Biomass And Bioenergy Production For Economic And Environmental Benefits

FRANCIS MARION HOTEL
Charleston, South Carolina
November 7 - 10, 2004

Sponsors:

Short Rotation Woody Crops Operations Working Group
IEA Bioenergy (Task 30), Short Rotation Crops for Bioenergy Systems
IUFRO Working Unit 1.09.01, *Integrated research in temperate short-rotation energy plantations*

Biomass and Bioenergy Production for Economic and Environmental Benefits

A conference hosted by
Short Rotation Woody Crops Operations Working Group
and
IEA Bioenergy (Task 30), Short Rotation Crops for Bioenergy Systems
and
IUFRO Working Unit 1.09.01, Integrated research in temperate short-rotation energy plantations

7 to 10 November 2004
Historic Francis Marion Hotel
Charleston, South Carolina, USA

Sunday, 7 November 2004

Starting 1600	Registration
1745 – 1945	Vendor display/Poster session (displayed entire meeting) with refreshments
	Dinner on your own

Monday, 8 November 2004

0700 – 0800	Continental Breakfast (provided), SRWC OWG Business Meeting
Starting at 0800	Registration
0830 – 0840	Welcome, Jake Eaton
0840 – 0925	Don Dickmann. Silviculture and biology of short-rotation woody crops, then and now
0925 – 1010	Lynn Wright and Gerald R. Elliott. Worldwide Commercial Development of Bioenergy: Examples, Success Factors, and Constraints
1010 – 1030	Break
1030 – 1130	**North American Regional Reports, Theo Verwijst presiding**
1030	US Pacific Northwest (J. A. Eaton)
1045	Northeastern US (T. A. Volk, E. Nordman, L. P. Abrahamson, E. H. White and L. B. Smart)
1100	Southern Region (John Stanturf)
1115	Lake States (Bill Berguson and Wendell Johnson)
1130 – 1200	**IEA Task 30 Country Reports**
1130	Sweden (Theo Verwijst)
1145	New Zealand (Ian Nicholas)
1200 – 1300	Catered Lunch
1300 – 1415	**IEA Task 30 Country Reports (Continued), Nils-Erik Nordh presiding**
1300	Australia (Don McGuire)
1315	Canada (Andrew Gordon)
1330	United Kingdom (Keith Richards)
1345	Brazil (Laércio Couto)
1400	Croatia (Davorin Kajba)
1415 – 1445	Break
1445 – 1600	**Production Systems, Pests and Disease, Ian Nicholas presiding**
1445	T. A. Volk, L. P. Abrahamson, L. B. Smart and E. H. White. Recent

	Experiences with Willow Biomass Crops in New York
1500	H. K. Nielsen and M. Ahlhaus. Growth, productivity, and combustion characteristics of short rotation energy crops in southern Norway
1515	D. R. Coyle and M. D. Coleman. Irrigation and fertilization have contrasting effects on growth and biomass partitioning of sweetgum and loblolly pine
1530	Theo Verwijst and Nils-Erik Nordh. Sustainable short rotation crop systems – improving production systems efficiencies
1545	Vicente N. G. Mazzarella, et. al.. Elephant grass pilot project: charcoal source for industrial uses
1600 – 1620	Break
1620 – 1720	**Production Systems, Pests and Disease (Continued), John Stanturf presiding**
1620	Neal T. Kittelson, Eugene R. Hannon and John J. Brown. Mating disruption for control of the Western Poplar Clearwing Moth in irrigated hybrid poplars
1635	Eugene R. Hannon, Neal T. Kittelson and John J. Brown. Developing strategies to control Carpenterworm Moth and Poplar/Willow Borer in irrigated hybrid poplars
1650	Laércio Couto, Marcelo Dias Muller, Daniel Câmara Barcellos, Michelle Margarido Fonseca Couto. Eucalypt based agroforestry systems as an alternative to produce biomass for energy in Brazil
1705	Aletta Davis and C. C. Trettin. Hardwood plantation productivity on former agricultural land in South Carolina
1720 – 1900	**Vendor Display/Poster Session – Mixer with Refreshments**
Posters	
1001	W. A. Geyer. Biomass production in the central great plains under various coppice regimes
1002	David R. Coyle, Mark D. Coleman, Jaclin A. Durant and Lee A. Newman. Productivity and pest susceptibility of 31 *Populus* clones in South Carolina, USA
1003	Rodney E. Will, Robert C. McGarvey, W. Russ Cobb, Richard F. Daniels and Marshall A. Jacobson. The effects of irrigation and fertilization on stem allometry of four short-rotation woody crop species
1004	Mark Coleman, David Tolsted and Jud Isebrands. Mid-rotation fertilization of Minnesota hybrid poplar plantations and the evaluation of nutrient balance
1005	T. A. Volk, J. Mirck, M. Farber, L. P. Abrahamson and D. Daley. Initial success establishing willow on solvay wastebeds in Syracuse, NY
1006	John A. Stanturf, Dexter Bland, Lisa Samuelson, Theodor Leininger and Bryce Burke. Three-year growth response of four clones of eastern cottonwood (*Populus deltoids* Bartr. Ex Marsh.) to fertigation
1007	F. Marcos Martin, F. Garcia Robredo and S. Villegas Ortiz de la Torre. Economic analysis of short rotation poplar crops in west central Spain
1008	Per S. Nielsen, Carolyn J. Anderson and Ian Nicholas. Environmental benefits of a wood pellet market in New Zealand
1009	L. Davis, C. Svensen, P. Rogers, J. Pearce and P. Peiris. Evaluation of a *Zymomonas mobilis*-based ethanol production process

1010	R. D. Perlack, L. L. Wright. Types of agricultural and forestry changes needed to annually produce 1 billion dry tons of biomass per year in the United States
1930	Dinner (Provided)

Tuesday, 9 November

	Breakfast on Own
Field Trip	
0700	Depart from Francis Marion Hotel
0800 – 0900	Mead Westvaco, Intensive loblolly pine clonal blocks (Phil Dougherty)
0900 – 0930	Santee Cooper Power, Rational for bioenergy production
1030 – 1130	University of Georgia/Mead Westvaco, Culture density trial (Rod Will)
1130 – 1200	Lunch
1330 – 1400	Savannah River Badging Office
1400 – 1530	Savannah River Exp A (Mark Coleman)
1800	Return to Francis Marion Hotel
	Dinner (On your own)

Wednesday, 10 November

0730 – 0830	Breakfast Buffet and SRWC OWG Business Meeting
0830 – 1015	**Phytoremediation/Environmental Benefits, Tim Volk presiding**
0830	G. Brubaker, J. Tillery and K. Owens. Reclaimed water use and biomass production on JEA's biomass energy research farm – Third year results
0845	J. G. Isebrands, D. R. Rockwood, R. B. Hall, et al. Phytoremediation of a perchloroethylene contaminated site in LaSalle, Illinois with *Populus* clones through hydraulic uptake and enhanced microbial activity
0900	Robert H. Kim, Cassandra L. Bayer, Daniel R. Hitchcock, Lee A. Newman. Remediation of VOC-contaminated groundwater at the Savannah River Site by phyto-irrigation
0915	Ronald S. Zalesny, Jr., Adam H. Wiese, Edmund O. Bauer, Don E. Riemenschneider, and Bart Sexton. Water usage and establishment success of *Populus* during phytoremediation of landfill effluent
0930	M. Gordon and N. V. Thevathasan. Biomass production and other ecological processes in temperate agroforestry systems in Canada
1000	I. Nicholas, L. Garrett, S. Pearce, G. Oliver, T. Evanson and P. Gearing. Biomass production for bioenergy from a young eucalypt plantation receiving untreated municipal effluent by sub-surface irrigation
1015 – 1035	Break
1035 – 1150	**Genetics, Breeding, Physiology and Wood Properties, Marilyn Buford, presiding**
1035	R. Francis, R. B. Hanna, S. –J. Shin, A. F. Brown, D. E. Riemenschneider. Poplar breeding for superior papermaking fibers
1050	R. J. Rousseau and T. L. Robison. Biomass productivity improvement of eastern cottonwood and American sycamore through genetics and physiology research

1105	R. J. Kodrzycki et al. A genomic approach to improvement of short rotation woody biomass crops
1120	Christopher B. Allen, Rodney E. Will, Marshall A. Jacobson and Richard F. Daniels. Production efficiency, radiation use efficiency, and canopy dynamics of four tree species receiving irrigation and fertilization
1135	Richard F. Daniels, Alexander Clark III, H. Lee Allen, Bruce E. Borders. Fertilization and irrigation effects on wood properties of fast grown loblolly pine
1200 – 1300	Catered Lunch
1300 – 1430	**Bioenergy/Economics/Policy/Barriers to commercialization, Jim Shepard presiding**
1300	David I. Bransby, Jose Ramirez-Zaragoza, Gerald R. (Gary) Elliot. Relationships between ash fusion temperature and ash composition for biomass and coal
1315	David I. Bransby. A cost analysis of co-firing biomass with coal in the Southeastern USA
1330	Lloyd Webb, Matthew McArdle and David I. Bransby. Tampa Electric Polk Power Station herbaceous biomass gasification test burn
1345	Tom Gallagher and Robert Shaffer. Assessing the cost and operational feasibility of "Green" hardwood winter inventory for southeastern pulp mills
1400	Rodney L. Busby, Donald L. Grebner. Barriers and institutional factors affecting short-rotation woody crops establishment
1415	G. Alker, C. Bruton, K. M. Richards. Large-scale implementation of SRC systems: assessment of technical and non-technical barriers
1430 – 1450	Break
1430 – 1630	Panel considering challenges to implementation: economics and regulations, Bryce Stokes presiding Gary Elliot, International Applied Engineering, Biomass Project Developer Jim Reaves, USDA Forest Service, Staff Director for Vegetation Management and Protection Research Mark Downing, DOE Oak Ridge National Laboratory Bill Garbett, International Paper Company Theo Verwijst, European perspective
1630 – 1800	IEA Biomass Business Meeting (or have on Thursday morning)

Large-Scale Implementation of SRC Systems: Assessment of Technical and Non-Technical Barriers

G. Alker, C. Bruton, K. M. Richards

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The development of short rotation crops for energy use has, in most member countries, been slow to develop and often remains a low priority for government. Interestingly, where the introduction of crops has been possible, alternative uses for short rotation crops tend to dominate. Such uses include phytoremediation, bioremediation, watercourse staving and wastewater treatment.

TV Energy, on behalf of Task 30 members, is investigating the technical and non-technical barriers to the large-scale introduction of short rotation coppice (SRC). This follows identification of the matter as a "high priority area" at the Task meeting in Denmark in 2001.

The proposed paper will report on the conclusions of the study currently underway across member countries. Comparisons will be made and recommendations for joint working arrangements between member countries suggested. In this way, effective partnership solutions to overcome barriers may be found, enhancing the rate of uptake of SRC.

Production efficiency, radiation use efficiency, and canopy dynamics of four tree species receiving irrigation and fertilization

Christopher B. Allen[1], Rodney E. Will[2], Marshall A. Jacobson[3], and Richard F. Daniels[2]

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To determine the effect of resource availability on stem production, canopy dynamics, and the efficiency of stem production, we measured the influence of irrigation and fertilization on leaf area index (LAI), intercepted photosynthetically active radiation (IPAR), foliar nitrogen concentration (foliar [N]), radiation use efficiency of stem growth (ε_{stem}), and production efficiency of stem growth (PE_{stem}). All measurements were made during the sixth growing season in stands of loblolly pine (*Pinus taeda* L.), slash pine (*P. elliottii* Engelm.), sweetgum (*Liquidambar styraciflua* L.), and sycamore (*Platanus occidentalis* L.) receiving five treatments: control, irrigation only, and irrigation with 57, 85, and 114 kg N ha^{-1} yr^{-1}. Beginning in March 2002, IPAR, litter biomass, and foliar [N] were sampled at regular intervals during the growing season. Litter biomass was converted to LAI while IPAR was scaled to annual PAR capture using solar radiation data. The increases in stem biomass growth produced by the irrigation with 85 kg N ha^{-1} (most productive treatment), compared to the control treatment were: 8.7 to 15.0 Mg ha^{-1} yr^{-1} for loblolly pine, 6.0 to 10.7 Mg ha^{-1} yr^{-1} for slash pine, 1.2 to 12.8 Mg ha^{-1} yr^{-1} for sweetgum, and 0.5 to 9.6 Mg ha^{-1} yr^{-1} for sycamore. Both LAI and PAR capture were well correlated with stem biomass growth ($r^2 = 0.68$, $r^2 = 0.79$, respectively – average of 4 species). Fertilization increased ε_{stem} and PE_{stem} for sweetgum and sycamore. Irrigation increased PE_{stem} for pines and sycamore as well as ε_{stem} for sycamore. Both PE_{stem} and ε_{stem} were positively correlated with foliar [N] for sweetgum and sycamore. These results indicate that for the hardwood species, fertilization may have influenced photosynthetic capacity, thereby shifting efficiencies. For the pine species, canopy size (PAR capture in particular) was the predominant driving factor behind growth regardless of resource availability.

A cost analysis of co-firing biomass with coal in the southeastern USA

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Co-firing biomass with coal to produce electricity offers multiple benefits, including reduction of emissions such as CO_2, NOx, SOx and mercury, and generation of new markets for agriculture. These benefits could be particularly helpful in southeastern states where most of the electricity produced is from coal-fired power plants, and where rural economies are in crisis. Alabama serves as a good example. About 70% of the electricity in this state is produced from coal. Ten years ago all the coal used for this purpose was mined in Alabama, but by 2002 the state imported 62% of the coal it needs from other states, mainly Wyoming. The primary reason for this change is that coal from Wyoming is lower in sulfur, and $450 million now leaves the state every year to buy coal. An economic analysis indicated that a 1.8-cents/kWh tax credit for electricity produced from biomass would largely offset the higher cost of this option. In addition, even if the higher cost of biomass were passed on to the consumer, the increase in the retail price of electricity from co-firing 10% biomass with coal would be negligible. Therefore, state governments should seriously consider enacting renewable portfolio standards.

Relationships between ash fusion temperature and ash composition for biomass and coal

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Biomass materials have developed a bad reputation in the utility industry for causing slagging in boilers, and this is one of the major barriers to widespread commercial use of these materials as a combustion fuel. The reason for the greater tendency of biomass materials to slag, compared to coal, is thought to be their generally higher content of potassium and calcium in the ash. However, no data are available on the relationship between ash composition and ash fusion temperature for different biomass materials. Therefore, the objective of this study was to examine relationships between ash composition and ash fusion temperature for a wide range of biomass materials and coal. Ash fusion temperature and ash composition were determined for 25 biomass materials, and similar data were also obtained for 21 samples of coal. Initial ash fusion temperature was higher for non-grass biomass than for grasses. This appeared to be related to high concentration of silica in the grasses. Regression relationships between components in the ash and initial ash fusion temperature were markedly different for biomass and coal.

Reclaimed water use and biomass production on JEA's Biomass Energy Research Farm – third year results

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In 1999, the JEA, a water, wastewater, and power utility in Jacksonville, Florida, implemented a 19-acre demonstration project (Biomass Energy Research Farm or BERF) adjacent to their District 2 WRF, to investigate the viability of using irrigated, short-rotation-intensive-culture (SRIC) biomass farms to produce woody and/or herbaceous biomass for green power and other co-products.

Approximately 10,000 trees, consisting of 4 fast-growing hardwood species (eastern cottonwood, hybrid poplar, yellow poplar, sycamore) and loblolly pine, were planted in April 2001. In June 2002, 4 fast-growing herbaceous species (Giant Reed [*Arundo donax*], two bamboos [*Bambusa ventricosa* and *Bambusa bambos*], and Alamo switchgrass [*Panicum virgatum*]) were planted on approximately 1 acre of the site. The site is irrigated with up to 454 m^3d^{-1} of reclaimed water using both drip and sprinkler irrigation systems. In 2003, Giant Reed demonstrated the highest biomass production of all woody and herbaceous species (34.2 $Mgha^{-1}yr^{-1}$), while eastern cottonwood has had the highest average yield of all woody species (8.0 $Mgha^{-1}yr^{-1}$).

This paper presents an overview of JEA's BERF project and summarizes biomass production, energy yield, nutrient removal, and transpiration data collected from the first 3 growing seasons of the project. Particular emphasis is placed on JEA's efforts to develop a sustainable natural treatment system to address environmental degradation concerns resulting from their wastewater treatment and power production operations.

United Kingdom Country Report

Charlotte Bruton, Gillian Alker and Keith Richards

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After the short rotation coppice (SRC) site/clone interaction trials of the late 1980s and early 1990s conducted by the Forestry Commission and ETSU, the late 1990s saw a boom time for SRC and medium-scale biomass plants in the UK. Companies such as First Renewables, Border Biofuels and Ambient Energy were awarded NFFO contracts for a variety of biomass developments, most of which proposed using advanced technologies such as gasification or pyrolysis with a commitment to draw on a combination of forestry residues and SRC. However, delays occurred with many of the projects for reasons such as technical difficulties with plants, issues with road access and planning permission, and eventually all the projects failed.

The most significant was Project ARBRE (ARable Biomass Renewable Energy), which was to be an 8MWe gasification plant utilizing combined cycle technology and sited in Eggborough, Yorkshire. Both the DTI (Department of Trade and Industry) and the European Commission agreed on grant funding of £3m and £10m respectively, with the remainder of the financing coming from private companies.

Project ARBRE was estimated to require 43,000 odt (oven dried tons) of wood chip per annum and it was planned to utilize biomass fuels from two main sources, forestry residues and SRC. As a result of this perceived need, farmers in a 40-mile radius of the plant were encouraged to plant SRC and were awarded contracts to guarantee a market for the fuel grown. In total, over 1500 ha of short rotation coppice was planted in a 40-mile radius of the plant.

Unfortunately, in 2002, the developers of Project ARBRE pulled out of the program due to long delays in commissioning and the many technical problems encountered. As a result, ARBRE has been inactive for over a year and although it now has a new owner, there has as yet been no resolution on how to bring the plant to commercial production. As a result of the failure of this project, a high level of scepticism was generated within the farming community and has significantly delayed progress in the UK.

At the present time in the UK there are a number of key policy drivers for the development of SRC for bioenergy; namely:

- The creation of a low carbon economy, so reducing greenhouse gas emissions and meeting renewable energy targets (10% of the UK's electricity to come from renewables by 2010 and increasing thereafter)
- Providing diversification opportunities for farmers and growers
- Creating a more sustainable and environmentally-balanced countryside
- Creating opportunities for rural employment.

To assist in getting farmers and growers interested in growing SRC, the Defra (Department for Environment, Food and Rural Affairs) runs the "Energy Crops Scheme" (ECS), which has two main streams of funding; establishment grants and producer groups. Establishment grants aim to cover 50% of the cost of establishing SRC. In the UK, the two main energy crops are willow coppice and miscanthus. For willow coppice, the grant available is either £1600/ha or £1000/ha, depending on previous land-use. For miscanthus, the establishment grant available is £920/ha. The producer-group funding scheme can provide 50% of the costs of establishing a grower group, up to a maximum of £200k per group. The aim of establishing producer groups is to enable growers to work together to harvest and supply crops to an end market, sharing the risk and the profits to be made.

Another key driver for change in the UK is the amendment to the "co-firing rules" as part of the Renewable Obligation Order (RO). Under the RO, existing fossil fuel power stations can claim ROCs (Renewable Obligation Certificates) through the co-firing of fossil fuel with biomass up until 2016. Until 2009 there is no requirement to burn a proportion of energy crops, however, subsequently the following must be adhered to in order to qualify for ROCs:

Period	**Minimum % of Energy Crops**
1st April 2009 –31st March 2010	25%
1st April 2010 – 31st March 2011	50%
1st April 2011 – 31st March 2016	75%

The aim of these rules is to encourage the early and large-scale development of energy crops (and related infrastructure) in the UK by ensuring a guaranteed market for the fuel. This "market-enabling measure" will then, it is believed, catalyze the supply of fuel to dedicated biomass plants post 2016 when the amount of SRC required for co-firing is likely to diminish.

An important factor will be the reform of the Common Agriculture Policy (CAP) with implementation in the UK in 2005. The overall aim of the reform is to decouple subsidies and production through the introduction of a Single Farm Payment (SFP). This change in the way that subsidies are to be paid under CAP reform, releasing farmers from production of certain crops in order to gain subsidies, could have positive implications for SRC. It may open up markets to non-conventional crops and offer an economic way for farmers to diversify. In advance of the reform, an annual aid payment for energy crops was introduced on January 1, 2004. This payment of €45/ha is available to growers with energy crops planted on non set-aside land with a contract with an end user.

There remain many barriers to the introduction of large-scale SRC plantations in the UK, many of which are linked to uncertainties in the market. Underlining this national position is a constantly changing set of European policies and legislation relating not only to energy crop production, but also to farming directly, and to related industries such as waste management. Cumulatively, these have a dramatic impact on the confidence of farmers and growers when contemplating diversifying into SRC for energy production.

Other biomass fuels, such as forestry and sawmill residues, are generally available at a lower cost than SRC. This is primarily because the SRC industry is still in its embryonic stage and the special equipment required to manage SRC is expensive and in short supply. Since energy producers have the option to purchase lower priced alternatives, there is limited opportunity for the higher-priced SRC wood chips to compete.

The RO and other drivers are expected to increase the market for SRC in the future, however, at the present time, there is a lack of confirmed markets. Many large power producers have not yet committed to setting up co-firing contracts with growers, despite the "co-firing rules" now in place. Dedicated biomass plants are also limited in number and those that have been proposed struggle to be constructed for various financial, regulatory and planning reasons.

Despite these barriers, there are a few examples where the SRC industry is starting to develop in the UK, fueled by the new drivers discussed above. New employment opportunities are being created, habitats diversified, and a range of other benefits accrued.

At present in the UK there are three Defra funded SRC producer groups taking the lead in organizing the wider-scale planting and production of SRC-based fuels. The first of the three is the Renewable Energy Growers (REG) Group and was established around project ARBRE with the aim of providing the fuel necessary to run the power station. Since project ARBRE failed, the group has been sourcing alternative end markets for the SRC, and a number of the farmers have installed their own small-scale biomass heating systems in order to utilize the willow coppice on-farm. Another exciting opportunity arose in March 2004 when Renewable Fuels Ltd. announced an agreement between themselves and Drax Power Ltd. to supply short-rotation coppice to the 4,000MWe coal-fired power station. The bulk of the SRC fuel is to be sourced through the REG producer group.

The second producer group was formed in 2002 to supply SRC to the proposed 5.5MWe power station at Eye in Suffolk. The group, Anglia Encrops, has 6 members with approximately 80 ha of willow coppice growing. Due to the failure of the Eye project, the group is looking for alternative markets for the fuel. It is expected that the main market for the fuel will be a cluster of small-scale heating applications.

The most recent producer group to be formed is TV Bioenergy Coppice. This group was formed in 2003 and covers the region of the Thames Valley, Surrey and north Hampshire. The group was established to provide SRC fuel to the existing 90MWe power station in Slough, the proposed biomass CHP plant at Bracknell, and the developing small-scale heating market in the region. In addition, the group is researching opportunities to supply fossil-fueled power stations for co-firing such as the 2,000MWe plant at Didcot. To date, the group has 5 members and 45 ha of SRC, but plans to expand considerably over the next 5 years. It is hoped that due to the existence of an existing biomass power station in the local area (which has strong connections with parent company TV Energy), the group will not run into the same problems as other producer groups in the UK.

The views expressed in this report are those of TV Energy and do not necessarily represent those of DEFRA or the DTI.

The status of hybrid poplar breeding and productivity research in the lake states

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Plantation culture of hybrid poplar has been the subject of research for the past 3 decades in the Lake States and has involved numerous universities and public and private agencies in the states of Iowa, Michigan, Minnesota and Wisconsin. Although funding for research in plantation culture has decreased substantially since the mid-1990s, a significant effort in genetic improvement of poplars and plantation culture continues. High stumpage prices for traditional commercial species in Minnesota have focused efforts in poplar production to supply feedstock for paper production. Also, biomass energy continues to be a subject of interest and a plantation-based project is currently being considered in Minnesota.

Plantation Culture and Commercial Application: Hybrid poplar is currently being applied commercially in the Lake States. Minnesota has the largest acreage of commercial-scale plantations with approximately 30,000 acres in production. The bulk of this acreage has been planted by the International Paper Company to supply feedstock for their paper mill at Sartell, Minnesota with 2,000 acres being established annually. In addition to activities by International Paper, approximately 6,000 acres of poplar plantations have been established in the past as part of the Department of Energy’s Biomass Feedstock Development Program, as well as the “Oklee Project” in northwestern Minnesota. Large-scale plantings began in 1995 and some plantations are expected to be harvested beginning in 2008. Plantings in Iowa, Michigan and Wisconsin have been limited primarily to research and demonstration plantings with little large-scale commercial activity.

In the past, biomass production research has included a variety of plant spacings with rotation ages ranging from 5-15 years. More recently, research has focused on plant spacings from as low as 435 to 1,200 trees per acre. However, the majority of research is aimed at production of larger-sized trees for pulpwood production with plant populations ranging from 500 to 680 trees per acre. Rotation age is expected to range from 10-15 years.

Research Institutions: A variety of research institutions have been involved in hybrid poplar research over the past 2 decades in the region. These include the University of Iowa (Rick Hall, Woody Hart), the University of Minnesota (Bill Berguson-UM Duluth-NRRI, Wendell Johnson-UM Crookston, Carl Mohn, UM-St. Paul), Michigan State University (Don Dickmann) and the University of Wisconsin (Glenn Stanoz). In addition to university research, the USDA Forest Service (Ed Hansen, Don Riemenschneider, Dan Netzer, Jud Isebrands, Mike Ostry) has been a major force in development of poplars in the region. Also, Ed Wene at the Agricultural Utilization Research Institute (AURI) has been actively involved in the commercial application of poplars in Minnesota. Research has involved a range of topics related to cultural practices in poplar plantations, disease and insect control, as well as genetic improvement of poplars. This research was supported financially by a variety of state and federal agencies with the DOE-Biofuels Feedstock Development Program and Oak Ridge, Tennessee being a major contributor to these efforts. Focused statewide efforts such as the Minnesota Hybrid Poplar Research Cooperative (MHPRC) have supplemented these efforts.

Cultural Practices Research: Research in vegetation management has been led by the US Forest Service at Rhinelander, Wisconsin (Dan Netzer), with additional studies done by various cooperators. Effective pre- and post-emergent herbicide recommendations have been developed and this research has contributed greatly to the commercial application of poplars in the region. Herbicides currently in use in plantation culture in the region include imazaquin (Scepter), pendimethalin (Prowl) for broad-spectrum control and quizalofop (Assure) for post-emergent grass control.

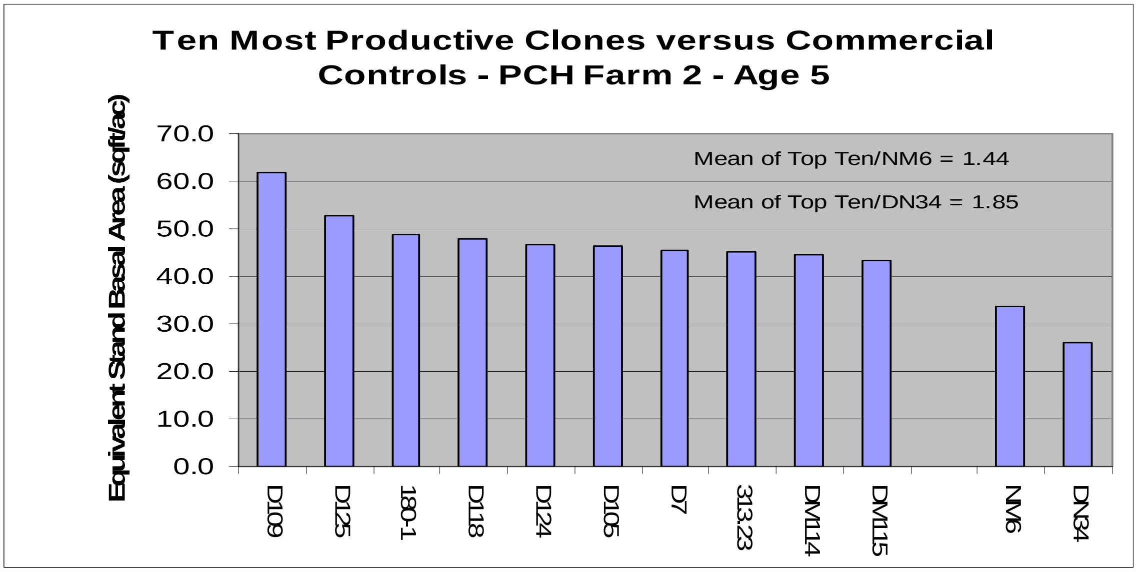
Lack of information on post-harvest replanting methods and cost has been identified as a barrier to small private landowners that might consider hybrid poplar as an alternative crop. The Agricultural Utilization Research Institute (AURI), the University of Minnesota-Crookston (UMC) and the Natural Resource Research Institute (NRRI) have conducted numerous small-scale (100-200 trees) winter- and summer-harvest coppice studies in northwestern Minnesota. To date, none of these tests have shown suitable growth after coppice to recommend as a post-harvest option. The feasibility of options such as replanting within-row or complete stump removal followed by replanting is being explored by the UM-Crookston and the AURI.

Fertilization of poplar plantations has been a subject of research since the mid-1990s. The Minnesota Hybrid Poplar Research Cooperative began establishing field experiments in 1997. These experiments have demonstrated cost-effective responses of hybrid poplar to nitrogen fertilization with responses ranging from 20-50% greater than unfertilized controls. A rate of 100 pounds per acre of elemental nitrogen applied as urea beginning in year 4 and continuing as biennial applications is the current recommended practice.

Growth and Yield: Many research sites in the region have included large-block yield trials of various clones. Yield blocks have typically been planted using clones DN2, DN17, DN34, DN182 and NM6. Yields reported by Netzer et al. were found to vary widely by clone and site with average mean annual increment in the range of 3.0 to 4.5 ovendry tons per acre per year at culmination. Mean annual yields of the best clones at the best sites are approaching 10 tons per acre per year. Yields of large-block trials in more northerly locations in Minnesota measured by NRRI were reported to be 2.5 to 3.5 tons per acre per year.

Genetic Improvement Research: The majority of poplar research activity in the region has been targeted at genetic improvement of hybrid poplar for plantation culture. With few exceptions, all research institutions in the region have been involved in some aspect of genetic improvement whether it be clone testing or breeding efforts. Clone testing has been underway since the early days of DOE-supported research and has led to identification of high-yielding, disease-resistant genotypes recommended for commercial planting. Of the initial 100-plus genotypes screened in field sites in the region, clones NM6 (*P. nigra X maximowiczii*), DN2 (*P. deltoides X nigra*), DN5 (*P. deltoides X nigra*) and DN34 (*P. deltoides X nigra*) were identified for potential commercial planting. At this time, the majority of commercial acreage is planted to NM6.

Prior to 1996, clone trials in the region consisted of pre-existing clones that have been made available by other programs in Europe and Canada. These include older Euramericana clones as well as material from Belgian and Canadian breeding efforts. Planting of clone tests of native cottonwood and F1 hybrids created through breeding and selection efforts in the region were established beginning in 1997. Results of these tests indicate significant potential to improve yield through focused breeding and field testing with average yields of the ten highest yielding clones typically 1.3 to 1.5 times that of commercial standards such as DN34 and NM6. Figure 1 below shows a typical result of these tests.



In light of the limited breadth of genetic material available for commercial plantations, research has concentrated on genetic improvement of poplars through breeding and field testing. The University of Iowa, the USDA Forest Service and the University of Minnesota have been instrumental in this effort. The focus of this work is to improve growth rates, disease resistance and rooting ability of *P. deltoides* as well as production of F1 hybrids and backcrosses. This includes hybrids of *P. deltoides*, *nigra*, *maximowiczii* and *trichocarpa*. At this time, the only active poplar breeding program is located at the University of Minnesota, NRRI. In addition to development of genetic material for commercial application, a goal of current breeding is production of a sufficient number of individuals of a TD X D family to support an ongoing DOE-USFS-UM joint project to determine the function of genes controlling carbon allocation and sequestration in poplars.

Barriers and institutional factors affecting short-rotation woody crops establishment

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Short-rotation woody crops (SRWC) are an alternative investment opportunity for landowners to produce more wood fiber per unit area and non-timber outputs. Increased urbanization is affecting land-use patterns and stimulating the need to produce more on fewer acres. Greater production of wood fiber per unit area provides greater flexibility to decision makers to meet society's demands. The problem that this study examines is whether existing institutional factors and potential barriers such as taxes, forestry regulations, and environmental concerns affect a landowner's decision to establish SRWC in the United States. An objective of this study is to identify, document, and compare existing tax structures, forestry regulations, and environmental issues that directly and indirectly affect short-rotation woody crops across selected states in the United States. The methods used include internet and library searches of pertinent information. The validation process involved numerous telephone and field visits with relevant experts.

Landowners considering the establishment of SRWC are subject to federal taxes using the same rules as any other timber crop, despite similarities of SRWC in rotation length to Christmas trees. For both non-industrial and industrial landowners, land, equipment, and timber accounts must be created to track capitalized costs. Capitalized costs can only be recovered by those methods deemed acceptable for each account category. For instance, installation costs for land improvements such as access roads and water pumping stations have to be capitalized until the land is sold, which may hurt since SRWC plantations may require large irrigation systems. Establishment costs for SRWC are placed in the timber account and not depleted until the timber is sold, but SRWC's shorter rotation length makes this a relative advantage. Equipment costs can be depreciated over IRS specified life spans. For landowners interested in establishing SRWC on a smaller scale, the IRS does allow the amortization of establishment cost, excluding costs of installing irrigation systems, over an eight-year period. In addition, revenues generated from SRWCs face capital gains treatment as any other timber crop.

Non-industrial and industrial landowners interested in establishing SRWC face a variety of state taxes. Typically, SRWC face common forestry taxes such as property or land-use taxes and severance taxes. Land-use taxes are applied at the county level where tax rates reflect the current land-use. Tax rates for forest land-use are generally lower than are those for agricultural land-use, except for places like the Mississippi Delta. Severance taxes are enforced by the state on all timber products severed from the landowner's property. In general, these state-specific taxes are deductible for federal income tax purposes in the year in which they occur, according to IRS §164. The frequency and details of these state-specific taxes can make certain locales more favorable for establishing SRWC.

The type and number of state taxes paid depend on where the landowner is interested in establishing a SRWC plantation. For instance, Idaho, Oregon, and Washington treat SRWC plantations as an agricultural land-use, subject to higher agricultural property taxes, but exempt them from state severance taxes. In the southern US, state governments treat SRWC plantations as a forest land-use and subject them to severance taxes. States subjecting SRWC plantations to severance taxes include Alabama, Arkansas, Georgia, Louisiana, Mississippi, North Carolina, and

South Carolina. Another important issue is whether irrigation equipment used in SRWC plantation establishment and cultivation is subject to taxation. Only Louisiana, Mississippi, and South Carolina do not subject irrigation equipment to taxation. Other states such as Arkansas, Florida, Georgia, Louisiana, Kentucky, and North Carolina impose a tax on irrigation equipment.

Environmental concerns are a major factor impacting SRWC establishment. Many plantations are established on former agricultural fields with the view that the intensive management practiced is, in part, less environmentally objectionable than previous agricultural regimes.

A major issue that affects forestry regulations is the Clean Water Act of 1977. It authorizes the administrator of the Environmental Protection Agency (EPA) to issue federal and state agencies information pertaining to guidelines for identifying and evaluating the nature and extent of non-point sources of pollutants. In addition, it outlines processes, procedures, and methods for controlling pollution stemming from non-point sources including silvicultural activities, which are relevant to SRWC. This has resulted in the development of voluntary and regulatory state best-management practices to control pollution from forestry activities.

Although most southern states use voluntary best-management practices to meet the Clean Water Act of 1977 standards, mandatory state forestry acts explicitly define forest practices and which ones are required to have approved permits prior to implementation. For instance, in Washington, permitting is necessary for timber harvesting, constructing roads or applying forest chemicals. Failure to comply with this permitting process subjects violators to both criminal and civil actions. Washington does clearly state which forest practices are exempted from the application process. Among those exempted from the act are SRWC. In the act, SRWC are referred to as intensively managed hardwoods (WAC 458-30-200). This exemption for SRWC also exists for Oregon's forest practice act, but to date Idaho has no such exemption.

Another important barrier to SRWC is access to a dependable water supply. In the Pacific Northwest, the Columbia/Snake River System is an important natural resource for the economies of Idaho, Oregon, and Washington. It is comprised of a series of locks and dams that manage water levels along the whole river system. It provides flood control to local areas, generates 75% of the Northwest's electricity, provides transportation for the wheat export industry, supports recreational activities, and supplies water for agricultural land-uses. In addition, this river system supports several salmon runs, which are currently endangered. This potential trade-off has led to efforts for salmon recovery within this system.

Since many industrial fiber farms incorporate fertigation systems for managing SRWC, then dam breaching may adversely affect the growth and vigor of their investment. Several reports on how dam removal affects river water levels exist around the country. Removal of the four dams along the Snake River could adversely affect thirty-five thousand acres of irrigated farmland. Other sources suggest that as much as 7.3 million acres of irrigated farmland in the tri-state area could be affected. Recently, a US Corps of Engineers study determined that there is no technically or economically viable way to modify irrigation pump intakes to make them operate without the Snake River dams. This is due to the increased sediment loads clogging irrigation lines. In addition, local forest products mills would face greater raw material costs by importing wood fiber to support mill needs if existing SRWC were eliminated.

During the Clinton Administration, the most aggressive dam removal proposal would leave the dams standing for 10-15 years. According to the same source, a decision to breach the 4 dams would not be made for another 5-10 years. Environmental groups and supporting legislators continue to strategize on ways to achieve salmon recovery through dam breaching given President

Bush's opposition prior to the 2000 national elections. Recently, Democratic Congressman Jim McDermott from Seattle introduced legislation aimed at removing the 4 lower Snake River dams. However, the bill faces stiff opposition on the House floor and is not expected to reach a vote. Nevertheless, other efforts for salmon recovery include an introduced bill with $600 million earmarked to restore critical salmon habitat in the Pacific Northwest. Regardless of whether the 4 lower Snake River dams are breached or not to recover endangered salmon populations, SRWC landowners who use fertigation face an uncertain future with regards to their water supply.

Many SWRC are heavily dependent on traditional tree-breeding practices to develop trees with desirable attributes. The most prevalent practice is cross-pollination, which is common for agricultural crops. Attributes that are desirable and commonly selected include those that improve tree vigor, height, and diameter. Other practices that are not typical include the use of molecular biology for obtaining desirable tree attributes. Planted trees which have attributes selected by molecular biology practices are considered genetically engineered (GE). In general, the development of new tree breeds allows landowners to produce more wood with desirable attributes on a per acre basis. In addition, SRWC establishment on agricultural lands leads to wildlife habitat diversification.

Despite the benefits derived from traditional tree breeding programs, numerous environmental groups do not differentiate between trees derived from traditional or non-traditional breeding practices and lump them under the classification of genetically engineered. These groups believe that SRWC with GE trees are generally sterile environments, promote soil erosion, water pollution, gene escape, and degenerate soil productivity. They use the terms "Frankentrees", "Frankenscience" and "Frankenforestry" to describe genetically engineered trees. Some of these groups have utilized terrorist tactics such as burning down research labs, vehicles, endangered species, and destroying genetically engineered crops and trees. Groups claiming responsibility include "Reclaim the Genes," "Genetix Goblins," "Earth Liberation Front," and "The Washington Tree Improvement Association" for activities in British Columbia, Oregon, and Washington. From late 1999 to mid-2001, 16 attacks have been made against research facilities conducting genetic engineering of plants. Of these attacks, 6 focused specifically on species such as poplar used as SRWC, resulting in millions of dollars in losses.

For landowners interested in establishing SRWC, it is important to focus on attacks by eco-terrorists on SRWC with genetically engineered trees and advocacy campaigns against genetically engineered plants. Attacks by eco-terrorists, although gaining publicity, have not affected large acreages of SRWC. A review of the literature and Internet sources reveals that only a few environmental groups are targeting genetically engineered wood plantations as being ecologically unsound despite evidence to the contrary.

Landowners have to consider a wide variety of factors when considering the establishment of SRWC. Although landowners benefit by producing more wood fiber per unit area, there are many potential factors that may adversely affect their investment. For instance, maintaining operational flexibility may require paying higher agricultural land-use taxes in some regions. In addition, SRWC owners may face water supply issues and potential marketing problem for their harvested fiber because of the growing environmental movement against genetically engineered wood.

Mid-rotation fertilization of Minnesota hybrid poplar plantations and the evaluation of nutrient balance

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Fertilization of hybrid poplar in Minnesota, USA results in over 70% increase in productivity. However, some plantations respond little, if at all, to fertilizer application. This study tests methods for diagnosing fertilizer response through field trials in 4 locations growing hybrid poplar near Alexandria, MN. Study sites received three annual 50 kg N ha^{-1} doses of urea for comparison to a single dose of 150 kg N ha^{-1} urea applied in the first year. By the end of the third year productivity increased almost 40% with repeated fertilization at 1 location while gains at other locations were more modest. Split applications were associated with greater growth and fertilizer use efficiency compared with the single large application. Split applications of a blended fertilizer including macro- and micronutrients did not improve growth over urea applications. Complete foliar nutrient analysis showed trees were in good nutritional balance and not limited by any nutrient besides N, explaining the lack of response to blended fertilizer. Leaf N levels were positively correlated with productivity, but this relationship changed with tree age. Measurement of LAI showed promise as an indicator of fertilizer response potential. Accurate diagnosis of fertilizer response potential will require considering multiple factors.

Eucalypt based agroforestry systems as an alternative to produce biomass for energy in Brazil

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Eucalyptus were introduced in Brazil in the early 1900s by Edmundo Navarro de Andrade with the objective of producing sleepers and firewood for the São Paulo State railroad Companhia Paulista de Estradas de Ferro in substitution of native timber. In the 1940s, large plantations of eucalypts were established in Minas Gerais, in the Rio Doce Valley, to be used as raw material to produce charcoal as a substitute for coke, to reduce the iron ore in the pig iron and steel industry of that state. From its introduction through 1966, 400,000 ha of eucalypt plantations were established in Brazil for industrial purposes.

To supply the increasing demand for timber as raw material for different sectors of the economy, the Brazilian government launched, on September 2, 1966, Law 5106, providing fiscal incentives for afforestation and reforestation. According to this law, people and companies could apply up to 50% of their revenue taxations in afforestation or reforestation projects. In the 1970s, the Brazilian government created new incentive programs for reforestation, such as FISET (Fundo de Investimentos Setoriais-Florestamento), as well as the National Program for Pulp and Paper and the National Plan for the Charcoal-based Pig Iron and Steel industry. All these programs contributed to the increase of short rotation forest plantations in Brazil. In 1989, when the Brazilian government extinguished the fiscal incentives for reforestation, the country had about 6 million ha of eucalypt and pine short rotation plantations.

To meet the significant demand for a permanent supply of timber for various sectors of the Brazilian economy, the eucalypt has been the first choice. Eucalypt offers a large number of species, considerable adaptability to different soil and climatic conditions of Brazil, availability of improved seeds and genetic material for vegetative propagation, existence of hybrids and clones adapted to Brazilian conditions for different uses of the timber, and known silvicultural treatments and techniques to establish large plantations of this genus in Brazil. Eucalypt timber is used for pulp and paper production, charcoal production, solid wood products, medium density fiber boards (MDF), fiber and particleboards, oriented stranded board (OSB), plywood and veneer, pole construction, and firewood and biomass for energy.

The soil and climatic conditions of the Brazilian territory have led to the development of advanced eucalypt-based forestry and agroforestry activities. The productivity of the short rotation eucalypt plantations in Brazil can reach 45-80 $m^3ha^{-1}year^{-1}$, while in other regions of the world it is around 25 $m^3ha^{-1}year^{-1}$. This has stimulated most forest companies to establish eucalypt plantations, diminishing the pressure on native forests. Brazilian researchers and industry have studied not only the technical aspects of highly productive eucalypts, but also economic, environmental and social aspects of such plantations. Recent studies have shown that the short rotation eucalypt plantations in Brazil do not adversely interfere in the hydrologic cycle or water production in the region where they are located. The demands for water and nutrients of the eucalypt plantations are similar to those of other forest and agricultural crops in Brazil. However, the efficiency of the eucalypts to use water, nutrients and solar radiation in the biomass production of their plantations is greater. Additionally, being a forest, eucalypt plantations promote nutrient cycling, protect the soil against erosion, and provide shelter for wildlife, contributing to an increase in biodiversity.

In Brazil, forest activities correspond to 4.5% of the NGP (US$28 billion), generating 2 million direct and indirect jobs. More than 100,000 small farmers plant eucalypt on their properties utilizing family members for labor, thus contributing to the fixation of those families in the rural areas of the country, increasing their income and improving their way of life. With Kyoto's protocol and the advent of the Clean Mechanism Development activities, there is an opportunity in Brazil for additional income by using eucalypt forest plantations to sequester CO_2. Some companies such as PLANTAR and V & M Florestal have these kinds of projects underway already for carbon credits commercialization.

Short rotation eucalypt plantations in Brazil are established with consideration for sustainability. Sound and well-researched nutrient cycling and fertilizer utilization are always considered, and constantly improved upon by the research institutions, universities and affiliated forest companies. In the 1980s, eucalypt based agroforestry systems began to get more attention from researchers and today they have been used not only by small farmers, but also by large companies in their own plantations and in tree farm extension programs. This land-use system allows a better occupation of the site and favorable generation of jobs in rural areas. Perhaps the best example of the practice of eucalypt-based agroforestry in Brazil (and in the world) is the case of the Votorantim Metais in Minas Gerais state, Brazil. In year 0, eucalypt is planted in 10 m x 4 m spacing with intercropped rice. In years 1 and 2, soybeans are intercropped between the rows of eucalypt, and from years 3-11 pastures and cattle compose the final silvopastoral system.

The sustainable use of these short rotation eucalypt plantations in Brazil produces goods and services and generates jobs and income for the country's population. This is the best way to keep eucalypt plantations permanently contributing to the development of Brazil and the protection of its forest capitol.

There are about 3 million ha of eucalypt plantations in Brazil, located mainly in the states of Amapá and Pará in the north region, in Pernambuco and Bahia in the northeastern region, in Mato Grosso, Goiás, Mato Grosso do Sul in the central west region, in Espirito Santo, Minas Gerais, Rio de Janeiro and São Paulo in the southern region and in Paraná, Santa Catarina and Rio Grande do Sul in the southern region of the country. Minas Gerais state is the leader with about 1.2 million ha of eucalypt plantations for timber, charcoal, pulp, solid wood and fiberboard production.

The main species planted are: *Eucalyptus grandis, E. urophylla, E. camaldulensis, E. saligna, E. citriodora, E. cloeziana,* hybrids of *E. grandis* with *E. urophylla* and with *E. camaldulensis.* The productivity ranges from 25-80 cubic meters per ha per year depending upon the region, the site and the genetic material used in the plantations (clones of high productivity and disease resistance). Several advances in eucalypt plantation management have occurred in Brazil. There was a reduction of 50% in the production costs between the 1970s and 2000s due to technological improvements of the forest companies. At the same time, environmentally correct silvicultural practices have been adopted and social considerations have been included into the forestry framework.

Eucalypt plantations in Brazil are established under very advanced silvicultural practices. The first step consists of choosing the best genetic material to suit the site and to meet the objectives of the enterprise. Most of the eucalypt plantations in Brazil are established in areas previously occupied by eucalypt or pine plantations or in degraded pastures. There is no reason for a company or landowner in Brazil, which has less than 1% of its territory occupied by forest plantations, to remove native forest vegetation to plant any exotic or native forest species. The amount of degraded pasture and agricultural land in Brazil for reforestation purposes is considerable, but most often, the forest companies prefer to use their own land, renewing their harvested stands with new and improved genetic material. This way, forest companies in Brazil are able to increase their timber production without increasing their forest areas. On the other hand, most of the forest companies in Brazil today are engaged in some tree farm program so they can get part of their supply of timber from local rural landowners.

The first step in the annual reforestation program of each company consists of acquiring the seeds and/or the clonal seedlings. It takes about 2-3 months to prepare a 25-30 cm tall eucalypt seedling for reforestation in Brazil. Prior to planting, site preparation often begins with control of leaf cutting ants, a very damaging insect. This is done with baits containing sulfluramid as the active ingredient. Soil termites, which feed on the roots of seedlings and juvenile eucalypt plants, must also be controlled. The use of fire for site preparation in reforestation projects in Brazil is not a common practice today, and it is forbidden in some states. Land preparation for eucalypt plantations follows a minimum cultivation technique with the use of herbicides to avoid early competition with weeds. Seedlings are usually planted in a 3 m x 2.0 m, 3 m x 2.5 m, or 3 m x 3 m initial spacing in holes or planting spots, or in rows where the soil and subsoil are cut with appropriate equipment pulled by a farm tractor to help early establishment of the small tree. A basic NPK fertilizer is applied in each planting spot, sometimes with Boron and Zinc as micronutrients. The most important fertilizer for the eucalypt plantations in Brazil is phosphorus due to the nature of our tropical, lateritic, soils, which are poor in this nutrient. Planting operations occur year round due to the increasing use of irrigation. This is done with the help of water tanks pulled by tractors or on top of trucks, allowing the application of 2-3 liters of water per seedling 2-3 times after planting.

Post planting, silvicultural treatments in eucalypt plantations are carried out mainly in the first 2 years of stand establishment and consist of weed control, fire protection, fertilization and pest control. Weed control can be mechanical or with herbicides. Forest stands must be protected against forest fires by means of firebreaks. Sometimes it is necessary to provide additional fertilization, mainly with nitrogen and potassium, and micronutrients, such as boron and zinc. There are several pests and diseases that occur in the eucalypt plantations in Brazil. Disease is controlled by using hybrids and clones which are resistant. Natural enemies developed at the universities and Forest Research Centers control caterpillars and other insects that might become plagues in the eucalypt plantations. One of the most effective ways to avoid the increase of problem insects is to keep the preservation areas of native forest in a mosaic pattern with the plantations in such a way as to improve the biological control of such potential plagues by birds and other biological agents.

Rotation of eucalypt plantations ranges from 5-17 years, depending on the objective of the enterprise. Usually for the eucalypt based charcoal production companies, the pulp and paper companies, and the fiber and particleboard producing companies, the rotation is 5-7 years. For solid wood products, such as sawn timber, veneer and plywood, the rotation can vary from 12-17 years.

Forest harvesting of eucalypt plantations in Brazil is very sophisticated today. It is mechanized, even in some hilly regions such as the Rio Doce valley in Minas Gerais, where a very big pulp company has its forest operations and industrial production. Trees are cropped in clearcutting operations by harvesters who remove the limbs and the branches and cut them into specific sizes to be transported to the plant yard. Most of the companies debark the logs in the factory yard using waste biomass for energy generation. However, there is a tendency now to debark the trees in the field avoiding the removal of nutrients from the site, since most nutrients are concentrated on that part of the stem. The residual of the harvesting operations, such as branches and treetops, are left on the site for nutrient recycling. Studies have shown the importance of this decision on the growth of the coppice or on the growth of the new stand planted in that specific area.

Irrigation and fertilization have contrasting effects on growth and biomass partitioning of sweetgum and loblolly pine

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Benefits of intensively managed forest technology are realized by maintaining high productivity. Productivity increases in intensively managed forests have been attained by improved resource availability through water and nutrient amendments. Increased stem productivity has been attributed to productivity shifts from roots to shoot. We examined above and belowground growth and biomass accumulation and distribution in sweetgum and loblolly pine receiving irrigation (I), fertilization (F), or irrigation + fertilization (IF) treatments via a drip irrigation system or no treatment (C). Aboveground growth and biomass accumulation was affected positively by increased resource availability in both species. All tissues in both species responded positively to F, but some did not respond to I. After four growing seasons, total productivity rates in the IF treatment for sweetgum and loblolly pine were >8.5 and >8.0 Mg ha^{-1} yr^{-1}, respectively. Stem biomass was not affected by irrigation in loblolly pine, as productivity in the F (3.6 Mg ha^{-1} yr^{-1}) and IF (3.7 Mg ha^{-1} yr^{-1}) treatments were not significantly different. Sweetgum stem biomass increased 20% with irrigation and no fertilization and increased 60% with irrigation when fertilizer was added. Root mass fractions declined with both increasing resource availability and stand aged.

Productivity and pest susceptibility of 31 *Populus* clones in South Carolina, USA

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Populus species and hybrids have many practical applications, but there is a paucity of data regarding selections that perform well in the southeastern United States. We compared mortality, growth, and pest susceptibility of 31 *Populus* clones over 3 years in South Carolina, USA. Clones on the sandy, upland site received irrigation and fertilization throughout the growing season, while those planted in the bottomland site received granular fertilizer each year and irrigation in the first 2 years only. Mortality, productivity, and susceptibility to 3 defoliating pests differed significantly among clones. Hybrid clones I45/51, Eridano, and NM6 had very low mortality at both sites, while pure *P. deltoides* clones consistently had the highest mortality. However, the quality of the material received may have influenced mortality. The *P. deltoides* clone WV416 had high productivity at both sites. *P. deltoides* clones S13C20 and Kentucky 8 grew well on the bottomland site, and hybrids 184-41 and 52-225 performed well on the upland site. Pest damage varied throughout each growing season and among clones at both sites. Clone Kentucky 8 was resistant to some pests, but susceptible to others on the bottomland site. Clones 184-441 and 52-225 showed low defoliation levels on the upland site. Overall, clone WV416 would be recommended for planting in this region. Kentucky 8 and S13C20 grow well and are resistant to most pests, but initial mortality was high. Double planting and ensuring that quality cutting material is used could help alleviate this problem.

Fertilization and irrigation effects on wood properties of fast-grown loblolly pine

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Wood properties were examined in several existing field experiments designed to test the effects of fertilization and/or irrigation on the growth and development of intensively managed loblolly pine plantations, including regionwide mid-rotation fertilization installations from the NC State University Forest Nutrition Research Cooperative, the USDA Forest Service SETRES study, and the University of Georgia CAPPS study. Growth responses to these intensive treatments are well documented. The effects of fertilization and irrigation on wood density will be presented and compared. Recommendations will be presented for intensive management regimes that lead to high quality forest products.

Hardwood plantation productivity on former agricultural land in South Carolina

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Sustainable production of short rotation woody crops (SRWC) is dependent on the development of highly productive growing stock and land management practices that conserve soil and water resources. Sustainable plantations should be able to provide high fiber yields over multiple rotations and conserve or enhance environmental quality. Former agricultural lands present a significant land base to support SRWC plantations, while providing an opportunity to enhance environmental quality and soil carbon pools.

In 1997, first rotation sycamore and sweetgum plantations were established on agricultural soils historically planted (through 1996) with cotton, soybeans, and wheat. The soils on the experimental catchments consisted of artificially drained Ultisols with a sandy loam or loamy sand epipedons. The soils had a well-developed plow pan, which was ripped prior to tree planting. Three treatments, operational scale sycamore and sweet gum plantation management, sycamore management, and water management, were established on replicated headwater catchments instrumented to measure changes in soils, vegetation, water quality and surface water discharge.

Sycamore was significantly more productive than sweetgum in the first 7 years following plantation establishment. At the end of the 7th growing season, the average sycamore was twice as tall (11.6 m) as the average sweetgum (5.8 m) with a diameter (10.9 cm) more than a third larger than that of the sweetgum (7.0 cm). Sweetgum (16 Mg/ha) yielded approximately 40% of the total aboveground biomass of the sycamore, 38 and 42 Mg/ ha for the 2 sycamore treatments. Mean annual increment has not culminated for either species after 7 growing seasons. Significant differences in mortality, most occurring in the 2nd growing season, are responsible for the differences in sycamore biomass at the end of the 7th growing season. The reduced sweetgum yield was partially due to higher mortality (30 % for sweetgum, 14 and 22 % for the sycamore treatments), and heavier competition from herbaceous plants, vines particularly, throughout the first 5 growing seasons. Vines covered the smaller sweetgum trees, snapping leaders and constraining growth. Approximately one-third of the total biomass was belowground for both species. The allometric relationships for both sweetgum and sycamore changed significantly during the 7 years of measurement, demonstrating the need for caution in the application of biomass equations to un-calibrated sites.

Evaluation of a Zymomonas mobilis- based ethanol production process

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In Australia, 95% of the total fuel ethanol produced annually is fermented from enzyme hydrolyzed wheat starch using *Saccharomyces cerevisiae*. The process of producing ethanol from wheat can be made more efficient by fermenting both starch and hemicellulosic distillers grain to ethanol after hydrolysis.

A 1-stage hydrolysis method using dilute sulphuric acid and temperatures 80 ^{O}C –120 ^{O}C was investigated. This process was optimized to achieve significant levels of monomeric fermentable sugars: xylose 35g/l, arabinose 20g/l and glucose 10g/l using 2% v/v sulphuric acid at 100^{O}C from 18% stillage loading. Stillage loadings higher than 18% created problems of poor mixing and heat distribution. Enzyme studies (0.1 –1% w/v) were not successful in achieving significant sugar release.

Zymomonas mobilis has attracted wide attention for fuel ethanol production because of its higher specific rates of sugar uptake and ethanol production, higher alcohol tolerance and higher ethanol conversion efficiencies when compared to *S. cerevisiae*. Fermentation of unsupplemented hydrolysate (xylose 17g/l, glucose 16g/l, arabinose 20g/l), by recombinant *Zymomonas mobilis* ZM4(pZB5) capable of utilizing both glucose and xylose, produced 21g/l of ethanol after 30h, with residual xylose 4g/l and arabinose 20g/l. Media optimization studies for the higher sugar hydrolysate stream are continuing.

A comparison of *Z. mobilis* and *S. cerevisiae* ethanol production on wheat starch hydrolysate supplemented with yeast extract (5g/L) at pH 5, 30°C demonstrates a higher ethanol yield $Y_{p/s}$ 0.50 (g/g) for *Z. mobilis* compared with 0.46 (g/g) for *S. cerevisiae*.

The potential exists to develop a high production ethanol process for both hexoses and pentoses based on *Z. mobilis.*

Silviculture and biology of short-rotation woody crops, then and now

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Although its roots are in antiquity, the concept of short-rotation woody crops (SRWC) for fiber and energy evolved scientifically from pioneering poplar breeding work begun in the early 20th century. A natural outgrowth of this work was the culture of fast-growing poplar clones on rotations of 10-12 years or less. Close-spaced tree culture received further impetus with the introduction of the "silage sycamore" concept in the southeastern U.S. in the mid-1960s and from trials begun at several locations in North America and Europe the early 1970s. Early silvicultural research focused on spacing and species trials, propagation methods, weed management, nutrition, and growth and yield. Because these trials were based on small plots, and pest depredations or site variation were not fully factored in, early biomass yield predictions tended to be overly optimistic. Soon physiologists and ecologists began to unravel the biological characteristics of SRWC plantations and their responses to environment. Knowledge of the influence and diversity of pests (insects, diseases, and animals) provided a necessary reality check. Although many hardwood tree species have been evaluated over the years, clones of *Populus,* and more recently *Salix,* became the dominant material for SRWC because of their inherently rapid growth and ease of propagation. Beginning in the last decades of the 20th century, strongly focused genetics and breeding programs began to provide new genotypes along with an understanding of the poplar genome. Thus, current commercial applications of SRWC rest on a substantial base of silvicultural and biological knowledge and provide more reliable estimates of biomass yield.

Short rotation woody crops in the US Pacific Northwest

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The history of short rotation woody crops in the Pacific Northwest now spans more than 20 years. From the groundbreaking work by Crown Zellerbach (later James River) in the early 1980s, to the current large-scale industrial plantations of Boise, Potlatch and Greenwood, the technology of growing hybrid poplar has come a long way. In the 10-year period beginning in the mid 1980s these fiber farms were a growth industry, as companies scrambled to secure wood fiber furnish for their pulp mills. Since this period of growth, the industry has stabilized at about 60,000 acres in the PNW.

Most recently, faced with historically low pulp chip prices, the industry has begun to investigate higher value uses of the poplar fiber. Potlatch is leading the way to move poplar saw logs into the furniture, molding, veneer, and cabinetry markets. This avenue looks very promising, but much work needs to be done to introduce this new species to the market place.

The future will always hold a place for hybrid poplar production for pulp chip furnish. Further diversifying the use of poplar into the solid wood and biomass energy markets will help secure its long-term viability.

Poplar breeding for superior papermaking fibers

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According to some projections there may be regional shortages of hardwood fibers for papermaking starting around 2010 [1,2]. There are many publications showing that several fast-growing hybrid poplars do produce high quality pulps from the dominant kraft process. However, the low wood density of these poplars is a major drawback to commercial use. The capital cost associated with kraft digester capacity (volume) is quite high and pulp is sold by weight. Therefore, for a given digester volume sugar maple chips with basic density (oven dried wt./water swollen volume) of ~550 kg/m^3 [3] would produce ~60% more pulp by weight as compared to a hybrid poplar with basic density of ~350 kg/m^3. For a hybrid poplar to be used in the kraft process it would have to possess other superior attributes in addition to high growth rate when compared to the traditional North American hardwoods. One such attribute that appears to be quite common in hybrid poplars (<15 years old) is a high tensile energy absorption (TEA) during papermaking [4]. The TEA (at the point of rupture) for kraft sheets from an 11-year-old DN 30 *(P. deltoides* x *P. nigra)* was 75% higher than for sheets from mature aspen *(P. tremuloides)* [4]. There are enormous tensile stresses on modern paper machines running at 30 to 50 m/s. Therefore, a 75% increase in TEA would represent a significant increase in strength and should allow for less fibers and more inexpensive fillers ($CaCO_3$) to be used in papermaking.

Twenty-two poplars grown on 3 different sites are being evaluated for their wood and papermaking properties in a 3-year investigation. The 3 sites are Arlington, WI (ARL), Iowa State University, Ames, Iowa (ISU), and Westport, MN (WPT). Data on parentage and growth rate for all the poplars are documented by Riemenschneider et al. [5]. A preliminary report is now being given for the poplars at 7.5 years of age. The report is focused on only 2 of the poplars. The first is an aspen hybrid identified as Crandon that had a very high growth rate [5] and the highest basic wood density (399 kg/m^3 versus an average of 330 kg/m^3). The second was a *deltoides* clone identified as 220-5 that had the highest area-weighted MFA (30.9° averaged across 3 sites) and above average basic density (353 kg/m^3). Microfibril angle was determined by CSIRO, Tasmania, Australia using X-ray diffraction (SilviScan-2). They also measured wood density by X-ray densitometry.

All of the logs were analyzed for lignin and extractives content using Tappi standard methods. The weight percent of various carbohydrates was also determined by a ^{1}H NMR method developed at SUNY-ESF. The correlation between fiber yield after kraft pulping and cellulose content of the wood is shown in Figure 1 for 4 of the poplars (all 3 sites) and aspen. The 2 poplars above are included in Figure 1.

The kappa number of the unbleached and O_2 delignified pulps (wt. % lignin ≅ 0.15 x kappa #) and pulp yield are presented in Table 1. The Crandons were the most responsive to pulping and bleaching. The correlation between post O_2 kappa number and final brightness after $D_0E_PD_1$ bleaching is shown in Figure 2.

Table 1. Kraft Pulping and O_2 Delignification Results

Sample	Kappa Number	Screened Yield [2]
Crandon (ARL)	13.7 (7.0) [1]	56.4
Crandon (ISU)	15.3 (7.4)	55.9
Crandon (WPT)	15.5 (7.4)	55.3
220-5 (ARL)	17.8 (9.3)	56.4
220-5 (ISU)	17.5 (8.6)	54.2
220-5 (WPT)	18.2 (10.2)	53.6
Aspen	16.7 (8.8)	57.1

[1] After O_2 delignification
[2] of unbleached pulp, % on chips

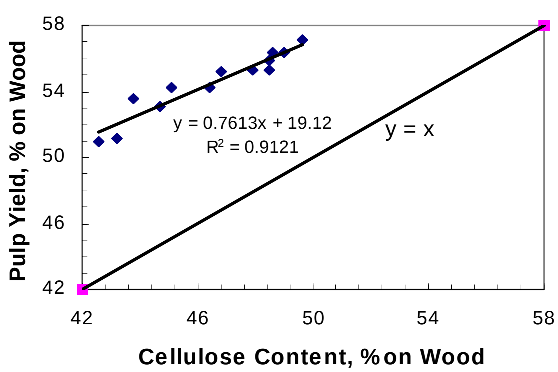

Figure 1. Kraft pulp yield vs. estimated cellulose content of starting wood

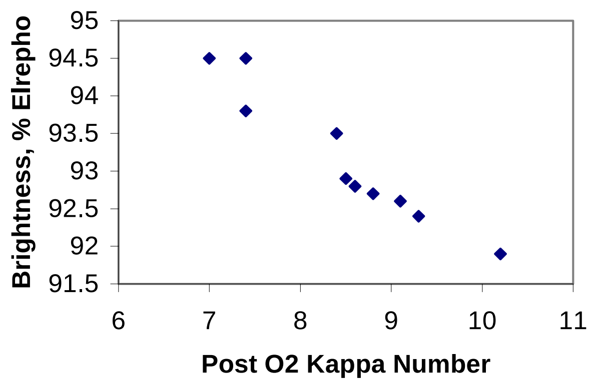

Figure 2. Post O_2 kappa number vs. final brightness

The significant variation in delignification rate amongst the poplars was somewhat unexpected and led to an investigation of shorter pulping times for the Crandon. The chips from Arlington are compared to sugar maple in Table 2 using rapid impregnation – short time or RIST Kraft pulping.

The digester capacity required to handle 550 kg of maple chips would handle 399 kg of Crandon chips. The maple chips would produce 289.3 kg of pulp after 180 minutes (550x0.526), while 225.4 kg of Crandon pulp would be produced after 120 minutes (338 kg in 180 min). It may be possible to achieve a higher production rate of Crandon pulp as compared to sugar maple in either a batch or a continuous digester.

The effect of MFA on % strain and TEA (to the point of sheet rupture) are demonstrated in Figures 3 and 4. Bleaching of hardwoods is reported to increase % strain to the point of rupture by ~40% [6]. The strongest of our pulps (after 7.5 years) was the 220-5 from ISU with an average MFA of 29.8°.

Tensile results for this pulp (unbleached and bleached) are compared to aspen, sugar maple, and loblolly pine in Table 3. It appears that much less than 220-5 fibers would be required to withstand the tensile stresses on a paper machine.

Table 2. Kraft Pulping at 170°C with Short Retention Times

Species	Total Time, Minutes	Kappa Number	Screened Yield	% Rejects
Sugar Maple	120 (60[1])	25.1	53.0	1.5
	160 (90)	22.5	53.3	0.6
	180 (90)	17.9	52.6	0.2
Crandon -ARL	105 (45)	19.8	56.5	0.9
	120 (60)	16.5	56.3	0.4

[1]Time to maximum temperature of 170°C

Table 3 Tensile Properties of 220-5 Poplar Pulp Compared to other Pulps

	Tensile Index	% Strain	TEA J/m^2
Aspen (unbl.)	93	3.4	132
220-5 (unbl.)	90	5.1	202
220-5 (O_2)	81	7.2	280
Sugar Maple (O_2)	91	4.0	156
Lobl. Pine (O_2)	79	5.0	164

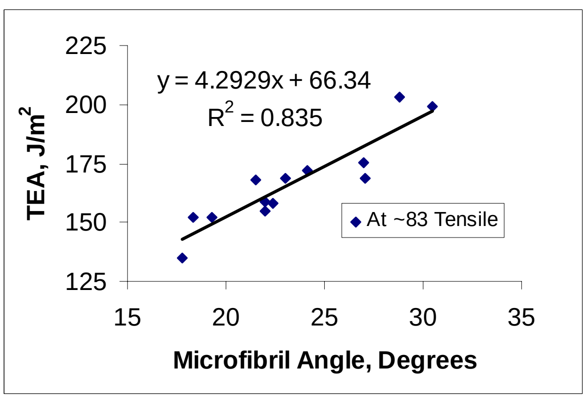

Figure 4. MFA versus Tensile Energy Absorption for Poplars

References

1. McNutt, J. PIMA 78(1), 28 (1996).
2. Ince, P. J. Solutions Magazine, p. 40 (June 2002).
3. Isenberg, I. H. Pulpwoods of the United States and Canada, Vol. II, 3rd Ed. (Revised by M.L Harder and L. Louden), Institute of Paper Chemistry (1981).

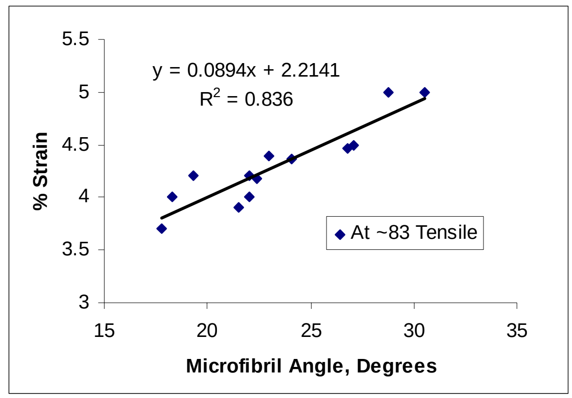

Figure 3. MFA versus % Strain for Poplars

4. Francis, R. C., Brown, A. F., Hanna, R. B. and Kamdem, D. P. Tappi J. 3(2), 3 (2004).
5. Riemenschneider, D. E., Berguson, W. E., Dickmann, D. I., Hall, R. B., Isebrands, J. G., Mohn, C. A., Stanosz, G. R., and Tuskan, G. A. Forestry Chron. 77:245 (2001).
6. Gurnagul, N., Page, D. H. and Seth, R. S. J. Pulp Pap. Sci. 16:36 (1990).

Assessing the cost and operational feasibility of "green" hardwood winter inventory for southeastern pulp mills

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Procuring wood, especially hardwood, during the winter months for a pulp mill in the Southeast can be difficult. Soft ground reduces the operational feasibility of many sites, forcing companies to store hardwood in wood yards for retrieval during wet weather. Could intensively-managed, short-rotation hardwood grown on dry sites economically supply a pulp mill during a wood shortage, thereby eliminating stop-gap measures taken by procurement organizations?

This paper analyzes the costs associated with short-rotation hardwood plantations, along with the potential growth of such plantations. A delivered unit price for the raw material was estimated. Using wood costs from 3 southeastern pulp mills over a 3-year period, it was determined that even under a "best case" scenario, short-rotation hardwood delivered to the pulp mill is not cost effective.

This paper also analyzes the feasibility of using short rotation hardwood plantations as "green inventory" for the same 3 pulp mills. Over the 3-year period, all 3 mills would have lowered wood costs with "green inventory" by reducing the amount of wood put into dry inventory. Savings during dry years offsets the higher cost hardwood of plantation deliveries.

Biomass production in the central great plains under various coppice regimes

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Woody biomass grown under the short rotation intensive culture (SRIC) system is an appealing concept for fiber production in a minimal period of time. Close planting densities, fast-growing tree species, short rotation ages, improved genetic stock, fertile sites, and possibly coppicing are components of this approach. This report summarizes the results from coppicing studies with several fast-growing, deciduous tree species in the central great plains of the United States.

High density, close spacing trials: Two studies were conducted to verify biomass production in close spacing and wood-grass type plantings. The first was with 1 species, silver maple, and frequent harvesting, and the second had 5 additional species.

Three different spacings (0.3 x 0.3, 0.45 x 0.45, or 0.6 x 0.6m) were replicated 3 times in 1.8 x 1.8m plots and hand-cultivated. Trees were cut and weighed on 1- to 3-year cutting cycles for a period of 3 growing seasons. Close spacing significantly decreased survival and increased yield during the first 2 growing seasons. Mortality was highest at the closer spacing and increased with successive harvests. Survival was 30-50% after 8 years. Yields averaged nearly 9 dry tons/ha annually. Annual growth rate increased with longer cutting cycles.

The second study was established at 0.3 x 0.3m spacing. Three replicates of Siberian elm, silver maple, honey locust, cottonwood and black locust were planted. Weeds were controlled with herbicides and dormant season harvests were made for yield determinations. Comparisons between first year seedlings and subsequent coppice yields showed tonnage increases of 6-11 for black locust, 4-10 for cottonwood, and 4-5 for the other species after 3 cuttings.

Close density trials: Several additional species were studies. Ten rows were planted at 1.2m by 0.3, 0.6 or 1.2m apart. Boxelder, sycamore, sandbar willow, E. black alder, silver maple, a male cottonwood clone, and native cottonwood were the species used. Closer spacings produced 25% greater yield than wider spacings. The first 2-year coppice harvest was 50% greater than the first 2-year seedling harvest. Mortality increased after each harvest, especially at the closer spacing. Yields averaged about 5+ tons/ha/yr. Three coppice harvests were 50% better than the seedling harvest. The maples responded well to multiple cuttings.

Conventional spacing trials: A Nelder wheel design was used to test silver maple, cottonwood and black locust, with average spacing ranging from 1.2 to 2.6m. The 5-year seedling yields were 9.7, 11.8, and 14.2 tons/ha/yr, respectively. Three subsequent coppice cuts at 5-year intervals showed remarkably consistent yields over time. Cottonwood was the greatest followed by the maple and locust at about a 20% lower rate. Mortality was high; maple from 2-46%, cottonwood from 18-88%, and locust from 6-46^ after 20 years' growth. Even though cottonwood mortality was high, the site was nearly completely utilized, showing little reduction in yield.

Maple, locust and cottonwood are consistent growers, but mortality increases substantially at all spacings with numerous coppice cuttings. Larger trees are produced with cottonwood, but yields remain high. Spacings of about 2m are recommended for fiber production. The longer the cutting cycle, the farther apart the trees should be planted.

Biomass production and other ecological processes in temperate agroforestry systems in Canada

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In North America, agroforestry means the incorporation of trees into farming systems and embraces silvopasture (pasture, trees, animals), intercropping (trees, crops), integrated riparian management systems (streambank forests), and windbreaks (trees around field borders). In many instances, short rotation woody species that could be used for bioenergy purposes can be utilized in system design and development at a variety of temporal and spatial scales.

Numerous environmental benefits may be associated with the adoption of these agroforestry practices, including enhanced biodiversity, increased carbon sequestration, increased efficiency of nutrient cycling, decreased soil erosion and the maintenance of animal welfare.

In southern Ontario, Canada, for example, long-term research on the intercropping of fast-growing tree species with agricultural crops has indicated that, while remaining economically productive, net C-sequestration may reach 1.65 t C ha^{-1} y^{-1}. Soil erosion and nutrient loadings to adjacent waterways may also be decreased, while at the same time, the diversity of bird, earthworm and insect populations may increase.

The environmental benefits of these systems are reviewed within the context of C-sequestration, nutrient cycling and other ecological parameters. A summary of the role of these systems in sustainable agricultural and landscape management in Canada is also presented with reference to non-traditional sources of biomass (e.g. reed canary grass).

Developing strategies to control Carpenterworm Moth and Poplar/Willow Borer in irrigated hybrid poplars

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The Carpenterworm Moth (CW), *Prionoxystus robiniae* (Cossidae) and Poplar/Willow Borer (PWB), *Cryptorhynchus lapathi* (Curculionidae) are pests of economic importance in hybrid poplars in eastern Washington and Oregon. Both CW and PWB damage trees during their immature stages when they burrow into the heartwood, which discolors wood and attributes to wind breakage. Our aim is to exploit constraints in the life cycle and behavior of the pests in order to achieve control. The various strategies being developed reflect differences in life history.

The strategy being developed for CW will use the moth's natural sex pheromone. Prior research indicates we can shut down the ability of males to find sex pheromone baited traps as low as 0.3 grams/acre. Future research will implement use of pheromone strategies such as mating disruption, mass trapping, and attract-n-kill for control of CW.

Several strategies are being developed to control PWB. Broadly, these strategies fall into two main categories: 1) using insecticides or repellents to target larvae and adults to reduce their population and/or reduce their attraction to the trees, and 2) developing a methodology to screen clones that have "resistance" to feeding and ovipositing PWB.

Phytoremediation of a perchloroethylene contaminated site in LaSalle, Illinois USA with *Populus* clones through hydraulic uptake and enhanced microbial activity

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Populus clones are being used throughout North America for phytoremediation (phyto) of chlorinated solvent contaminated soil and groundwater; one of the challenges of phyto is matching the proper clone (species) to the contaminated site through field evaluations. Our approach is to use a phased phytoremediation strategy consisting of Phase I: experimental screening studies of plant materials; Phase II: verification of choice of Phase I plant materials; Phase III: demonstration plantings and small scale testing; and Phase IV: scale up and implementation.

To determine the effectiveness of phyto to clean up a perchloroethylene (PCE) contaminated plume of soil and groundwater at the former LaSalle Electrice Utilities site in LaSalle, Illinois USA, we established a replicated poplar clonal test upon the plume in 2002. Rooted cuttings of 18 clones from Iowa State University were used (Table 1). Tree growth, health, and survival were monitored over 2 growing seasons. Groundwater sampling was conducted several times each year. In July 2003, heterotrophic and methanotrophic microbes were collected from the soil and rhizosphere near trees from within and outside the plume and analyzed with standard quantitative microbe methods. In October 2003, 8 trees from within and outside the plume were excavated to access PCE uptake. Stem cores and disks, as well as branch samples, were collected for field screening with the Color Tech colormetric method and laboratory gas chromatography PCE analyses. In July 2004, 2 branch samples were taken from 10 trees to verify the 2003 results.

Tree heights averaged 4.1m and diameter breast height averaged 3.3cm at the end of 2 years overall; clonal means ranged from 3.4-5.1m and 2.0-4.5cm, respectively. The cottonwood and cottonwood hybrid clones proved to be the fastest growing trees; they include cottonwood clone 51-5 from southern Ohio, hybrid family 80 from southern Illinois, and ISU hybrid family 25 from Iowa State University, Ames, Iowa. Clone 51-5 averaged 4.5m and 4.0cm in height and diameter, respectively, while clone 80x01107 averaged 4.3m and 3.9cm and clone ISU 25-R4 averaged 5.1m and 4.5cm, respectively. Biomass estimates varied among clones by ten fold. Survival was excellent except for a few frost susceptible clones. There was significant growth reduction within the most concentrated part of the plume.

Microbial analyses showed significant increases of both heterotrophic and methantrophic microorganisms at several depths in the rhizosphere of the trees growing in the plume (Figure 1). Significant uptake of PCE was found in stem samples and corresponding branch samples from several clones sampled within the plume. Lab analyses correlated well with field screening methods. The branch disk method was the most promising as it was a timely, low-cost, non-destructive onsite method. Poplar clones with significant PCE uptake were not the largest trees indicating a possible clone (genetic) effect on PCE uptake. These positive early results are encouraging and indicate that poplar clones may be effective in phytoremediation of this PCE contaminated site.

Table 1. Identity, pedigree and origin of 18 poplar clones under evaluation at LaSalle Electric Utilities, LaSalle, Illinois site.

Clone	**Pedigree**	**Origin**
7300501	*P. deltoids*	Southern Illinois
119.16	*P. deltoids*	Ohio x (Nebraska x Minnesota)
220-5	*P. deltoids*	Ohio
252-4	*P. deltoids*	Central Missouri
42-7	*P. deltoids*	Southern Indiana
51-5	*P. deltoids*	Southern Ohio
80x00601	*P. deltoids*	Southern Illinois x Southern Illinois
80x01015	*P. deltoids*	Southern Illinois x Southern Illinois
80x01107	*P. deltoids*	Southern Illinois x Southern Illinois
ISU 25-21	*P. deltoids*	Southern Illinois x Southern Illinois
ISU 25-35	*P. deltoids*	Southern Illinois x Southern Illinois
ISU 25-R4	*P. deltoids*	Southern Illinois x Southern Illinois
ISU 25-R5	*P. deltoids*	Southern Illinois x Southern Illinois
Eugenei	*P. deltoids x P. nigra*	North America x Europe
I 45/51	*P. deltoids x P. nigra*	North America x Europe
Belgian 25	*P. nigra x P. maximowiczii*	Europe x Japan
NM-2	*P. nigra x P. maximowiczii*	Europe x Japan
Crandon	*P. alba x P. grandidentata*	Europe x Southern Iowa

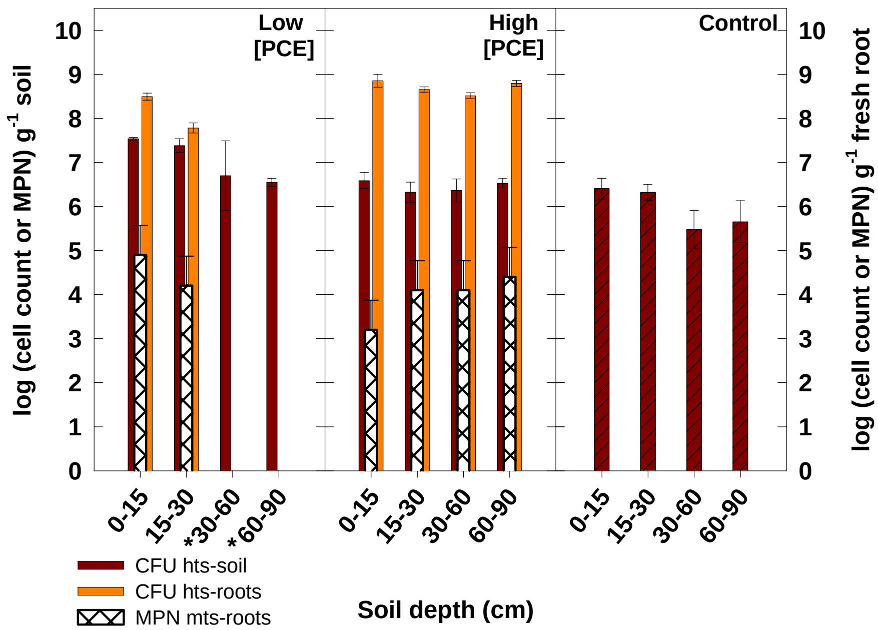

Figure 1**.** Enumeration of microorganisms in rhizosphere soil and in or on roots obtained from I 45/51 trees located at a PCE contaminated site at LaSalle Electric Utilities. LaSalle, Illinois. July 2003. CFU = colony forming units, MPN = most probably number, hts = heterotrophs, mts = methanotrophs. *At low [PCE] depths of 30 to 90 cm no roots were observed.

Remediation of VOC-contaminated groundwater at the Savannah River Site by phyto-irrigation

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Trichloroethylene (TCE) was widely used as a degreasing solvent from the 1920s to the late 1970s and gained widespread notoriety for its role in contamination of drinking water wells in the 1960s. Health risks caused by chronic exposure to TCE began to surface with increased use. While it does not significantly bioaccumulate in plants and animals, breathing small amounts can result in headaches, lung irritation, dizziness, poor coordination, and difficulty concentrating. Breathing in large amounts can cause impaired heart function, unconsciousness, and death. Inhalation over long periods may cause nerve, kidney, and liver damage. Ingestion of TCE can cause liver damage, unconsciousness, impaired heart function, or death while chronic ingestion of small amounts can cause liver and kidney damage, impaired immune system function, and impaired fetal development in pregnant women. Dermal contact with TCE may cause skin rashes.

When TCE enters the environment, it is slightly soluble in water. Once solubilized in water, however, it can be readily stripped from the liquid phase into the atmosphere. Phytoremediation has been tested as a possible remediation technology for the removal of TCE from groundwater and soils. Much attention has been placed on using hybrid poplars for this purpose. The deep rooting depths and large volumes of water taken up by poplar trees appear to make them ideal for the remediation of groundwater contaminants in solution. Combining the uptake capacities of these trees with a relatively inexpensive and low-maintenance mechanical method of safely stripping solubilized TCE out of the groundwater should result in a technology capable of remediating groundwater of volatile organic compounds (VOCs) such as TCE quickly and inexpensively.

Irrigation is often used for the sole purpose of supplying plants with water, but it can also be used as part of this overall remediation technology. Phyto-irrigation is such a method that combines natural processes and air-stripping phenomena to remove VOCs from contaminated waters. This is suitable for use at sites where VOC contamination in the water exceeds regulatory levels, but when volatilized into the atmosphere, contamination levels remain below regulatory limits in the air.

Phyto-irrigation is an economical and viable alternative to conventional phytoremediation technologies when there is some barrier between the expected root mass of the trees and the contaminated aquifer; i.e., a confining layer or depth considerations. In order to investigate the effectiveness of this method, a pilot-scale study has been initiated at the Savannah River Site (SRS) on a 2-acre test area with 8 total ¼-

acre plots separated by buffer zones of native vegetation and soil. The baseline phase of this project was completed in November 2002 with approximately three million gallons of contaminated water used for site irrigation for the season. Irrigation water was analyzed monthly for TCE and perchloroethylene (PCE) at the water source, at the exit ports to the sprinklers, and after leaving the sprinklers. Plant tissues, soil, and leachate were also analyzed for target contaminants, which included TCE, perchloroethylene (PCE), trichloroethanol (TCOH), dichloroacetic acid (DCAA), and trichloroacetic acid (TCAA).

While target compounds were detected in some of the plant tissue and soil samples, their levels remained well below regulatory limits as mandated by the South Carolina Department of Health and Environmental Control (SCDHEC) and shown in Table 1, except for in the soils of one of the native vegetation plots for September 2002, which had an average concentration of PCE of 33.9 ppb (n=32, σ=56.6). After removal of outliers, the maximum PCE concentration in this plot was 170 ppb at a depth of 3 feet.

The sprinklers were effective in removing at least 99.6% of the TCE contamination from groundwater as a result of the spray irrigation. There were no detectable levels of PCE in any water samples taken from the sprinklers.

Table 1. SCDHEC contaminant regulatory limits

Sample type	**SCDHEC regulatory limits**
Plant tissues	TCE: 100 µg/g (ppm)
	PCE: 100 µg/g (ppm)
	Trichloroethanol: 10 µg/g (ppm)
	Dichloroacetic acid: 10 µg/g (ppm)
	Trichloroacetic acid: 24 µg/g (ppm)
Surface soil	N/A
Subsurface soil (3 ft)	TCE or PCE: 18 µg/kg (ppb)
Water (well & sprinkler head)	TCE or PCE: < 5 µg/L (ppb)
Air	TCE or PCE: < 0.05 lb/hr
Leachate (3 ft & 8 ft)	TCE or PCE: 30 ppb at 8 ft

The relatively small costs and maintenance incurred for phyto-irrigation can be spread out over the total project scope. This method of VOC removal not only remediates contaminated groundwater of TCE and PCE but also reuses this water for irrigation. This study supports the feasibility of using this remedial technique to provide safe irrigation while concurrently removing water contamination. A similar study conducted by the EPA SITE Program and the University of Nebraska-Lincoln showed promise in using this method for the simultaneous tasks of groundwater cleanup and crop irrigation.

Mating disruption for control of the Western Poplar Clearwing Moth in irrigated hybrid poplars

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The Western Poplar Clearwing Moth (WPCM), *Paranthrene robiniae* (Sessiidae) is the most economically important pest of hybrid poplar in eastern Washington and Oregon. WPCM larvae burrow into poplar causing galleries that discolor the heartwood and weaken limbs and trunks to the point of breakage.

Historically, poplars have only been used for high quality paper pulp, but with pulp value dropping, Potlatch® has switched their target product to quality "veneer" logs and WPCM galleries cannot be tolerated.

Chloropyrifos (44,000 pounds) failed to control WPCM in 2002. Potlatch® is restricted by guidelines of the Forest Stewardship Council, which prohibits the use of broad-spectrum pesticides. Boise® is not as restricted in their choice of insecticides, but are still very enthusiastic toward a 'soft' management strategy.

We received a Section 18 and implemented a pheromone based "mating disruption" strategy in that targeted 8,000 acres of newly planted and one-year-old trees in 2003, and 25,000 acres of all-age trees in 2004. Here we will report our season-long trap catch data, the effects of the pheromone treatments, and the results of our damage survey. Membrane dispensers were more effective, but expensive to apply, and flowable formulations of 0.5 g/acre/season effectively suppressed capture.

A genomic approach to improvement of short rotation woody biomass crops

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Functional genomics has the potential to redefine plantation forestry through introduction of traits not easily tractable through traditional breeding. ArborGen is using technology for efficient gene transfer in plantation forestry species including Loblolly pine (*Pinus taeda*) and Eastern cottonwood (*Populus deltoides*) allowing screening of gene function directly in commercial species. Genes that affect growth rate, volume, and wood chemistry can be very useful in developing short rotation trees useful for biomass and bioenergy applications. ArborGen has the capability of evaluating a large collection of pine and Eucalyptus genes in a high-throughput functional testing program in transgenic trees. Hundreds of genes are in the process of being tested in Populus and pine for their effect on growth rate, biomass, stem architecture, wood properties, vascular development and wood chemical composition at three different stages of growth: in tissue culture, in the greenhouse and in short rotation field trails. To date, functional testing has yielded genes that appear to confer rapid volume growth, altered form such as improved branch angle and stronger apical dominance, and altered wood chemical composition. These traits may prove very useful in biomass and bioenergy applications.

Economic analysis of short rotation poplar crops in west central Spain

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Introduction and Objectives: Short rotation woody crops were initially studied by Stokes et al. almost 20 years ago (1986) in Alabama. At the State University of New York, Abrahamson et al. (1998) and Tharakan et al. (2003) are working with willow and poplar, with densities from 15,000 plants/ha to 18,500 plants/ha, and a 3-year rotation period. They are using 30 different willow clones from Yugoslavia, Canada, the USA and Japan, and 7 hybrid poplar clones from the USA and Canada. Gallagher (2002), in Virginia (USA), is working with poplar in densities lower than 5,000 plants/ha and 4 to 10 year rotation.

The present research explores the technical feasibility and financial characteristics of higher densities and shorter rotations (two years) in coppices of poplar trees (*Populus x euroamericana* I-214) used for energy production. The objective of the research was to estimate crop productivity figures, to perform an economic analysis of the biomass production process and to compare it with plantations of poplar I-214 aimed at wood production for classical industrial processes. The usual investment analysis indicators such as present net worth, internal rate of return and benefit-cost ratio will be used to draw some conclusions on the economic return of this kind of energy crops.

Materials and Methods: The experimental site is located in Cabrerizos (Salamanca, Spain), at a latitude of 40°59′N, a longitude of 5°36′W, a height of 790m above sea level and a slope under 2%. The climate is continental humid, and the soil, which has an alluvial origin, is not very sandy and is moderately basic. Soil basicity may cause some problems regarding iron assimilation.

The planting spacing is 0.33m by 0.90m and the essayed rotations are 2, 3 and 4 years. The expected life cycle of the plantation is 8 years. The production activities started with the preparation of the site by means of a deep tilling and the addition of manure (300 kg/ha). The 30-40cm long cuttings were planted by hand. Previously, the cuttings were introduced for 5 minutes in a solution consisting of 50cc of pesticide and 50 grams of fungicide in 100 liters of water. Weed control was carried out every year, passing a small tractor between the 0.90m separated rows. The experimental crop was irrigated 29 times in odd years (2,574 l/m^2) and 20 times in even years (3,300 l/m^2). A manual pruning was performed in years 1, 3, 5 and 7, in order to remove the low branches and improve height growth. This task favors the incorporation into the soil of the leaf biomass thus contributing to CO_2 fixation. Fertilization and pest and disease control treatments were carried out every year. At the end of the expected life cycle of the plantation (8 years) the harvest will be followed by the removal of the stumps. As a summary, Table 1 shows the crop management activities carried out in the study site.

After harvest, biomass production was measured and the amount of CO_2 fixed was estimated following the procedure described by Marcos (2000). Measured productivity has attained an average figure of 22.46 $odt/ha^{-1}/year^{-1}$.

Table 1. Schedule of the activities performed in the study site.

Year	Weed Control	Irrigation	Pruning "Milking"	Pest & Disease Control Treatments	Fertilization	Harvest	Stump Extraction
0	Site preparation (leveling and ploughing) and plantation						
1	XXX	XXX	XXX	XXX	XXX		
2,4,6	XXX	XXX		XXX	XXX	XXX	
3,5,7	XXX	XXX	XXX	XXX	XXX		
8	XXX	XXX		XXX	XXX	XXX	XXX

The revenues and costs generated in the production process were properly assessed and the obtained values were used to calculate the usual investment analysis indicators.

Presentation and interpretation of results: The economic return of the energy crop (2-year rotation and stump extraction every 8 years) was assessed and compared to that of a plantation aimed at wood production for industrial use (12-year rotation). For the purpose of the analysis, the following hypotheses were made: Discount rate: 6%, biomass price: 24.04 €/odt, price of the CO_2 emission rights ranging from 4 to 10 €/t of CO_2 fixed (a conservative figure of 6 €/t was finally used). Revenues and costs along an 8-year cycle are shown in Table 2.

Table 2. Revenues and costs in the studied energy crop.

Year	Activities	Revenues (€/ha)	Costs (€/ha)
0	Site preparation (deep tilling)		193.33
	Preparation of cuttings		1,138.32
	Planting		492.26
	TOTAL INITIAL COSTS		**1,733.91**
1	Crop maintenance subsidy	63.00	
	CO_2 emission rights	1.146·P·p	
	Weed control		60.10
	Fertilization		94.85
	Irrigation		150.25
	Pest & disease control treatments		94.85
	Pruning (milking)		306.61
	TOTAL YEAR 1	**1.146·P·p+63**	**706.66**
2	Crop maintenance subsidy	63.00	
	Fuel production subsidy	15.484·P	
	CO_2 emission rights	1.146·P·p	
	Weed control		60.10
	Fertilization		94.85
	Irrigation		180.30
	Pest & disease control treatments		94.85
	Harvest and loading	24.04·P	300.51
	TOTAL YEAR 2	**39.524·P+1.146·P·p+63**	**730.60**
3,5.7	Same costs & revenues as Year 1	**1.146·P·p+63**	**706.66**

4,6	Same costs & revenues as Year 2	**39.524·P+1.146·P·p+63**	**730.60**
8	Same costs & revenues as Year 2 Stump extraction **TOTAL YEAR 8**	Same as year 2 **39.524 P++1.146 P·p+63**	730.60 1,322.23 2,052.83
P=Biomass yield (odt/(ha·2years))		P=Price of the emission rights (6 €/t)	

From the values in Table 2, present net worth (PNW), annualized PNW, benefit cost ratio (B/C) and internal rate of return (IRR) for 6 different levels of biomass production have been calculated. The results are shown in Table 3. The last row of the table depicts the values of the investment analysis indicators for the plantation aimed at wood production.

Table 3. Economic analysis indicators.

Biomass yield ($odt \cdot ha^{-1} \cdot year^{-1}$)	PNW.24-year time horizon ($€ \cdot ha^{-1}$)	Annual equivalent net benefit ($€ \cdot ha^{-1} \cdot year^{-1}$)	Benefit/Cost Ratio B/C	I.R.R. (%)
18	-1,629.87	-129.87	0.89	-
20	-321.53	-25.62	0.98	3.30
22	986.81	78.63	1.07	12.93
24	2,295.16	182.88	1.16	20.40
26	3,603.50	287.12	1.25	26.84
28	4,911.84	391.37	1.35	32.66
Timber production (m^3/ha) at age of harvest (12 years)				
300	6,263.88	499.10	2.05	14.01

PNW takes a positive value when biomass yield is over 21 $odt \cdot ha^{-1} \cdot year^{-1}$. In the experimental site, biomass production slightly exceeds this threshold. Thus, the values obtained for PNW and B/C are moderately positive, and the somewhat higher values of the IRR are explained by the short payback period of the investment. In fact, in the energy crop there is revenue every 2 years coming from the harvest and sale of the biomass produced.

Conclusions: Estimated biomass production is over 22 $odt \cdot ha^{-1} \cdot year^{-1}$ from the first harvest and yields a positive economic return. However, under the current subsidies and circumstances, poplar plantations aimed at wood production for industrial uses provide a higher financial return than energy crops of the same species. Thus, energy crops are not attractive for private investors.

On the other hand, energy plantations of poplar I-214 have a very positive effect regarding CO2 fixation. Besides, an additional advantage of this kind of crops is the short payback period, which allows investment recovery in just 6 years instead of the 12 years needed for industrial wood production.

Elephant grass pilot project: charcoal source for industrial uses

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Research on energy applications of elephant grass started with Carlos Dias Brosch, more than 30 years ago, continued by Mazzarella and Katayama since 1990, with Biomass Integrated Project (BIP), whose results were presented at São Paulo (1994); at Brighton (1999); Seoul (2000); Capri (2002) and São Paulo (2002). In November 2003, Samarco, a large iron ore pellets producer (13 Mt/year) signed a contract to develop a pilot project to establish a 50 ha plantation of different varieties of elephant grass aimed at getting charcoal to substitute for the present 200,000 t of imported coal fines being used in the pelletizing process.

If this goal proves to be technically and economically achievable, a new challenge would constitute the second phase of the project: use dried bagasse of the elephant grass to substitute for 200,000 t of combustible oil in the pelletizing furnaces, placing the iron ore pellets very near to a green seal.

Former results reported in previous Congresses showed elephant grass productivity (*Pennisetum Purpureum CV. Guaçu* variety) near 40 t d.m./ha/y (d.m. = dry mass), although these figures referred to small areas, carefully controlled. A breakthrough innovation was brought by Embrapa (Urquiaga, S. et al.), with Biological Nitrogen Fixation (BNF) techniques switching from the classical emphasis on heavy N fertilization to produce more protein for cattle feeding, to a new focus of zero N, decreasing the protein content of the grass and enhancing its fiber percentage, more favorable for energy applications. Sequences of 5-year experiments with BNF in very small scales showed that some grass varieties could reach up to 80 t d.m./ha/y. One particular problem with elephant grass resides in their high water content (75% to 80%) when they reach maximum growth. If harvested in this condition, they cannot be left to dry by themselves, as it would lead to rotting of the biomass. Their humidity has to be lowered either by heating or by squeezing and heating. The first alternative, only by heating, would consume 72% of the contained energy. The second alternative would leave around 80% of the energy available for use. Other findings of previous works with tall grasses on carbonization lead to a humid process (220ºC, 60 atm), with high yield (62%) and pre-charcoal as final product – high volatiles content, and also to a fluid bed process that rendered 15% charcoal, 70% bio-oil (with ~ 25% water).

Both processes had disadvantages: the high pressures of the humid process, and the low charcoal yield and operational difficulties of the fluidized bed.

Regarding the necessary sap extraction to avoid rotting, experiments were conducted to precipitate the sap protein and make animal feed for cattle, pork and fish. This path was temporarily abandoned because of competition with low price protein derived from soya. Other experiments tried to extract chlorophyll from the sap, but in this case also, work was suspended because of the high price of solvents. An inexpensive alternative is to give the sap back to the harvested soils, profiting from its macro and micronutrients.

The present Samarco pilot project will test 8 of the most promising grass varieties. The initial project should last for 2 years, with another 3 years, to reach conclusions on the BNF. Six varieties were planted (3 in February, suggested by local Incaper: CNPGL 91F27-1, 91F06-3 and 92F79-2) (3 in March, suggested by Embrapa: Gramafante, Cameroon and BAG-02). They were harvested in July, with 5 and 4 months respectively.

Preliminary results showed productivity (for 5 of the 6 species) in the range of 14.4 to 20.7 t d.m./ha/y, which extrapolated to 12 months would reach 48 t d.m./ha/y. It should be noted that productivity of 40 t d.m./ha/y can be expected for the first 2 cuts, but there is a tendency to 30 to 40 t d.m./ha/y in subsequent harvests. On the other hand, BNF has shown increasing productivities up to 5 years. This is one of the answers that have to be found in this pilot project.

Other aspects analyzed in these preliminary results:

- Sugar content in the sap: 4 to 6 Brix, which is 1/3 to 1/5 of the sugar cane Brix content. This is not low if we consider that the green biomass production of the 6 tested varieties resides around 200 t g.m/ha/y (g.m. = green mass), whereas the sugar cane productivity is around 80:90 t g.m./ha/y, which leads to the initial conclusion that the sugar content of the tall grasses may be equivalent to 45 to 83% of the sugar cane.
- C:N ratio: this ratio for fast-growing species that are not demanding on N, generally, is above 100. This means that these genotypes show more fibers and are better suited for carbonization, besides their high productivity being less dependent on accumulated N. The 3 species suggested by Embrapa, however, showed an average ratio of 90, probably due to excess N available in the soil that was recently revolved. As time goes on, available N will decrease, productivity will be maintained on account of BNF and inherent characteristics of these three varieties, and consequently the C:N ratio will surpass the 100 level, confirming their known performance in low N soils.
- Nutrients in the aerial part of the plants: in general, analysis showed potassium as half the usual, what is favorable for charcoal obtention. Other nutrients (Ca, Mg, P) are in the usual ranges, as the biomasses were harvested soon after the use of normal quantities of lime and fertilizers (2.5 t of lime and 500 kg of 4-14-8 per ha), but they will exhibit lower levels of these elements in subsequent harvests, as fertilizers will be used just in minimum amounts to avoid soil impoverishment. Higher Ca levels were observed in Cameroon and Gramafante, which may mean higher fiber content and better biomass quality for charcoal.

These preliminary results indicate that Ca and K should be carefully managed and kept under control to get biomasses properly suited for carbonization.

The 8 ha area harvested in July will grow the stems to plant the 36 (or 48 ha) definitive areas of the 6 (or 8) different varieties. The larger area will be planted in November 2004. Each genotype will use 6 strips of 1 ha to test the following factors: use of N or not (case of BNF); irrigation or not; 1 and 2 harvests per year; use of a drying agent; smaller spacing between rows. The first 4 strips (N, irrigation, number of harvests) will be divided in 0.125 ha portions to allow random distribution of combinations.

Beyond the 6 varieties already being evaluated, there are 2 more being considered: “Paraiso”, that reproduces by seed, and “Guaçu”, that was the genus used in all the previous works and that should serve as standard for comparisons. If it is decided to plant both, the total area needed will go to 48 ha.

More harvests are scheduled for March and November 2005. Regarding carbonization, another process (DPC = drying, pirolysis, cooling) shall be tested in three different reactors. The present problem being faced is the heterogeneity of the chopped grass charge, which tends to form preferential pathways for the gases, giving rise to operational difficulties and non-uniform products. Efforts are being made to overcome this problem.

A feasibility study will follow each group of test results using the Tornado diagram. The objective is to reach a cost below US$16/t d.m., which is thought plausible if we can get a 40:50 t d.m./ha/y.

The British biomass project based on Miscanthus, near Cambridge, started in 2001, plans to plant an area of 22,000 ha to feed a brand new thermoelectric power plant, already functioning, to supply energy for 400,000 people. This project works with productivity figures for Miscanthus, around 15 t d.m./ha/y, well below our goal. Their advantage is the harvesting of dry biomass (<20% humidity) made possible by the local climate.

The Samarco pilot project comprises a study of the distance around their plant where small farm communities could economically supply elephant grass to them. First figures indicate that this would be possible up to 100 km. As Samarco has excess hot gases from the pelletizing process, there would be no problem in using part of this excess energy to dry out the biomass before its carbonization. This could be applied to nearby suppliers of elephant grass. However, as farm distances increase, the cost to transport green biomass (up to 75% water) would become prohibitive. For these cases, the farmers should form cooperatives to extract the sap, bring the humidity down to 20% through dissecation and, eventually, produce charcoal themselves.

Charcoal from elephant grass will serve Samarco’s objective to produce iron ore pellets, but could be used in several other industrial applications such as the steel industry, foundries, non-ferrous metallurgy, industrial kitchens, etc.

The dried biomass pellet (below 20% water) is much easier to store, transport and use. Its applications include Samarco iron ore pelletizing furnaces, cement mills, red clay ceramics, bakeries, etc. An interesting work on biofuel pellets was done by R. Samson, Resource Efficient Agricultural Production - Canadá.

The long elephant grass fibers can also be of interest to the pulp and paper industry, and as raw materials to make panels and boards with binders for industrial, automotive and housing applications as well.

Biomass energy prospects in New Zealand

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Bioenergy in New Zealand is developing a higher profile than it has had in the past. Renewable energy sources include hydro, geothermal, biomass (mainly wood and landfill gas), waste heat, wind and solar. Renewable energy contributed about 29% of total primary energy supply in New Zealand for the year end March 2003. Of the total renewable energy supply, wind, biomass and wastes contributed 23%, while hydro contributed 39%, and geothermal 38% .

New Zealand government policy has a target of improved energy efficiency and an increase in renewable energy supply of 30PJ by 2012. Some of the policies are being implemented as part of the Government's Climate Change Policy and through the government's Renewable Energy Program. With New Zealand a signatory to the Kyoto Protocol, the leadership of the Climate Change Policy is very important in the development of renewable energy.

While Radiata pine residues from harvesting operations and log processing are likely to be the main feedstock for bioenergy in New Zealand, purpose-grown species also have a role to play as a feedstock for bioenergy plants, which may be relying on other providers for material. In New Zealand conditions, well-grown hardwood bioenergy stands could be expected to produce from 15-25 ODT/ha/yr.

For bioenergy to gain momentum in New Zealand, a biofuel market must occur to create an awareness of the role of bioenergy as an option in energy supply. This paper will discuss the current market and its prospects.

Biomass production for bioenergy from a young eucalypt plantation receiving untreated municipal effluent by sub-surface irrigation

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Land application of wastewater is becoming popular worldwide, in part due to increasing public environmental awareness. In New Zealand, this method has additional relevance due to the Resource Management Act 1991, New Zealand Waste Strategy 2002, and Maori cultural beliefs. Wastewater application to forested land offers a number of advantages: it may balance water and nutrient demand and reduce risk of food-chain contamination, it requires low intensive management, has social acceptability, and provides multiple uses for wood, such as bioenergy.

Wastewater irrigation techniques have evolved, over time, from flood irrigation to sprinkler irrigation, and more recently subsurface drip irrigation. Key physical characteristics of Subsurface Drip Irrigation (SDI) are uniform emission of water, the soil surface remains dry, and there are potentially less running costs than sprinkler systems. SDI also has numerous health and environmental advantages over other irrigation systems, which include no human contact, lack of aerosols and odors, and reduced risk of cross-contaminating surface runoff water. The SDI trial at Waihi Beach is a URS New Zealand project, with technical input from Forest Research, aimed at testing and quantifying the performance of SDI as an effective method for land treatment of primary untreated municipal effluent, in association with short rotation (*eucalyptus*) forestry. This paper reports on the changes in biomass production over the first 4 years of the plantation's growth.

Growth, productivity, and combustion characteristics of short rotation energy crops in Southern Norway

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Norway has less than 10 ha of short rotation crops, all established after 1993. In spite of reasonable yields, production has not increased. One important reason is a low consumption of wood chips, 0.2 TWh and straw, 0.1 TWh [1]. The consumption is increasing slowly as the use of electrical heating is decreasing. As part of this development, Agder University College established an energy park in Grimstad in 2000. The purpose is teaching, demonstration and R&D in renewable energy. In 2002, 4 different short rotation crops were established on 0.3 ha.

- Willow, 16,000 plants ha^{-1} *Salix schwerinii x Salix viminalis* “Steffan” and “Aage” plus *Salix viminalis* “Christina”. In total, 1680 cuttings were planted with a spacing of 0.55 m by 0.75 m / 1.50 m.
- Elephant grass, 11,000 plants ha^{-1} *Miscanthus x giganteus*. 1800 rhizomes were planted with spacing of 0.40 m by 0.80 m.
- Reed canary grass, 30 kg ha^{-1} *Phalaris arundinacea* “Bamse”. Established 18 July.
- Poplar *Populus trichocarpa* “Spirit” and “Muhle Larsen”, and *Populus trichocarpa x Populus maximoviczii* “O.P. 42”. A small collection of 90 cuttings was planted.

The climate in Grimstad, located 58º20'N 8º31'E, is coastal with heavy snowfalls. Annual mean temperature is 6.9ºC, and mean precipitation is 1230 mm. The period of growth averages 202 days (5ºC base temperature) [2]. The soil is medium sandy with clay content below 5%. To achieve a better soil structure, 5 cm of composted sewage sludge and sawdust was harrowed in prior to establishment. In subsequent years mineral fertilizer was applied. The amounts are listed in Table 1, where the fertilization effect of compost is stated as available nutrients the first year.

Table 1. Fertilization in kg ha^{-1} the first three growing years.

Crop Year	2002			2003			2004		
Nutrient	N	P	K	N	P	K	N	P	K
Willow and poplar	320	420	180	44	0	0	99	0	0
Reed canary grass and elephant grass	320	420	180	84	16	40	85	16	40

In April 2004, the content of available N, P and K in 0-20 cm depth for willow was 40, 580 and 290 kg ha^{-1} respectively before fertilization. For reed canary grass the corresponding content was 18, 560 and 290 kg ha^{-1}.

Management of the planting: No spraying and irrigation was carried out. Weeding was done in willow once in the establishment year, manually. Weeds covered the soil in elephant grass, willow and poplar.

Half of the willow was harvested in March 2003 to get more shoots and a better covering of the soil. Forty percent of the remaining willow was harvested in February

2004 to evaluate the dry matter production. Reed canary grass was harvested for the first time in March 2004, with a power scythe; though 10 m² was harvested in November 2003 to evaluate the winter loss of dry matter and heating value. Due to poor growth of elephant grass, only survival was observed and weeds were removed manually around each living plant.

Results and discussion: The height of new shoots from cuttings in 2002 and coppice in 2003 and 2004 were measured with intervals during the respective summers. In “Aage” and ”Steffan” the height increased 4-5 cm per day on average between mid-June and mid-August 2003. “Christina” had a lower growth rate during the summer and only compensated a little by having the highest growth rate in May and September. “Christina” actually stayed green until Christmas.

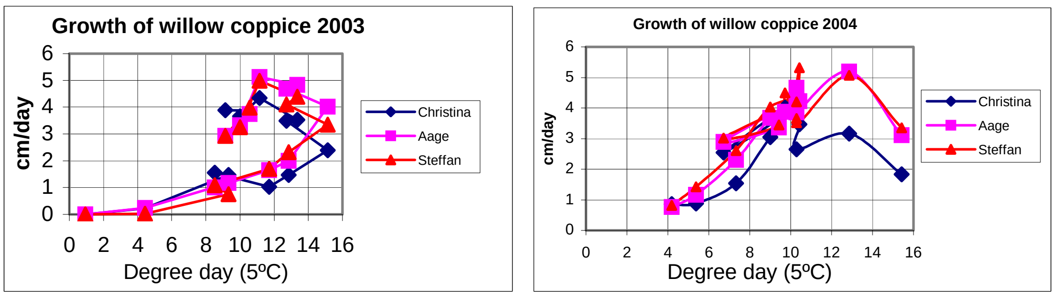


Figure 1. Growth is in cm per day for 2003, and 2004 until 11 August. An arrow marks the start of the growth. “Degree day” is an average per day in the period between previous and actual measurement of height.

In Figure 1 the relationship between growth and degree day is shown for 2003 and 2004 coppice. The establishment year 2002 looks similar to part of 2003, which is below 3 cm/day, while the 2003 growth above 3 cm/day is very much similar to the growth in 2004. The displacement in 2003 is coincident with a drought in August. This occurred in 2004 too and decreased the growth rate obtained by the highest degree day. The first years only revealed a limited correlation between growth rate in cm per day and degree day. According to Kopp et al. [3] the annual dry matter production is correlated to the sum degree day (5ºC) per year for willow 4-10 years old harvested annually. Our roots are younger and the relation between height and weight might change through the growing season.

Biomass assessment and yield: Yield and combustion characteristics of willow and reed canary grass are shown in Table 2.

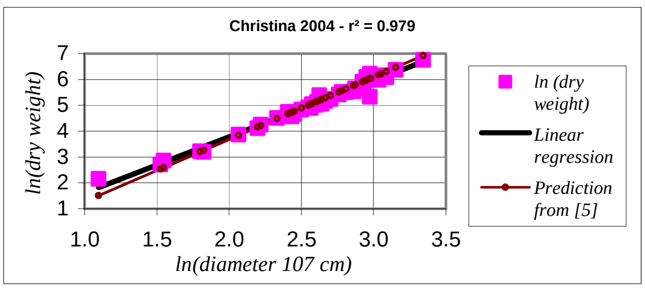
Table 2: Yield in willow and reed canary grass after first and second growing season.

	WILLOW			**REED CANARY GRASS**
	Christina	**Aage**	**Steffan**	**Bamse**
First year 2003, kg DM ha^{-1}	4200	3100	1300	-
Second year 2004, kg DM ha^{-1}	3700	10800	16700	6650
Two years, kg DM ha^{-1}	7900	13900	18000	6650
Water content 2003, %	60.5	59.8	59.0	-
Water content 2004, %	58.0	51.1	51.8	11.9
Net calorific value, MJ/kg_{DM}	17.4	17.7	18.1	16.6
Volatiles, $\%_{DM}$	75.7	76.4	77.0	72.3
Ash, determined by kiln $\%_{DM}$	1.4	1.2	1.2	2.6
Plants alive December 2003, %	97.6	89.6	99.1	-

The preliminary results indicate, that “Steffan” uses some time for establishment, but does more then catch up with “Christina” and “Aage” during the second year.

Harvested willow stored outdoors, uncovered, in bundles, over one summer, had a water content below 20% in August 2003, and 14, 21 and 22% for 2-year-old shoots of "Christina", "Aage" and "Steffan" respectively in August 2004.

A non-destructive prediction of the dry matter production based on shoot diameter in 4-year-old willow [4] was tested. Dry weight W, [g] of shoots harvested 5 cm above base and diameter D, [mm] measured 105 cm above shoot base, is according to [4]: $W=0.320*D^{2.411}$ (parameters determined for "Christina"). In Figure 2, this prediction is compared to the actual yield from 2-year-old shoots from 20 cuttings in our "Christina" planting with diameter measured 107 cm above ground and harvested 7 cm above ground. In addition, a linear regression is shown. The prediction overestimates the actual yield by 10%. Besides the age, a difference in water content of 4% may have influenced the estimation. The best linear fit based on our planting occurs in "Steffan" for $W = 12.20+0.001832D^2H$ (see Figure 2). A biomass assessment based only on measuring the diameter in a comfortable height is less time-consuming and more ergonomic.



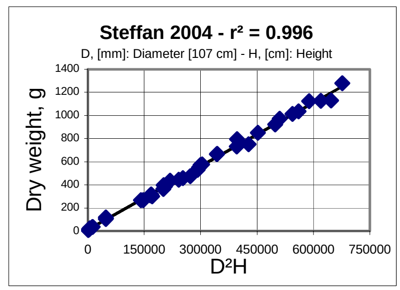


Figure 2. Biomass assessment based on diameter 107 cm above ground ("Christina"), and height and diameter ("Steffan").

Reed canary grass "Bamse" lost 15% dry matter in the field from November 2003 to March 2004. The water content decreased from 61.9% to 11.9%, the content of volatiles increased and ashes decreased. These findings agree with [5] for the same soil type.

Survival of elephant grass: only 13.5% of the living plants in autumn 2002 survived the first winter, while 85% of the living plants in autumn 2003 survived the second winter. The loss of plants the first winter is perhaps caused by high fertilization levels and an unusually quick temperature drop; from daily 5ºC mean air temperature to frost in only a few days in October 2002. The maximum height so far is 302 cm.

References:

[1] Berg L. N., Jørgensen P. F., Heyerdahl P. H. Wilhelmsen G. Bioenergiressurser i Norge. Norges vassdrags- og energidirektorat. Oppdragsrapport 7/2003, 32 p.

[2] www.vips-landbruk.no/klima/: Climate date for Research Unit Landvik, The Norwegian Crop Research Institute (3 km from the energy crops).

[3] Kopp R. F., Abrahamson L. P., White E. H., Volk T. A., Nowak C. A., Fillhart R. C. 2001. Willow biomass production during ten successive annual harvests. Biomass and bioenergy 20 (1): 1-7

[4] Nordh N. E., Verwijst T. 2004. Above-ground biomass assessment and first cutting cycle production in willow (*salix* sp.) coppice – a comparison between destructive and non-destructive methods. Biomass and bioenergy 27 (1): 1-8

[5] Burvall, Jan. 1997. Influence of harvest time and soil type on fuel quality in reed canary grass (*Phalaris arundinacae* L.). Biomass and bioenergy 12 (3): 149-154

Environmental benefits of a wood pellet market in New Zealand.

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The wood pellet market in New Zealand is in its initial state. There are two producers of wood pellets for home heating fuel in New Zealand. One is based on the South Island and the other on the North Island of New Zealand.

Different wood pellet heating systems have been compared with alternatives, mostly fossil fuel-based heating systems. The study has evaluated 20 different residential heating systems in New Zealand.

The results indicate that the wood pellet heating systems, in an economic sense, are competitive with electricity and LPG for heating. In competition with fossil fuel-based systems, the costs are comparable, whereas the wood pellet heating systems are not competitive with traditional log burner heating systems. By including a carbon tax on fossil fuel systems, scheduled for 2007, the wood pellet heating system becomes competitive with the conventional fossil fuel heating system. Furthermore, the government of New Zealand will implement an air emission standard, which will have an impact on conventional log burners and is likely to take the cheapest systems out of the market. The implementation of the air emission standard is based on public health benefits and may make wood pellet heaters more competitive.

The overall environmental and socio-economic benefits of the use of wood pellet markets in New Zealand will be discussed in the paper.

Types of agricultural and forestry changes needed to annually produce 1 billion dry tons of biomass per year in the United States

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Forestland and cropland resources have the potential to provide for a six-fold increase in the amount of biomass energy currently consumed for bioenergy and biobased products in the 2050 timeframe. This potential exceeds 1.3 billion dry tons – the equivalent of more than one-third of the current demand for transportation fuels. About 30% of this potential could come from extensively managed forestlands and about 70% from intensively managed croplands. Many technical changes in biomass harvesting and crop production technology would have to occur in order to sustainably supply this much biomass annually.

The potential quantity of biomass from forestlands is estimated to be slightly more than 400 million dry tons annually. There are relatively large amounts of forest residue that is generated from logging and land clearing operations that goes uncollected (61 million dry tons) and there are significant quantities of forest residues that can be collected from fuel treatments to reduce fire hazards (96 million dry tons). The 400 million dry ton potential also includes 48 million dry tons of fuelwood that is extracted from forestland for residential and commercial uses, 73 million dry tons of wood residues generated and used by the forest products industry, 64 million dry tons of pulping liquors, and 61 million dry tons of urban wood waste. The more substantial amounts of unutilized forest biomass are potentially available from logging and other removal residue, fuel treatments, and urban wood wastes.

From agricultural lands, the potential sustainable supply of biomass is about 950 million dry tons annually. This projection includes annual crop residues, perennial crops, grains to biofuels, animal manures and wastes, and other miscellaneous feedstocks. The critical assumptions are that all crop production is managed with no-till methods, harvest technology is capable of taking 75% of annual crop residues and 90% of perennial crops (where they are sustainably removable), annual crop yields have improved by as much as 50%, and perennial crops are being produced for energy, fiber, and animal protein on 60 million acres of land at an average annual yield of 8 dry tons per acre.

Biomass productivity improvement of eastern cottonwood and American sycamore through genetics and physiology research

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Eastern cottonwood (*Populus deltoides* Marsh.) and American sycamore (*Platanus occidentalis* L.) are grown in plantations by MeadWestvaco for use at its Wickliffe Fine Papers Mill. Over the past two decades, research focused on genetic and silvicultural improvements has led to significant increases in per acre yield while cutting production costs.

Initially, genetic improvement efforts for cottonwood and sycamore have concentrated on developing families and clones for company lands on the Mississippi River alluvial floodplain near Wickliffe, Kentucky. Recommendations continue to be refined, while additional work is aimed at broadening the genetic base through introductions and breeding. Development of a fertigated fiber farm, since 1996, has led to additional genetic testing for this drastically different production environment. Biotechnology advances, including the use of genetic markers and transformation, have proven their worth with cottonwood, but social impacts limit their immediate operational use.

The alluvial sites in the Wickliffe Forest Area are some of the most productive sites found anywhere, but they are just as productive for weeds as they are for trees. MeadWestvaco relies heavily on mechanical cultivation, but herbicide use is increasing as research identifies improved cost savings. In the past five years, physiology research has helped control costs through defining optimal management regimes for the fertigated fiber farm. Data from water, nutrient use, and spacing studies indicate that initial fiber farm management regimes could be improved substantially.

Three-year growth response of four clones of eastern cottonwood (*Populus deltoides* Bartr. ex Marsh.) to fertigation

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Early growth response of four clones of eastern cottonwood (*Populus deltoides* Bartr. ex. Marsh) to augmented site resources was examined in a fertigation experiment. Three clones came from native populations along the Mississippi River (ST66, ST72, ST75) and one was from an east Texas population (S7C15); all four clones are used operationally in the Lower Mississippi Alluvial Valley. Five treatments were replicated three times in a completely randomized block experimental design with clones as subplots. Treatments included control, irrigation alone, fertilizer alone, irrigation plus fertilizer (fertigation), and extended season fertigation. Added nutrients and water significantly increased stand volume and woody biomass accumulation after three growing seasons; responses at the individual tree level were similar. The four clones grew differently but there were no interactions between treatment and clone for stand-level volume and biomass. Oven-dry leafless biomass increased from about 21 tons ac^{-1} in the control to almost 29 tons ac^{-1} in the extended season treatment. Stand volume increased from 826.8 ft^3 ac^{-1} in the control to 1165.7 ft^3 ac^{-1} in the extended season. Clone S7C-15 was the best performer and accumulated over 29 tons ac^{-1} in three years, significantly more biomass than ST-66 and ST-72.

Sustainable short rotation crop systems – improving production systems efficiencies

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Assessments of short rotation crop production systems efficiency can be done from several different perspectives. A biological and plant physiological point of view can be taken to bridge the gap between actual and potential production, by designing a management regime that provides resources (i.e. water and nutrients) and adapted technique (i.e. planting density and harvest intervals) to genetically defined plant material. This point of view can be exemplified by traditional agricultural elite crop production. However, such systems perform optimally under well-defined environmental conditions, but may collapse if environmental conditions change or deviate. "Generalist crops" that perform under wider ecological amplitude may provide a more secure/sustainable alternative in the long run.

Production systems efficiency can not only be looked upon from a biological perspective, but also from sociological and economical perspectives that may include multipurpose use and co-products of the systems, such as vegetation filters improving soil and water quality in addition to biomass production.

Finally, in the sociological and economical context, it can also be evaluated whether a small-scale rural production should be used, where job opportunities in the countryside are created, or if an industrial larger-scale production system is preferred.

Different aspects of these perspectives will be discussed in this paper.

Current and future status of short rotation woody crops in the northeastern United States

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Short-rotation woody crops (SRWC), like willow shrubs, can be used as an alternative farm crop to replace fossil fuels for the production of bioenergy and bioproducts, while providing numerous positive environmental and rural development benefits. Over 40 million ha of idle or surplus agricultural land are available for the deployment of short rotation woody crops (SRWC) in the U.S. (Graham et al. 1994). Projections indicate that biomass will provide 7.5 exajoules (7.1 quads) of energy by 2025. Woody biomass will make up 67% of that total. Dedicated energy crops (SRWC and herbaceous crops) are projected to develop rapidly, and will make up 32% (1.6 exajoules) of the woody biomass resource in 2025 (EIA 2003).

Interest in SRWC has developed over the past few decades because of the multiple environmental and rural development benefits associated with their production and use. SRWC development in the northeastern U.S. has concentrated on willow shrubs (*Salix spp.*) and hybrid poplar (*Populus spp.*). Willow shrubs have several characteristics that make them ideal for SRWC systems that are focusing on bioenergy and bioproduct markets, including: high yields that can be obtained in 3-4 years, ease of propagation from dormant hardwood cuttings, a broad genetic base, ease of breeding, ability to re-sprout after multiple harvests, and feedstock uniformity.

Willow biomass crops are being developed as sustainable systems that simultaneously produce a suite of environmental and rural development benefits, while providing a renewable feedstock for bioenergy and bioproducts. The perennial nature and extensive fine-root system of SRWC reduces soil erosion and non-point source pollution, promotes stable nutrient cycling and enhances soil carbon storage in roots and soil organic matter (Volk et al. 2004). Bird diversity in SRWC is comparable to diversity in native shrub land, successional habitat, and intact eastern forests (Dhondt and Wrege 2003). These characteristics have made willow attractive for other applications across the region including phytoremediation, riparian buffers, and living snowfences.

The near-term large-scale market for willow biomass is co-firing at coal power plants. Two pulverized coal power plants, AES Greenidge and NRG Energy's Dunkirk steam station in New York, are currently retrofit for co-firing woody biomass with coal, with the combined potential for about 20 MW of co-firing potential. Up to 294 MW of biomass co-firing could be developed in NY alone. The production of 1 MW of power would require about 300 ha of willow biomass crops (100 ha harvested per year with a 3-yr harvest rotation), if willow were the sole source of woody biomass for co-firing. Test firing of willow biomass at Greenidge provided valuable lessons about harvesting and processing so willow would flow through the system. Intensive test burns and air quality monitoring using an input of 10% woody biomass were completed at Dunkirk in November 2002 on a 100 MW boiler. Over 15 tons of willow biomass was included in the tests. Testing confirmed that SO_2, NO_x, and particulate matter emissions were significantly reduced when woody biomass was co-fired with coal.

In addition to co-firing, willow biomass can be used as part of the woody fuel mix in power plants that use 100% woody biomass for heat and/or power. Longer-term conversion technologies include gasification and pyrolysis. The future for willow and other woody biomass is in a modular "biorefinery" where an array of woody biomass resources are used as input to create an extensive portfolio of "value-added" co-products, including: liquid, gas and solid fuels, chemicals and advanced polymer materials. The development of these value-added bioproducts will provide several new markets for SRWC producers.

Despite the numerous environmental and rural development benefits associated with SRWC, their use as a feedstock for bioproducts and bioenergy has not yet been widely adopted in the U.S. The primary reason is their cost. Current costs to produce and deliver SRWC to an end user are \$43–50 odt^{-1} (Walsh et al. 1996, Tharakan et al. 2004). On an energy unit basis, these prices are greater than commonly used fossil fuels like coal. A commercial SRWC enterprise will not be viable unless the biomass price, including incentives and subsidies, is comparable to that of fossil fuels, and parties involved in growing, aggregating and converting the fuel, are able to realize a reasonable rate of return on their investment.

There are three pathways to make SRWC cost competitive with fossil fuels. One is to lower the cost of production by reducing operating costs and increasing yields. Another is to add value to the environmental and rural development benefits associated with the crop. The other pathway would be to tax the fossil fuels for their environmental damage. Ongoing research projects are focused on reducing operating costs and increasing yields. Recent policy developments in the federal Conservation Reserve Program (CRP) and state Renewable Portfolio Standards (RPS) are mechanisms that begin to add value to some of the benefits associated with willow biomass crops. Their implementation will have a significant impact on the delivered price of willow biomass and the potential to deploy SRWC in the Northeast.

Under the CRP program, landowners that meet a certain level on an environmental benefits index can opt voluntarily to enter into an agreement with the U. S. Department of Agriculture, wherein they retire land from agricultural production and maintain a permanent vegetative cover of grasses or trees that create wildlife habitat and improve soil and water quality. In return, the landowners are eligible for annual rent payments for the life of the contract as well as cost sharing funds to offset the establishment costs (not more than 50%) of a vegetation cover (FSA 2004). The duration of the contracts is between 10 and 15 years.

Until 2002, haying or grazing of land under CRP contract was not allowed, except under emergency conditions such as droughts or similar weather related emergencies. The 2002 Farm Bill modified these restrictions by including a managed haying and grazing option. Managed haying and grazing can occur no more frequently than 1 out of 3 years after the cover is fully established on the site (FSA 2004). These activities can only take place with approval from the local Farm Service Agency (FSA) office and in accordance with the conservation plans for those areas. Collaborative efforts over the past 5 years in New York have resulted in the development of state level draft guidelines that make the establishment and harvest of willow biomass crops an acceptable conservation practice that can be deployed across the state.

New York State has joined 13 other states, 7 of which are in the Northeast, in developing a RPS to increase the proportion of non-fossil fuel electricity purchases in the state. New York's RPS, when fully implemented in 2013, will require that 25% of the electricity retailed in the state be from renewable resources, up from the current baseline of 19%. Biomass co-firing will supply nearly 7% of the RPS increment. The RPS Biomass Eligibility Working Group has recommended that through 2008, 10% of the biomass used in co-firing should come from sustainably-managed energy crops, such as willow. Starting in 2009, that proportion should be increased to 25%.

Impact of Incentives: Modeling indicates that without incentives or supports the farm gate price and delivered price for willow under current yields was \$2.50 GJ^{-1} and \$3.00 GJ^{-1}. The delivered price of willow feedstock was more than twice the current delivered price of coal (\$1.30- 1.50 GJ^{-1}) (Tharakan et al. 2004). At this price, the power plant cannot afford to utilize the feedstock and a commercial willow enterprise cannot exist.

Growing willow on CRP land with the landowners receiving CRP payments significantly reduced the cost of producing willow feedstock. Farm gate and delivered price was \$1.42 and \$1.90 GJ^{-1} (Tharakan et al. 2004). This represents a 33% reduction in the delivered price of the feedstock, relative to the base case scenario. These delivered prices, however are still higher than coal, so the CRP program alone will not result in the large-scale deployment of willow unless other incentives or policies are put in place.
In the near term, co-firing can be an economically viable market for willow biomass if federal and state incentives that value environmental and rural development benefits associated with production and use of biomass feedstock or disincentives for use of fossil fuels are applied. The development of knowledge, experience and an infrastructure for growing and using willow in the near term will allow it to be deployed for other end uses in the future.

References

Dhondt A. A., and P. H. Wrege. 2003. Avian Biodiversity Studies in Short-Rotation Woody Crops. Final report prepared for the U.S. Dept. of Energy under cooperative agreement No. DE-FC36-96GO10132. Cornell University Laboratory of Ornithology, Ithaca, NY 38 pp.

Energy Information Administration. 2003. Assumptions for the Annual Energy Outlook 2003 with Projections to 2025. U.S. Dept. of Energy, Wash. (DC). DOE/EIA-0554(2003).

Farm Service Agency. 2004. Conservation Reserve Program Haying and Grazing of Acreage Fact Sheet. 2pp.

Graham R. L. 1994. An analysis of the potential land base for energy crops in the conterminous United States. Biomass and Bioenergy 6:175-189.

Tharakan, P. J., T. A. Volk, C. A. Lindsey, L. P. Abrahamson, E. H. White. (In press). Evaluating the impact of three incentive programs on co-firing willow biomass with coal in New York State. Energy Policy.

Volk, T. A., T. Verwijst, P. Tharakan, L. P. Abrahamson, and E. H. White. (In press). Are short-rotation woody crops sustainable? 2nd World Conference and Technology Exhibition on Biomass for Energy, Industry and Climate Protection. Rome, Italy 10-14 May 2004.

Walsh, M. E., Becker, D. and Graham, R. L. 1996. The conservation reserve program as a means to subsidize bioenergy crop prices. Proceedings of Bioenergy 96 – The Seventh National Bioenergy Conference: Partnerships to Develop and Apply Biomass Technologies, Sept 15-20, 1996, Nashville, Tennessee. 6 p.

Recent experiences with willow biomass crops in New York

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Research on willow as a locally produced, renewable, feedstock for bioenergy and bioproducts began in New York in the mid 1980s. Simultaneous and integrated activities including research, large-scale demonstrations, outreach and education, and market development, were initiated in the 1990s to facilitate the commercialization of willow biomass crops.

Significant progress occurred in the development and understanding of willow biomass crops over the past few years. Breeding efforts are resulting in yield increases of 20-30% and new clones are being identified for a wide range of applications. Research quantified environmental benefits including energy and carbon balances through life cycle analysis, and soil microarthropod and avian diversity. Focus on the establishment portion of the production system has yielded valuable results. Cover crops can be incorporated during the establishment of willow and hybrid poplar to minimize soil erosion potential without reducing biomass yields. Trials have shown that coppicing willow after the first year of growth does not increase yield.

The biological and physiological characteristics of willow biomass crops make them valuable for a wide array of applications across the landscape. Recent efforts have focused on testing and developing willows for phytoremediation applications, living snowfences, and riparian buffers.

Initial success establishing willow on solvay wastebeds in Syracuse, NY

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Beginning in 1881, sodium carbonate (soda ash), chlorine and caustic soda were manufactured in Syracuse using naturally occurring salt brines and limestone in the Solvay process. The last plant was closed in 1986. Byproducts from this process were pumped from the plants into settling ponds that eventually covered almost 600 ha around Onondaga Lake. Some of the older areas have been redeveloped over the past few decades for manufacturing, roads, parking areas etc., but several hundred ha of wastebeds remain. This project is focused on the wastebeds that received Solvay waste from 1944 through 1985 and encompass over 220 ha.

Solvay waste was hydraulically disposed of as a slurry (5 to 10% solids). After dewatering, the waste is primarily composed of calcium, magnesium and sodium compounds, resulting in harsh growing conditions for plants including high pH and electrical conductivity. The primary concern associated with the wastebeds is the potential impact of chlorides on surface and ground water resources.

A project is underway to assess the impact of establishing willow shrubs on the wastebeds and their ability to modify the overall water balance of the wastebeds. Willows, primarily *Salix alba, S. bebbiana, S. purpurea*, *S. eriocephala*, and *S. discolor* occur naturally on the wastebeds. This project has a number of tasks including greenhouse and field screening trials with various willow and hybrid poplar clones, monitoring and modeling of water budget inputs and outputs, site characterization, and use of organic amendments to enhance the growth of willows on the wastebeds. Results of the initial greenhouse screening trial are presented below.

Forty clones of willow and poplar were screened to determine which clones were likely to be the most successful when planted on the Solvay wastebeds. The trial was a 3 x 40 two-way factorial experiment set up in a completely randomized block design with 4 replications. Three soil treatments were used: (1) unamended Solvay waste collected from the top 15 cm of the wastebeds, (2) Solvay waste from the top 15cm of a section of the wastebed that was amended with biosolids in the late 1980s, and (3) a 1:1 volume ratio of Promix and fine sand as a control.

After growing in the greenhouse for 11 weeks under mist irrigation, above and belowground biomass for each of the 40 clones was harvested. Aboveground biomass included stems and leaves. Belowground material was washed in water baths to remove the soil attached to the roots. Roots were then separated from the cuttings and bagged separately. All plant parts were dried at 65^{o}C to a constant weight.

Survival was greater than 90% for all clones. Aboveground biomass ranged from 0.91 to 4.40 g plant^{-1}. Aboveground biomass was significantly different among the treatments for 19 of the 40 clones in the trial (Table 1). For 15 of these clones, biomass was greatest in the amended Solvay waste. Biomass was greatest in the Promix treatment for the other 4 clones, which included both hybrid poplar clones in the test. Although the differences were not statistically significant, 7 willow (9883-34, 9870-23, 98101-66, 9871-26, 98101-61, 9871-31, AusL) and 1 hybrid poplar clone (NM6) produced more aboveground biomass than our standard clone, SV1, in the amended Solvay waste. SV1 has consistently been one of the best aboveground biomass producers in trials across the northeastern U.S. and is used as a standard when screening new clones. Seven willows (SX64, 9870-23, 9871-31, S25, 98101-61, 9871-26, AusL) and 1 hybrid poplar (NM6) did better than SV1 on the unamended Solvay waste.

Root biomass varied from 0.08 to 0.92 g $plant^{-1}$ on the amended Solvay waste and 0.06 to 0.57 g $plant^{-1}$ on the unamended Solvay waste. Root biomass was significantly different among the 3 treatments for 7 different willow clones (Table 2.3). For all these clones, root biomass was lowest on the unamended Solvay waste. It was highest in the Promix and sand treatment in 6 of the 7 cases. The exception was 98101-66. Only 1 clone, 9871-31, had significantly higher root biomass than clone SV1 on the amended Solvay waste. Two other clones (98101-61, 9870-23) ranked higher in terms of root biomass than SV1, but the difference was not significant. All 3 of these clones had higher aboveground biomass production than SV1. In the unamended Solvay waste, none of the clones produced significantly more root biomass than clone SV1. Three clones (SX64, 9871-31, 9870-23) did rank higher than SV1 and 2 of these had higher aboveground biomass than SV1.

Five clones had significant differences in root:shoot ratios among the 3 treatments (Table 1). In all these cases the root:shoot ratio was highest in the Promix and sand treatment. Root:shoot ratios varied from 0.06 to 0.23 in the amended Solvay waste and 0.05 to 0.27 in the unamended Solvay waste and by a factor of 6 in the Promix and sand treatment. Of the 8 clones on the amended Solvay waste with aboveground biomass greater than SV1, 3 of them (AusL, 9882-34 and NM6) had significantly lower root:shoot ratios. Two of the clones had a higher root:shoot ratio, although the differences were not significant. Of the 8 clones that had more stem biomass than SV1 on the unamended Solvay waste, only 2 had significantly lower root:shoot ratios. Two of the clones had higher root:shoot ratios, but the differences were not statistically significant.

Results from this initial screening indicated that there are a large number of different willow clones that tolerate conditions on the Solvay wastebeds and could be productive. A number of clones had better biomass production than our standard high biomass-producing clone SV1. Among these clones, there were differences in the root:shoot ratios. Most of these plants had high root:shoot ratios, but a few had low ratios. The clones with low root:shoot ratios may be more susceptible to dry conditions found on the wastebeds during certain parts of the growing season. A subset of the most successful clones has been planted in a field trial on the wastebeds using 2 different sizes of plant cutting material.

The previously organic material amended Solvay waste is a better growth medium for plants compared to the unamended Solvay waste. Rapid above and belowground growth are important aspects involved in selecting plants to alter the water balance on the wastebeds. Ongoing greenhouse and field trials are testing the response of several clones to various mixes of Solvay waste and different locally available organic amendments.

Table 1. Aboveground biomass and root:shoot ratios for 40 clones of willow and hybrid poplar grown for 11 weeks on unamended Solvay waste, previously amended Solvay waste and promix and sand.

	Aboveground biomass (g $plant^{-1}$)			Root:shoot ratio		
Clone	unamended	amended	Promix	unamended	amended	Promix
95018	**2.74 a**	**1.34 b**	**2.35 ab**	0.10 a	0.12 a	0.11 a
95042	1.13 a	0.58 a	0.88 a	0.10 a	0.09 a	0.11 a
95061	**1.69 ab**	**0.84 a**	**2.00 b**	**0.13 a**	**0.13 b**	**0.22 ab**
95311	1.48 a	0.57 a	1.25 a	0.10 a	0.15 a	0.13 a
95316	**2.89 a**	**1.35 b**	**3.26 a**	0.07 a	0.08 a	0.08 a
98101-57	2.56 a	1.68 a	2.58 a	**0.16 a**	**0.17 b**	**0.24 ab**
98101-61	**3.99 a**	**2.43 b**	**3.21 ab**	0.14 a	0.16 a	0.14 a
98101-66	**3.66 a**	**1.94 b**	**2.46 b**	0.15 a	0.13 a	0.17 a
9832-49	1.81 a	0.82 a	1.23 a	0.14 a	0.15 a	0.18 a
9870-1	2.34 a	1.45 a	1.92 a	0.15 a	0.16 a	0.19 a
9870-23	**3.43 a**	**2.13 b**	**2.84 ab**	**0.23 a**	**0.27 b**	**0.32 a**
9870-40	2.69 a	1.85 a	2.34 a	0.14 a	0.15 a	0.15 a
9870-42	2.22 a	1.52 a	2.21 a	0.13 a	0.14 a	0.14 a
9871-26	**3.95 a**	**2.46 b**	**3.03 ab**	0.12 a	0.16 a	0.17 a
9871-31	**4.24 a**	**2.23 b**	**3.10 b**	**0.23 a**	**0.25 b**	**0.33 ab**
9871-41	1.72 a	1.17 a	2.15 a	**0.14 a**	**0.16 b**	**0.21 a**
9882-34	**3.35 a**	**2.07 b**	**3.22 ab**	0.06 a	0.08 a	0.09 a
9882-41	**2.43 a**	**1.35 b**	**1.82 ab**	0.07 a	0.08 a	0.07 a
9882-5	**1.54 a**	**0.92 a**	**2.03 a**	0.07 a	0.09 a	0.10 a
AusC	2.95 a	2.01 a	2.53 a	0.12 a	0.12 a	0.14 a
AusL	4.40 a	3.76 a	3.57 a	0.09 a	0.08 a	0.09 a
B193	2.25 a	1.30 a	1.65 a	0.09 a	0.12 a	0.13 a
B197	1.85 a	1.18 a	1.55 a	0.08 a	0.10 a	0.08 a
B198	1.39 a	0.97 a	1.48 a	0.06 a	0.08 a	0.06 a
FC185	1.49 a	0.73 a	1.06 a	0.14 a	0.17 a	0.17 a
FC187	0.91 a	0.80 a	1.20 a	0.10 a	0.12 a	0.10 a
FC189	1.99 a	1.18 a	1.40 a	0.08 a	0.11 a	0.12 a
FC190	**2.75 a**	**1.43 b**	**1.93 ab**	0.09 a	0.10 a	0.09 a
NM5	**2.35 a**	**2.04 a**	**3.41 b**	0.06 a	0.06 a	0.06 a
NM6	**4.39 a**	**2.26 b**	**4.04 a**	0.06 a	0.05 a	0.05 a
PUR12	1.86 a	1.28 a	1.64 a	0.08 a	0.11 a	0.10 a
PUR34	1.08 a	0.56 a	0.84 a	0.11 a	0.15 a	0.14 a
S25	**2.95 ab**	**2.23 a**	**3.50 b**	0.09 a	0.14 a	0.09 a
S301	1.22 a	0.62 a	1.24 a	0.12 a	0.17 a	0.18 a
S365	**2.02 ab**	**1.94 a**	**3.02 b**	0.08 a	0.09 a	0.11 a
S625	**2.68 a**	**1.36 b**	**2.56 a**	0.19 a	0.18 a	0.22 a
S652	2.76 a	1.95 a	2.50 a	0.15 a	0.14 a	0.15 a
SV1	**3.17 a**	**2.09 b**	**2.31 ab**	0.17 a	0.20 a	0.21 a
SX61	**2.67 a**	**1.64 b**	**1.89 ab**	0.16 a	0.13 a	0.17 a
SX64	2.74 a	2.10 a	2.45 a	0.15 a	0.15 a	0.15 a

† Different letters in a row (highlighted in bold text) indicate significant differences ($p<0.05$) in root biomass among treatments within a clone.

Tampa Electric Polk Power Station herbaceous biomass gasification test burn

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The Tampa Electric Polk Power Station Herbaceous Biomass Gasification Test Burn was conducted in April 2004 in Mulberry, Florida. Polk Power Station Unit 1 is an Integrated Gasification Combined Cycle (IGCC) unit that is owned and operated by the Tampa Electric Company. The unit began commercial operation in September 1996 and was partially funded under the Department of Energy's Clean Coal Technology Program.

The 250 MW (net) unit uses an oxygen blown, slurry fed, entrained flow gasifier integrated with gas clean up systems and a highly efficient combined cycle to generate electricity with significantly lower SO2, NOx and particulate emissions than existing coal fired power plants. This project has demonstrated the technical feasibility of commercial-scale IGCC Technology.

The unit is designed to operate on a coal feedstock and has successfully operated on over 20 different coals and blends of coal with petroleum coke. The unit has also demonstrated the capability to co-utilize up to 5% biomass as a component in the feedstock during tests using wood and grass. During the test conducted in December 2001, technical challenges were identified in blending woody biomass into the coal slurry feedstock for injection into the gasifier.

The test conducted in April 2004 focused on utilizing herbaceous biomass as a component in the slurry feedstock. Fifty tons of Bahiagrass, a common Florida grass already growing at the Polk site was used as the feedstock for the test. The test resulted in no increase in plant emissions and no negative impacts to the plant systems.

Polk offers a unique opportunity for biomass utilization. The plant property consists of over 4,500 acres of reclaimed phosphate mining land. Significant acreage is available on the plant property and in the immediate vicinity to supply all of the herbaceous fuel requirements of the plant. Polk County is home to a large phosphate mining industry that has well over 100,000 acres of reclaimed land that could be put into agricultural use.

The goal of the Polk Power Station biomass test program is to evaluate the economic and technical feasibility of co-utilizing biomass fuels in the IGCC process. One of the largest impediments to the utilization of biomass in power generation is the relatively high cost of the biomass when compared to the standard plant fossil fuels. The paper discusses the results of the April 2004 test and approaches to minimizing biomass supply chain costs to lower the delivered price of a dedicated herbaceous biomass energy crop.

The effects of irrigation and fertilization on stem allometry of four short-rotation woody crop species

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To determine how fertilization and irrigation affect stem allometry we determined the relationship between D^2H and stem volume and the relationship between D^2H and stem biomass following the sixth growing season for stands of loblolly pine (*Pinus taeda* L.), slash pine (*P. elliottii* Engelm.), sweetgum (*Liquidambar styraciflua* L.), and sycamore (*Platanus occidentalis* L.) growing in southeast Georgia. Three trees each were harvested from 3 replications of 5 treatments: control, irrigation only, and irrigation with 57, 85, and 114 kg N ha^{-1} yr^{-1}. Stem volume per D^2H was greatest for slash pine, similar between sweetgum and sycamore, and least for loblolly pine. However, there were not differences in the D^2H-volume relationship due to irrigation or fertilization, with one equation per species explaining greater than 97% of the variation. When compared on a stem biomass basis, the biomass produced for a given D^2H increased for the hardwoods relative to the pines due to greater stem density, but as with the case for volume, irrigation and fertilization did not affect the species-specific relationships between D^2H and stem biomass (minimum r^2 of 0.92). These results indicate that when compared on the same site, irrigation and fertilization did not affect stem allometry and that one growth equation based on simple tree measurements was sufficient to accurately predict stem volume or biomass.

Worldwide commercial development of bioenergy; examples, success factors, and constraints

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Utilization of biomass to produce energy is increasing worldwide but at a relatively slow rate compared to increasing energy demand. Total renewable electricity generation worldwide is expected to double between 2001 and 2025 with wind being the fuel of choice. Net electricity generation from renewables worldwide has increased from ~ 164 billion kwh to ~274 billion kwh. In the United States, increases in renewable electricity generation have come primarily from installation of wind turbines and use of landfill gas, animal manures and other agricultural wastes. Ethanol and biodiesel production are also increasing but currently rely on conventional crops (such as sugar cane, corn grain, rapeseed, soybeans) as the biomass resource. Evidence for commercial use of perennial short rotation crops for bioenergy is scant in the internet literature. Yet short-rotation crop development for bioenergy has been an important focus of IEA members and many other countries for over 20 years, resulting in much research and some demonstration projects.

There are many reasons why the emergence of commercial projects using short rotation crops or even crop residues has been slow. Agricultural biomass energy development constraints exist in 7 different areas. Furthermore, all of the constraint areas are interdependent. Thus, there are 5,040 interdependencies to be addressed.

Lynn Wright will summarize the current status of bioenergy development in the US, Europe, Brazil and other countries, providing summary statistics on bioenergy production, bioenergy projects, types of feedstock used, and ha of short-rotation crops in commercial production. Gary Elliott will discuss the constraints affecting biomass energy project development with specific examples.

Water usage and establishment success of *Populus* during phytoremediation of landfill effluent

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Poplars are ideal for phytoremediation because of their exceptional water usage and biomass production. Assuming these traits are proportional to remedial benefit, our objectives were to test the: (1) water usage of poplars planted as a biological filter of landfill effluent and (2) efficacy of growing poplars in landfill effluent in a greenhouse treatability study.

The transpiration per tree over 18.5 days in 2002 (n=15) and 2003 (n=9) was 14.3 and 60.3 $L \cdot d^{-1}$, respectively. The estimated transpiration assuming a 50-day growing season in 2002 and 2003 was 1,202,459.6 and 5,063,530.5 $L \cdot ha^{-1}$, respectively. Water usage (sap flow rate) was 0.006 and 0.011 $cm \cdot s^{-1}$ for trees of mean cross sectional area of 69.3 and 159.4 cm^2 in 2002 and 2003, respectively.

A split-split plot design was used to test two treatments (effluent and control), 6 clones, and 4 dates (28, 42, 56, and 70 days after planting-DAP). Treatments, applied every 2 days beginning 42 DAP, differed ($LSD_{0.05}$) for height, diameter, and number of leaves at 56 and 70 DAP, with effluent trees exhibiting the greatest growth. Stem and leaf dry weight were different and greatest for effluent trees; however, root dry weight did not differ and was greatest for control trees.

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