years each. With any species, the decision to manage the next rotation for coppice is weighed against production potential of the pending coppice stand as determined from coppice survival and vigor, and compared to the expected genetic improvement of available new improved seedlings. With the strong successes in the genetic improvement of varietal eucalypts in many parts of the world, eucalypt coppice rotations are often limited to one or two.

Production		6%		8%		10%	
per year (tons)	per rotation (tons)	per ton price	harvest value	per ton price	harvest value	per-ton price	harvest value
low 9.2	64.4	$12.40	$799	$13.98	$900	$15.73	$1,013
med 12.7	88.6	$ 9.02	$799	$10.17	$900	$11.44	$1,013
high 16.1	112.7	$ 7.09	$799	$ 7.99	$900	$ 8.99	$1,013

▲**TABLE 2** Required stumpage value and harvest value by landowner's required rate of return.

Rotation	Origin	Annual Productivity (tons)	Rotation Productivity (tons)	Required Stumpage Price		
				6%	10%	14%
1st	Seedlings	12.7	88.9	$9.02	$11.44	$14.41
2nd	Coppice	14.5	101.5	$3.42	$4.24	$5.23
3rd	Coppice	12.4	86.8	$3.86	$4.80	$5.91
Averages		13.2	92.4	$5.43	$6.83	$8.52

▲**TABLE 3** Required stumpage prices by rotation origin and required return rate (medium productivity).

Economic Analysis

Stumpage Price Analysis for a One Rotation Eucalypts Plantation

With an estimate of $500 to $550 per acre in up-front costs, the authors wanted to know how much must be paid to the landowner to incentivize the production of eucalypts. The answer depends on some primary drivers, including: the owner's productivity, the owner's management method (reoccurring plantation establishment versus coppice management), and the landowner's required rate of return on investment. Using the base management regime and cash flows provided above, we computed the stumpage prices required to provide the landowner a range of return rates from 6 to 10 or more percent on the plantation investment costs. These required stumpage prices were computed for a range of average annual productivities (mean annual increments), with a total biomass production low of 9.2 green tons per acre per year and a high of 16.1 tons per acre per year. Table 2 illustrates the impacts of productivity and required return rate on necessary stumpage price.

In this scenario, if a landowner invests $525 per acre early in the investment, he must produce $799 per acre at the end of a 7-year rotation to yield a 6 percent rate of return. If he only meets a medium level of productivity, he must be paid $9.02 per ton to meet this return rate hurdle. What if his investment hurdle rate is 10 percent? At the same level of productivity, he must receive $11.44 per ton to reach his goals. These basic calculations reveal a key point: the viability of an energy production system (such as biomass) in the southeastern U.S. depends greatly on the technology available to and productivity of its producers.

Eucalypt Plantation-Coppice Regime Analysis

In the coppice management section above, the authors noted benefits of coppice to include potentially increased productivity and decreased investment costs to be carried. For their economic analyses presented here, they used a model of an initial seven-year rotation from planted seedlings followed by two successive seven-year managed coppice rotations. In Table 3, note the productivity change over each rotation. The initial coppice rotation productivity is slightly greater than the initial stand due to the stored root energy used, but the third rotation, also from coppice, shows decreased productivity due to loss of sprouting stumps going into the follow-up coppice rotation. As with the single plantation calculations above, the authors solved for the average stumpage price required for the landowner to make to a range of required returns, first for the immediate rotation, and then computing an average of the three rotations. Table 3 shows the resulting impact of coppice productivity and savings differences ($215 per acre carried versus $525 per acre as noted above).

The positive impact is clearly demonstrated in this example. While a per-ton stumpage price of $11.44 per ton is required in the rotation from seedlings (to make a 10 percent return on investment), only a $4.24 and $4.80 per ton stumpage price is required from the two following coppice rotations respectively. The impact on the average is also strong, driven down to $6.83 per ton by the productivity increase and the management cost decrease.

				Delivered $/MBTU at Landowners' Rate of Return		
Rotation	Origin	Productivity	Tons/ac/yr	6%	10%	14%
1st	seedlings	medium	12.7	$3.55	$3.86	$4.23
2nd	coppice	medium	14.5	$2.85	$2.96	$3.08
3rd	coppice	medium	12.4	$2.91	$3.02	$3.16
Averages			13.2	$3.10	$3.28	$3.49

▲**TABLE 4** Case study delivered $/MBTU at landowners' rate of return for eucalypts in the Lower Gulf Coast area (4,000 BTU/lb of delivererd eucalypt wood).

Delivered Cost Analysis

The authors have presented a base silvicultural regime for eucalypts and discussed the cash flows and returns necessary to make these regimes attractive to an investor, but what about the prospective purchasers of this biomass feedstock? Can the emerging users and electricity producers afford to purchase it at these prices? If so, what would be the resulting effect on energy consumers, i.e., is this feedstock more expensive for each BTU? To answer this question, the authors moved from estimates of required stumpage prices, to estimated delivered prices for the base case study provided. The delivered price includes the stumpage rate plus the rate to put the wood on the truck (cutting, chipping, and loading) plus the haul rate. Using Timber-Mart South's published estimates of logging cost and hauling rate, with a chipping rate of $15 per ton, a 40-mile haul to the mill, and a $0.11 per ton mile rate for a 25-ton load, the authors calculated a cut-and-haul rate of $19.40 per ton for this example. Adding this rate to the stumpage prices from Table 3, and still assuming a medium productivity rate and 10 percent required return on investment, produces a delivered price range of $28.42 to $30.84 for the initial rotation from seedlings and a delivered price range of $24.83 to $26.23 for the seedling-coppice regime presented.

Can emerging and existing energy ventures work within delivered eucalypts costs in the range of $25 to $30 per ton? How does this delivered price estimate of eucalypt biomass compare with coal, the cheapest alternative source of electricity production? The June 2010 US Energy Information Administration (EIA) delivered coal price report showed a national average delivered cost of coal to the electricity sector of $2.30 per million BTU for coal. But for the southeastern U.S. where much of the eucalypts will be grown (Mississippi, Alabama, Georgia, South Carolina, and Florida), the reported price ranged from $2.84 per MBTU to $3.97 per MBTU. The other primary competitor, natural gas, is considerably higher still, over $4.50 per MBTU at the time of this writing. So in the case study example provided here, what would be a comparable delivered price for eucalypts, in dollars per delivered MBTU? Similar to coal, which has variable energy potential and moisture content based on the type of coal, eucalypt density, moisture content and BTU per pound varies by species. Assuming 8,000 BTU per pound dry and a 50 percent moisture content for delivered wood, then the BTU per green pound of delivered eucalypts would be 4000 BTU per pound. For each ton (2,000 pounds), there would be an estimated 8,000,000 BTU, or 8 MBTU delivered. At a delivered price of $24 per ton for example, this would compute to a dollars per MBTU price of $3 per MBTU. Table 4 demonstrates the calculated delivered MBTU price for the example presented in this article.

Compared to June 2010 regional reported prices from EIA of $2.84 to $3.97 per MBTU for coal, estimates of $3.10 to $3.49 per MBTU for delivered eucalypt chips would potentially be a strong additional biomass feedstock for the emerging alternative energy sector, falling in line well with current delivered coal costs for the southeastern U.S. and below natural gas prices. Additional benefits in the southeastern U.S. include production of electricity and energy from sustainable and locally grown forest plantation resources, as well as carbon capture from these forests.

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