short rotation WOODY CROPS operations working group

Proceedings

Proceedings of the Short Rotation Woody Crops Operations Working Group Conference

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Table of Contents

TN
Agenda 2020 Forest Products Vision - *Tom Foust, DOE/OIT, Washington, DC*

Technical Session **-SRWC Operations -- What's working?** Moderator - *Bob Perlack, ORNL, Oak Ridge, TN*

Southern Perspective: Boise Cascade's Short-Rotation Woody Crop Operations - *Steve Coleman, Boise Cascade, DeRidder, LA*
Central/Southern Perspective - Westvaco's Short-Rotation Operations - *Gail Simonds, Westvaco, Wickliffe, KY*
Western Perspective: Boise Cascade's Short-Rotation Operations in Washington and Oregon - *Steve Pottle, Boise Cascade, Wallula, WA*
Western Perspective: SRWC Operations - Field Conversion and Plantation Establishment - *Jake Eaton and John Finley, Potlatch, Boardman, OR*
Northeast Energy Perspective: Willow Biomass - Bioenergy Industry Development - *Ed Neuhauser, Niagara-Mohawk, Syracuse, NY; Larry Abrahamson, State University of NewYork, Syracuse, NY*
Intensive Culture of Hybrid Poplars in Minnesota - *Don E. Riemenschneider and Daniel A. Netzer, USDA Forest Services, Rhinelander, WI and Bill Berguson, Natural Resources Research Institute, Duluth, MN*

Technical Session **- SRWC Operations -- What's new?** Moderator - *Randy Richter, Simpson Timber Co., Corning, CA*

Guidelines for Drip Irrigation and Fertigation of Pines and Hardwoods - *Ilan Bar, Netafim, Altamonte Springs, FL*
Water Resource Planning Considerations for Irrigated Short Rotation Intensive Culture Projects - *Mark Madison, CH2M HILL, Portland, OR and Greg Brubaker, CH2M HILL, Gainesville, FL*
Weed Control Strategies for SRIC Hybrid Poplar Plantations: Farmer's Perspective - *Bill Schuette and Chuck Kaiser, James River, Clatskanie, OR*
Environmental Impacts of Converting Cropland to Short-Rotation Woody Crops - *Dev Joslin, TVA, Norris, TN*
Harvesting Systems for Short-Rotation Woody Crops - *Bruce Hartsough and David Yomogida, University of California, Davis CA and Bryce Stokes, USDA Forest Service, Auburn AL*
A Review of Short-Rotation Forestry Harvesting in Europe - *Raffaele Spinelli, CNR/IRL, Italy and Pieter Kofman, Danish Forest and Landscape Research Institute, Denmark*

Technical Session - **SRWC Operations Panel Discussion -- What's needed?** Moderator - *Bruce Hartsough, University of California, Davis CA*

Short-Rotational Woody Crops in the Industrial South - *Joe Cox, Champion International, Cantonment, FL*
Short-Rotational Woody Crops in the Industrial West - *Chuck Kaiser, Don*

APPENDICES

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Short Rotation Woody Crops Operations Working Group Conference Prologue

Presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

There is increasing interest in short rotation woody crops (SRWC), growing trees under intensive management as an agricultural crop. SRWC can provide high volumes of wood for fiber and/or energy in a relative short time period. Well managed plantations are an environmentally acceptable and potentially economically efficient method of producing wood. Such plantations can help meet the increased demand for hardwood fiber, reduce harvesting of natural forests, improve local rural economic development and ensure sustainable future wood supplies.

Even with a long history in developing genetically superior clones of woody crops and successfully developing intensive-managed plantations across the U.S. and around the world, there is still a need to increase efficiency and improve the management of these plantations. An area that would provide great benefits from substantial enhancements is the entire scope of SRWC operations. The successful commercialization of SRWC depends on a diversity of economical and environmentally- acceptable practices and machines. Since there was no formal organization addressing these needs and much interest, a grass-roots effort was initiated by several interested parties to develop a mechanism for bringing people together to improve operations in SRWC plantations. This effort is being called the **SRWC Operations Working Group** and is the group that sponsored this conference.

In a mutually beneficial and collaborative fashion, the USDA Forest Service, DOE's Oak Ridge National Laboratory (ORNL), and the Electric Power Research Institute (EPRI) established the SRWC Operations Working Group (SRWC-OWG) to consider the efficient development of practices and equipment to culture, harvest and handle large-scale woody biomass plantations. These organizers established an initial steering committee in 1995 that represented a cross-section of potential interested parties. This committee developed a proposed charter and planned this conference. At the 1996 conference, the Working Group was formally established and a SRWC-OWG Steering Committee was formed to finalize the charter and manage the general business of the Working Group. The final charter, current Steering Committee members, and business meeting information is enclosed in the Appendices. The Steering Committee members as well as specific functions of the Working Group will be re-assessed at annual meetings of the Working Group. The SRWC-OWG is opened to all interested persons and has no restrictions on membership.

The mission of the Working Group is to promote collaborative efforts in developing needed operations for SRWC plantations that comply with the principles of economic viability, ecological soundness, and social acceptance. This goal will be met primarily by improving communication and sharing of information among interested parties, and by sponsoring conference and workshops. As a working group, there will not be a formal infrastructure to provide membership services. Success of the Working Group will depend on each member and supporting organization contributing time and effort in fulfilling the group's goals.

The First Conference of the Short-Rotation Woody Crops Operations Working Group was a true success in terms of attendance, participation, support, and in terms of technical sessions and tour content. Hopefully, this precedent-setting meeting will continue into the future and become a fine tradition of offering the best and latest information concerning operating in SRWC plantations.

Many people and organizations were responsible for making this conference successful. Foremost, we must thank all of the speakers for their informative presentations and papers. We appreciate the fine job by the able moderators for the sessions. A special recognition goes to the sponsoring organizations and those who worked so hard to have a great conference, especially Lynn Wright, Bob Perlack, Kathy Ballew, and Wilma McNabb of the Oak Ridge National Laboratory, and Tim McDonald and Janice Jordan of the Southern Research Station, USDA Forest Service. We certainly appreciate the International Energy Agency, Short Rotation Forestry Activity, for supporting the printing and distribution of the proceedings, and to Netafim, CH2M-Hill, and Morbark Industries who provided funding support for the conference. Most of all, we want to express our greatest appreciation to Westvaco Corporation, especially Jim Baer, for co-sponsoring the conference and for providing a most excellent tour.

I want to personally express my appreciation to Lynn Wright, Bob Perlack, and Tim McDonald, who have shouldered the load of turning ideas into reality, and to all the members of the original and current Steering Committees for their support and efforts from the inception of the Working Group, through this conference, and beyond. Lastly, but most importantly, I want to thank each of you for your interest and support of working together to advance operations for short-rotation woody crops.

Finally, if you are not currently a member of SRWC-OWG, please see our homepage for more information. The SRWC-OWG Homepage is http://www.esd.ornl.gov/bfdp/srwcwgrp/index.html

Bryce J. Stokes, Proceedings Compiler and Chair, SWRC-OWG

International & North American Perspective: Short-Rotation Woody Crop Potential and Markets - Industrial/Fiber Perspective

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Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

Abstract

North America is well behind the Southern Hemisphere in development of short-rotation woody crops for commercial purposes. This has placed the Southern Hemisphere in a position of competitive advantage because of the low cost, reliability of supply, and uniformity of biological material represented in the short-rotation crops that have already been widely established. Because of thirty years of wide-scale development of these crops, the Southern Hemisphere has developed technological know-how that gives producers a measure of enduring advantage, likely to last for several decades.

Because of rapid expansion of North American forest products industries (pulp, paper, solid and engineered wood products) over the last half century, and because of dramatically increased pressures from the environmental community, the United States finds itself in a shortage of softwood timber in the Pacific Northwest. An emerging shortfall of commercial quantities of coniferous wood is also developing in the U.S. Southeast. On the other hand, it appears hardwood supplies are in sufficient supply in all regions to meet current volume requirements in North America.

An increasing measure of worldwide pressure on commercial wood resources is coming from another source. Many users of wood fiber-based products are requiring that their purchases contain fiber certified to have been attained from "sustainable" forest resources. There are several such initiatives in the U.S. and other countries. All are having some influence on availability of fiber supply.

These factors all increase the attractiveness of short-rotation woody crops as a potential commercial resource throughout North America. However, there are distinct biological and financial factors that limit the locations in which projects of fast-growing trees make commercial sense. Much the same as for agricultural food crops, there are geographies and climates that are suitable for development of these woody crops, and there are those that are not. Well designed trials of various

species, provenances, and hybrids are necessary to determine the commercial viability of proposed tree-growing projects. With the proper biological information in hand, an effective time-valued financial analysis will define the commercial attractiveness of a proposed project.

This paper discusses the underlying market factors, the biological requirements, the basics of commercial fast-growing tree technology, and the financial implications that must be considered in evaluating potential short-rotation woody crop plantation programs for commercial application. This applies whether the project is for traditional uses of woody crops, or for potential energy related applications.

Market Factors

Long term, the single most important factor driving utilization of the forest resources of the earth is likely to be population growth. As more people arrive on the face of the earth, their requirements for fuelwood, building materials of wood, paper products and the other materials that utilize wood as a resource to bring comfort to humans will all increase significantly. As the economies of third world nations improve and move to a condition where a substantial middle-class emerges, the amount of disposable income available will exponentially drive demand for wood-fiber-based products. According to Colin McKenzie, the chief executive of Groome Poyry Ltd. of Auckland, New Zealand, and the keynote speaker at the International Woodfiber Conference held in Atlanta in May of this year, the world is already "moving forever away from an era of plentiful and inexpensive woodfiber toward stepped-up prices and competition"1

In terms of roundwood demand, more than half the current world requirement of 3.6 billion cum is for fuelwood purposes. Industrial demand stands at 1.6 billion cum, with sawnwood at 54% of that total, and woodpulp at 28% of the primary roundwood demand. However, when primary manufacturing residues are included in global fiber utilization, at present, the woodpulp industry is estimated to be the largest single end-user of wood fiber in the world, accounting for more than 40% of the total industrial roundwood used2. Only 26.5% of the industrial supply actually ends up as sawnwood.

According to Mr. Colin McKenzie, a range of emerging discontinuities in the supply of worldwide timber are projected to continue into the 21st century3. They include:

- Withdrawal or reduction of timber cutting rights.
- Past overcutting and alternative land use impacts.
- Lack of investment to increase productivity and reforestation.
- Lack of infrastructure to cost effectively harvest and transport timber.

Mr. McKenzie suggests that even though "the theoretical cutting potential for the world's forests exceeds the projected demand for timber, the noted limitations will continue to reduce the area of forest land that is economically available for harvesting and will constrain management of timber resources that are available"3.

A further pressure on wood supply has come from the growing environmental sensitivity of the world community. Government initiatives and the actions of non-governmental groups calling for preservation of the tropical forests of the earth (which represent approximately 80% of the earth's biodiversity, while only representing 7% of the earth's land mass) have appropriately slowed the harvest of virgin wood from that resource. Preservation of old-growth virgin forests, protection of ecosystems, and species preservation have all been major issues in many areas of the world, and especially in Europe and in the Pacific Northwestern region of North America. This has led to litigation and new legislation that has taken much of public timberland out of production in the Pacific Northwest and has even restricted harvesting on large areas of privately held land. All of these factors have significantly reduced the forest cover available for commercial utilization.

International pressure from the consuming public has increased the level of recycling of paper products back into the primary paper production stream. During the next decade, recycling is projected to increase from the 20 to 30% range currently practiced to a practical maximum of about 50% of primary production. During that time, there will be short term dilution of demand for wood fiber from forest resources by the world's papermakers. Even so, at present, during the period while this increase in recycling is in full swing, the demand for industrial roundwood continues to grow at an average rate of 0.7% per year2. When recycling equilibrium is reached, the amount of fresh fiber that must be inserted into the product stream will once again increase to higher annual demand rates.

Finally, consumer pressure has increasingly strengthened the requirement that products containing wood fiber be shown by sound documentation to come from resources that can be certified to be operated in a fully sustainable manner. This means the humans associated with management and operation of these forest resources must be trained in and proven to be using sound forest sustainability practices. These requirements are being put into place in North America by agencies such as the American Forest & Paper Association (AF&PA), the Canadian Standards Association, and the Forest Stewardship Council (an international organization, headquartered in Mexico)4. Similar agencies are creating "sustainability" requirements on other continents.

With the exception of the current and short-term bulge in recycling, all of the pressures mentioned above are leading to the shift from plentiful wood fiber supply to local and regional shortfalls in an increasing number of locations. This sets the stage for increased demand for short rotation woody crops.

In the near term, there will not be major disruptions in supply and demand relationships for wood fiber. It is more likely to be a gradual change. As availability of supply shrinks, prices for roundwood and residuals will increase, drawing volumes of wood into the mix that were previously not supplied because of the low to nonexistent profit margins associated with their harvest and delivery into the demand stream. However, as timber available on the stump for harvest approaches the demand in given regions, the areas of shortfall will steadily increase.

In the Southern Hemisphere, development of both hardwood and softwood fast-growing tree crops has been in progress for more than thirty years. The result is a significant and continuing cost and supply advantage over producers in the

Northern Hemisphere. The genera most widely exploited have been various species of Eucalyptus and the tropical pines. Acacia is a lesser genera being utilized in the tropics, most especially in Indonesia. The country with the largest plantation resource is Brazil, where hardwood plantations cover 2.5 million hectares of land and softwood plantations amount to 1.5 million hectares5. Indonesia is vigorously expanding their planted forest resource, with most of the development in Acacia mangium (also known as Racosperma mangium).

In the Northern Hemisphere, the plantation of pines in the U.S. South constitutes the area with the single largest intensively managed fast-growing tree crop in the world. Over 9 million hectares of plantation pine is currently under management in the U.S. South. However, when it comes to fast-growing hardwoods, the Northern Hemisphere has barely gotten started. Portugal and Spain have planted Eucalyptus for most of this century, but the land devoted to this resource is less than 1 million hectares6. In the USA, only nominal amounts of land have yet been devoted to fast-growing hardwood plantations. Less than 40,000 hectares have been planted to hybrid Populus, and only about 5,000 hectares has been successfully planted in Eucalyptus. There were extensive trials of Eucalyptus in the U.S. South in the 1970's, but they all failed due to severe temperature depressions which killed all growing stock. These periods of low temperature inevitably occur, even if only once in a decade, and will occur again, making large scale plantation of Eucalyptus in that region infeasible.

In North America, the opportunities for fast-growing tree projects will increase as shortages of timber from traditional resources increase. From research done over the past twenty years, it is clear that hybrid Populus species will be those of most interest to commercial growers. While small scale trials have pointed the way to other species possibilities, the greatest emphasis in research and in actual commercial scale plantation development has been with Populus. This wood will be attractive in both pulp manufacture for paper products and for composite products, such as oriented strand board (OSB).

Clearly, the most attractive softwood plantations continue to be the pines in the U.S. South. As shortages increase, large companies will have increased incentive to acquire additional land base for their plantations. They will utilize the full benefit of contemporary technology and management practices to develop productive stands. This will almost certainly be an outcome, as small producers tend not to manage their timberlands in as aggressive fashion as the large companies. In northern areas, there have been limited trials of hybrid Larch that suggest potential benefit to the aggressive producer. Hybrid larch has potential to reach pulpwood maturities within 20 to 25 years, and should be pursued with well planned trials by timber producers with need for short-rotation softwood supply in more northern climates of North America. Additionally, Rhinelander, WI-based Forgene has a patented white spruce hybrid, sold under the trademark "Forgene Elite". It is projected to be ready for first pulpwood harvest in 20 to 25 years versus 35 to 40 years for conventional white spruce. At least six companies are reported to be field testing these trees7.

Keys to Fast-Growing Tree Project Success

It is clear that fast-growing trees are not a panacea that will solve all the wood resource needs of humans in the future, but they can be a much more important resource than is currently the case. This is especially true in the Northern Hemisphere for projects such as the manufacture of kraft pulp, chemithermomechanical pulp (CTMP), and panelboard products, such as OSB.

I may be "lecturing to the choir," but I feel it important to describe my view of the critical steps that must be taken to assure a successful fast-growing tree project. They are sufficiently important in my mind that I feel they bear repeating.

In order to determine what will constitute a successful project, a series of steps must be carefully taken. Most important of these is site selection. To be commercially successful, a project must be placed on a site that is properly suited to the growing potential of the species selected. Such considerations as rainfall, temperature ranges, soil conditions, land cost, and various environmental factors should be studied. Because of the rapid growth of the trees, plentiful rainfall, distributed over a substantial portion of the year is a key requirement. The species must be able to tolerate the greatest range of temperature that will occur over at least a one hundred year span. The failure of the Eucalyptus trials in the U.S. South is a tribute to that requirement. Soil fertility is necessary to feed the rapid creation of biomass. Even with good initial fertility, it is likely that fertilization of the land will be required in the first one to two years to properly launch the crop. Finally, the geography of the site and its proximity to the location at which the timber will be utilized is of considerable importance, as harvest and transportation costs can have significant bearing on the financial viability of the project.

At the same time that site selection is being considered, an interested grower should begin to think about development of scientifically designed trials to properly define the best growing stock and proper growing conditions. To manage such trials, best results are likely to be achieved by employing the services of one or two professional persons who have had experience in these developments elsewhere. For the most part, this means utilization of people who have experience in fast-growing tree projects in the Southern Hemisphere. Unfortunately, there are very few people in the Northern Hemisphere who yet fully understand the requirements of this technology.

In the trials, it will be important to examine the following:

- Various species and provenances of those species that are likely to be successful on the chosen site. This will include a range of hybrids as well as pure species. For these selections, it will be important to acquire the highest quality seed and/or seedlings available for planting.
- Soil preparation variants.
- Tree spacing trials.
- Evaluation of various fertilizer regimes.
- Evaluation of various weed control strategies. (Clean weeding may turn out to be the single most important factor in an effective project. The presence of phytotoxins in other plant material is likely to restrict the full growth potential of the chosen tree crop. Once the crown of the tree crop is closed, and photosynthesis of understory competition is eliminated, the need for additional weed control will be overcome.)

The amount of land devoted to these trials can be quite small. The important ingredient is that a full range of the above variants be incorporated in a statistically sound trial plan, and that excellent data collection be made during the years of the trials.

Closely following on the heels of any successful trial program, it is important to launch a well designed tree breeding program. It is very clear that some of the world's best fast-growing trees are hybrids that have been developed in breeding programs. Often, hybrids will perform at much better levels than the pure species from which they are derived.

For any program aimed at selecting the most desirable trees, it is important to give advance thought to the factors of greatest importance. It is appropriate to prioritize and to even give weight to these factors. They might include such things as:

- Straightness of the tree stem.
- Annual growth rate.
- Wood density.
- Disease resistance.
- Insect resistance.
- Tolerance to herbicides.
- Crown structure.
- Fiber morphology.
- Cellulose/lignin balance.
- Bark to solid wood under bark relationships.
- Ease of bark removal.
- Ease of conversion into the final end product.
- Effectiveness in optimization of the value stream associated with production of the end product.

There may very well be other factors. This list is just intended as a thought provoker.

One of the highly desirable factors in making tree selections is their ability to be clonally reproduced. This includes both the ability to produce vigorous coppice regrowth from the stump after harvest, and the readiness with which cuttings from a clonal hedge can be stimulated to produce plantable seedlings

If it is clear that the site is right and that selections have been made that will deliver an attractive return to the grower, it is time to develop a high quality nursery. Getting the growing of seedlings right can make or break a program. Selection of the growing medium, seedling containers, physical makeup of the nursery structures and supporting equipment, and methods for propagation of the seedlings can have strong bearing on the level of success in the field. Generally, one should expect that 95% survival rate in the field will be assured by choices made in the trials, in the nursery, and in the techniques used in preparing the field, planting the seedlings, and managing the crop thereafter.

If the program turns out to be successful at the beginning, the next step is to continually upgrade the growing stock. This means development of hybrids that grow at faster rates, have better and more productive utilization in downstream operations, and have better fit with the whole value chain to bring improved profitability and value to both the producer and the end use customer. Beyond traditional tree breeding activities, it may be of value to genetically alter the growing stock with gene splicing techniques. Genetically altered Populus is now being experimentally grown. It has been generated so as to be sexually sterile to prevent unwanted propagation of material that might turn out to be undesirable.

When utilizing clonal material for a plantation, it is critical that a series of clones be developed that are substantively different than one another. This is to protect against an outbreak of disease or an insect attack that would wipe out the entire growing stock. Even with tightly managed plantations, genetic diversity is necessary to assure an enduring and sustainable fiber resource.

Environmental considerations are paramount in this day and age. First, there is substantial opposition to any sort of plantation of trees by various environmentally sensitive individuals and groups. My thoughts on this issue are that new plantations should be on land already cleared, and not in place of biodiverse forests that have been harvested to make way for the plantations. Probably the least sensitive sites from a political perspective are those that would make use of former agricultural land that is no longer in food production. To generate the most environmentally acceptable projects, it may even be desirable to plant blocks of biodiverse forest species commingled with the monoculture.

Issues such as the protection of watersheds, animal habitat, and provision for recreation possibilities for humans are other matters that fall into the broad environmental category. Those organizations that choose to follow the guidelines for planted forests as established by the Forest Stewardship Council will likely have little to no trouble from the environmental community, recognizing there will always be those who will object to planted forests of any kind.

Finally, in order for a project to be successful, a high quality financial analysis should be conducted. It should show that a return better than the cost of capital will be forthcoming from the investment. The analysis should incorporate time value methodology and incorporate conservative assumptions.

Factors that must be included in such an analysis include:

- Land cost: Capital or annual rental.
- Infrastructure capital: Nursery, roads, buildings, vehicles, etc.
- Planting costs: Seedlings, weed control, site preparation, fertilizer, outplanting.
- Silviculture costs: Weed control, fertilizer, insect control, disease control, fire prevention and suppression, etc.
- Harvest cost.
- Transportation cost.
- Expected growth rates and wood densities.
- Selling price projections over time.
- Timing of capital investments.
- Headcount expectations and labor costs.
- Maintenance expenses.
- General and administrative costs.

- Species trial and tree breeding program costs.
- Interest on borrowed funds.
- Depreciation expense.

These are the most significant elements of cost and revenue streams, but are not meant to be all inclusive. From analysis of these elements, a net present value for the investment can be calculated, as well as an internal rate of return and other financial indicators of project vitality and robustness. It must be realized that the up front investment required to create this resource is much greater than traditional forestry cost. Positive cash flow is not likely to occur within the first ten years, so the project must be able to withstand a negative flow during all of that time and still show positive net present value. It is because of these considerations, that siting successful projects is a somewhat challenging process.

Recommendations

With the emerging shortfall of harvestable timber to resource the needs of all timber using populations in the U.S. it is time for the establishment of significant new short-rotation plantations. The most obvious of these should be in Pinus and Populus species. For Populus, the rather outstanding hybrids that have already been developed should be employed.

The most likely locations for new hardwood plantations are in river bottoms along the Pacific Coast, in the areas of best rainfall between the Cascade and Rocky Mountain ranges, where terrain is suitable, throughout the Northeast and North Central states, and in areas of more arid land where possibilities exist for carefully metered irrigation. In the U.S. South, cottonwoods can be propagated effectively in sandbank locations along river systems, where the trees can have their root structures under water during the spring floods, but these locations are highly limited. For hardwood species in the South, it is more likely that Sycamore, Willow, or other fast-growing indigenous species will prove effective.

Increased ownership of timberlands by large commercial organizations is likely to be needed to significantly increase the acreage of well managed pine plantations in the U.S. South. Only about one-quarter of the land in the hands of private owners is replanted and properly cared for after harvest at current levels of practice.

The other fast-growing softwood resource worth consideration is hybrid Larch. I have given my thoughts on that potential resource earlier in this paper.

With regard to the development of short-rotation woody crops for energy production, I offer the following thoughts.

1. Pulp mills with biomass boiler capabilities are likely to increase the utilization of biomass from various sources. It may well be that densely spaced short-rotation tree crops will be shown to be commercially attractive as feed sources for these operations. If so, it is likely that public utility companies will be able to justify development of such crops. A great deal will depend on what happens to the cost and availability of fossil fuels.
2. The single most available alternative energy resource for the U.S. is biomass.

Because of our growing dependence on foreign sources for our fossil fuel needs, national policy should be established to create significant biomass resource in the form of short-rotation woody crops and appropriate annual grass crops. How to bring proper attention to that cause should be the subject of other studies.

3. There is a significant environmental issue in shifting the country to more biomass resource for its fuel (either solid or liquid) and other hydrocarbon product needs. The acquisition of these resources from renewable crops will cause shift to a carbon cycle that is more in equilibrium. The carbon dioxide given off by combustion of the biomass will be the Q building block for the growing stock on the stump or in the field. In this way, less of the anciently stored carbon of fossil fuels will find its way into our atmosphere and the likelihood of problems from global warming will be attenuated.

The most likely areas for new projects are in pulp manufacturing (especially for potential new mills of CTMP), and for panel board production in products such as OSB. Bleached hardwood CTMP is proving to be an attractive low cost replacement for hardwood kraft pulps. The capital cost of a proper scale OSB plant is approximately $80 MM. The cost for a new greenfield kraft pulp mill is upwards of $1 billion.

For those who have the courage and determination to launch new fast-growing tree projects, I say start soon. Also, it is appropriate to start small, with well planned trials to prove the assumptions made in the preliminary analysis. Before starting, make sure you have a person well experienced in managing the technology leading the trial program, and a business leader with drive and entrepreneurial spirit heading the project. Once the best growing species stick their heads above the other trees, and appropriate strategies have been selected for successful future propagation, it will be possible to get a much clearer fix on the returns possible from the project. If it then is clear that attractive returns are possible, it is time to move ahead. Those who locate the sites, do the homework to create outstanding projects, and put the resource into the ground have the potential to become the low cost producers on the American scene.

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Proceedings

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Agriculture's Perspective of Short-Rotation Forestry

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From the farmer's perspective, does it make sense to get involved in short rotation forestry? Will we just get going to get knocked out of the saddle in a few years by South American competition, especially if we are operating in a part of the United States which is not terribly efficient in growing trees? I was asked to talk about the perspective of farmers on short rotation woody crops. Frankly I don't believe the farmers have a great deal of perspective right now. It is so new in terms of farming that there isn't much to look at in order to gain a perspective. However, in the past few years the value of fiber to be harvested whether it be in field or forest has increased to a level which should cause farmers to take a closer look.

There is as much variety among farming personalities and motives as is found in any other segment of our society. What we need to do is categorize the basic motivations behind farming in order to determine how this type of crop may fit in. In this exercise we can quickly recognize two distinct purposes in farming. One consists of farmers working at that profession day in and and day out as a means of putting groceries on their table. In other words, its their way of making a living. If I came home and said to my wife "Gee, I've heard there is a good return in raising trees. I'm going to put all the whole farm into trees. By the way, would you mind going to town and getting a job so we can buy groceries for the next ten years?" I think not! At this point in time we have had just one experimental project of some 2500 acres in Minnesota which provides an annual cash flow for the participants. By in large the users of fiber are not ready to provide a cash flow over a ten year period in order to support a farmer in raising trees. This will need to change if our first category of farmers is to get involved.

There is a second category of farmers which could be more aptly called investors.. This group includes a large number who farm but earn their living doing something else as well as an elite group of large successful farmers. Whatever the situation, if the returns for raising SRWC appears promising enough, some in this category can be enticed into devoting land and resources toward such an effort.

I want to share with you a strategy that may be beneficial in the future if you are going to be dealing with farmers. This is a concept every good farm machinery salesman understand and most certainly will come to play as you begin to bring farmers into SRWC.

As we look at the general bell shaped curve of all farmers, there is a small slice of the population way over on the left that we might term the innovators of the industry. They are not necessarily the most successful farmers, but they will try new concepts. These are the folks who will take that piece of land that doesn't work for much of anything and try planting trees.

A little larger group to the right on the curve is known as the early adaptors. This group represents many of the elite in American farming and they keep a close eye on the innovators. When the concept is proven they are quick to adapt. Since this group comprises the largest and most recognizably successful in farming they are eventually followed by the large numbers of farmers under the curve to their right. As a grain dryer salesman, I learned that selling a Farm Fans dryer to one of the early adaptors would earn then or twelve additional sales around the area over the following three to five years. In Minnesota the innovators have been playing with Hybrid Poplars for several years and now I am seeing some early adaptors taking up the cause on a considerably larger scale. The process seems to be evolving.

Since we are going to be dealing with farmers on the basis of investment rather than cash flow, we need to focus on the aspects of SRWC as they pertain to return on investment. Some of the terms used by forestry will need to be translated to the vocabulary of farming in order to do this effectively. To this end I struggle as I attempt to glean answers to my many questions about SRWC in an agricultural setting. One point is very clear. The cost of establishing and maintaining a SRWC can be very high and tat affects return.

A second item that is extremely important is land value. When determining land value we need to consider the various options available for use of that land. It never ceases to amaze me when a farmer continues to raise corn next to a shopping center year after year when he could sell that land and invest the money at a much higher return. Often times farmers tend to forget to evaluate all the options for their land. If irrigation is to be used, then the cost of that system needs to be added to the land value.

An important third factor that affects our return on investment is the length of time involved. I envy you folks in the western part of the country when you talk of raising a crop of Hybrid Poplars in six years while we look at ten. However, when I consider the cost of your irrigation systems and their management the return on our respective equations may equalize considerably.

When we put actual figures into our equation, we determine what return can be projected on our investment. By projecting a yield of 40 cords per acre to be sold at $50 per cord, on land costing $400 per acre, all happening over a ten year cycle at an initial establishment cost of $300 per acre, we end up with a projected return in the 13 to 15 percent range.

The risks involved are many. Can we achieve 4 cords per year growth? Will stumpage prices allow $50 per cord ten years from now? how likely is a crop failure for whatever reason several years down the line? I am a little nervous about a wind storm 7 or 8 years down the road.

My feeling is that a return in the 20 to 30 percent range may be necessary while such major questions remain unanswered. As the results of SRWC become more firmly established, the required return for getting involved will come down. It is clear for now that it will be restricted to a more marginal land proposition in Minnesota. Our formula pretty well eliminates competing with sugar beets on $1500 to $2000 land. For that matter, at current commodity prices, corn and soybeans on $800 to $1200 land look like a far better alternative also. However, there exists a large amount of marginal agricultural land in Minnesota with values of $500 and less on which SRWC may prove to provide the best alternative return on investment.

Utility's Interest in Using Wood for Power Production

Evan Hughes, Electric Power Research Institute, Palo Alto, CA

Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

[Transcribed from tape of presentation]

Abstract

Short Rotation Woody Crops are a way to capture solar energy, especially in places where water is abundant. There is much enthusiasm for using short rotation woody crops as a way to get a very high yield at low cost and have a competitive solar energy resource.

When looking at wood as a potential major source of energy, biomass energy today is mostly wood residues. Although it is an important source of energy, it can't grow to be a very major part of electricity supply. To get a major electricity supply from biomass we have to use land that would otherwise be idle farm land to specifically grow trees for energy.

The major objectives of our studies are to increase the yield in order to reduce costs, develop methods to irrigate at low cost to eliminate the dependency on a natural water supply, improve chipping operations, and drastically reduce the cost of harvesting. To reduce harvesting costs, specialized methods for crops that are uniform in size and shape should be incorporated instead of using methods utilized in natural forests.

There are possibilities for R & D to reduce costs, especially through collaboration. Since there are common interests among forest companies, collaboration is very important. In addition, it is important to prioritize and see where the biggest payoff will come.

There is also the area of collaboration or competition in the commercial arena. The price and value for pulp is so much higher than the value for fuel. With that kind of price differential it would appear that any woody crop would have a much higher likelihood of being used within the pulp industry. To cut the cost from both perspectives, a crop should be grown until its reached its most profitable potential, either for pulp or a higher value product. By moving to short rotation woody crops, this source of fuel would be much less costly.

Three important keywords to consider are residue, co-products, and co-firing. Using residues might be a basis for collaboration. With co-products, the value of one product, such as wood or pulp, subsidizes the price of fuel. Electric utilities are looking at co-firing, where a small amount of wood is burned along with coal using their existing equipment. The field price payed is very low, so there is a low incentive for growing a crop unless there is a breakthrough on the cost. Three factors that could result in a cost breakthrough would be high yield, low cost harvesting, and taking advantage of a subsidiary through a co-product or through the agriculture subsidiary that exists.

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next

Proceedings

The Role of Short-Rotation Woody Crops in Sustainable Development

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Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

Abstract

Trends in wood demand are closely correlated with population growth. While forest acreage in the United States has been essentially constant since 1930, the fraction of forest available for timber harvesting has decreased, particularly on public timberlands. National policies regarding the role of publicly-owned timberland have been changing toward ecosystem management, in which timber harvesting is an incidental consequence of management rather than an objective. Litigation, primarily concerning threatened and endangered species, has dramatically reduced planned harvests of public timber, particularly in the Pacific Northwest. The result is that total U.S. National Forest harvest volumes over the next 50 years are forecast to be half the levels of the previous several decades. National consumption of pulpwood is forecast to increase by 47% and lumber by 31% over the next 50 years. In addition, use of wood for bioenergy may increase substantially during this time period. How will these wood demands be met?

One answer is to increase wood production by increasing management intensity on existing timberland, especially in plantation forests. Another is to convert land currently in agriculture to timberland. Short- rotation woody crops can be used in both cases. But, what are the environmental consequences? Short- rotation woody crops can provide a net improvement in environmental quality at both local and global scales. Conversion of agricultural land to short-rotation woody crops can provide the most environmental quality enhancement by reducing erosion, improving soil quality, decreasing runoff, improving groundwater quality, and providing better wildlife habitat. Forest products companies can use increased production from intensively managed short-rotation woody crop systems to offset decreased yield from the portion of their timberland that is managed less intensively, e.g. streamside management zones and other ecologically sensitive or unique areas. At the global scale, use of short-rotation woody crops for bioenergy is part of the solution to reduce greenhouse gases produced by burning fossil fuels.

Incorporating short-rotation woody crops into the agricultural landscape also increases storage of carbon in the soil, thus reducing atmospheric concentrations. In addition, the use of wood instead of alternatives such as steel, concrete, and plastics generally consumes less energy and produces less greenhouse gases.

Cooperative research can be used to achieve energy, fiber, and environmental goals. This paper will highlight several examples of ongoing cooperative research projects that seek to enhance the environmental aspects of short-rotation woody crop systems. Partnerships between government, industry, and academia are conducting research to study soil quality, use of mill residuals, nutrients in runoff and groundwater, and wildlife use of short-rotation woody crop systems. Such research is vital to assure the role of short-rotation woody crops as a sustainable way of meeting society's needs.

Keywords: environment, energy crops, bioenergy, biomass crops, wildlife, breeding birds, small mammals, soil, water quality, erosion, soil quality, hydrology, carbon sequestration

Introduction

Trends in wood demand are closely correlated with population growth. Between 1950 and 1991 world population increased from 2.5 billion to 5.2 billion; meanwhile, wood consumption increased from 1.5 to 3.5 billion cubic meters (Sutton 1994). Forest area in the United States has been relatively constant since about 1920 (Powell et al. 1993). However, the fraction of forest area available for timber harvesting has decreased, particularly on public forests in recent years (Haynes et al. 1995). National policies regarding the role of publicly-owned timberland have been changing toward ecosystem management, in which timber harvesting is an incidental consequence of management rather than an objective. Litigation, primarily concerning threatened and endangered species, has dramatically reduced planned harvests of public timber, particularly in the Pacific Northwest. The result is that total U.S. National Forest harvest volumes over the next 50 years are forecast to be half the levels of the previous several decades, while national consumption of pulpwood is forecast to increase by 47% and lumber by 31% over the same period (Haynes et al. 1995). In addition, the use of wood for energy may increase substantially during this time period (Moore 1996). How will these wood demands be met?

One answer is to increase wood production by increasing management intensity on existing timberland, especially in plantation forests. Another is to convert idle or marginally productive agricultural land to timberland. Short-rotation woody crop (SRWC) systems can be used in both cases. But, what are the environmental consequences? Production of SRWCs can provide a net improvement in environmental quality at both local and global scales. Preliminary results are showing that shifting from production of row crops on marginal or erosion-prone agricultural land to SRWCs can reduce erosion, improve surface and ground water quality, provide better wildlife habitat, and reduce carbon dioxide emissions.

Erosion and Water Quality

A study to assess the environmental effects of converting conventional agricultural lands to SRWCs is ongoing at sites in Alabama, Mississippi, and Tennessee (Joslin and Schoenholtz *in press*, Thornton et al. *in review*). During the first few months of the first growing season, few differences in runoff water quality were observed between row crops and SRWCs because both still had substantial amounts of bare soil (Joslin and Schoenholtz *in press*). By the end of the first growing season, and during the following winter and spring of the second year, substantial differences in sediment lost via runoff were observed. In Mississippi, 16.2 Mg ha-1 of sediment was measured in runoff from conventionally-tilled cotton (*Gossypium hirsutum*) compared with 2.3 Mg ha-1 observed in runoff from cottonwood (*Populus deltoides*) over a 14-month period (Thornton et al. *in review*). Sediment loss from no-till corn (*Zea maize*) was three times that from sycamore (*Platinus occidentalis*) at the Tennessee site, although rates were much lower than at the Mississippi site (Thornton et al. *in review*). At the Alabama site, the sweetgum (*Liquidambar styraciflua*) SRWC treatment had greater sediment in runoff than no-till corn when a cover crop was not used in the SRWC treatment. With a fescue (*Fescue elitor*) cover crop, there were no differences between the row crop and SRWC (Thornton et al. 1996, Green et al. 1996, Tolbert and Wright *in review*). Nutrient concentrations in runoff were related to fertilizer applications and were generally higher from row crops than from SRWCs. Ground water nitrate concentrations exceeded EPA's maximum contaminant level of 10 mg l-1 nitrogen in several instances in the row crops but not in the SRWCs (Thornton et al. *in review*).

Soil Quality

Studies of small-scale planting of hybrid poplar in the north-central states have shown that over time significantly more organic matter built up under the SRWCs than under row crops or grasslands (Hansen 1993). Investigators assessing the environmental effects of converting land from row crops to SRWCs hypothesize that soil quality in different regions will be improved (Grigal and Berguson *in review*, Joslin and Schoenholtz *in press*). Improvements in soil porosity, bulk density, aggregate stability, soil organic matter, and infiltration are expected. These improvements may take several years to be detectable, however. Ongoing studies of SRWCs will identify the extent of differences in soil quality improvements over time for different soil type and regions.

An ongoing study in South Carolina is addressing the use of mill waste and residues as amendments to improve soil quality. Results to date are showing that paper mill residues provide more rapid and stable pH adjustment than agricultural residues alone (Camberato 1996, Tolbert and Schiller 1996). Field studies beginning in 1997 will verify these preliminary greenhouse results and will determine application rates that consider existing soil quality and SRWC nutrient requirements to enhance growth while minimizing the potential for soil and water quality impacts.

In the Tennessee study mentioned above, soil physical properties associated with soil quality were investigated in no-till corn, 1-year-old SRWCs, 12-year old sycamore and loblolly pine (*Pinus taeda*) plantations, and a 50-year-old forest (Bandaranayake et al. 1996). Findings generally confirmed the hypothesis of improvement in soil quality following replacement of row crops with SRWCs. Soil quality, as assessed by measurements of steady state infiltration, bulk density, and soil organic carbon, was highest in the 50-year-old forest and least in the corn crop. The 12-year-old sycamore and loblolly pine plantations had intermediate values for these soil parameters.

Carbon Storage

Use of SRWCs for bioenergy either for production of transportation fuels or for direct combustion has the obvious effect of reducing the amount of fossil fuel burned and thus reduces atmospheric CO2. Additional benefits can be gained when marginally productive or erosive agricultural cropland is replaced by SRWCs through carbon stored both in the soil (Hansen 1993) and in long-lived wood products (Marland and Marland 1992). Soil carbon may be lost in the early years of SRWC establishment due to mineralization of organic matter in the upper soil profile, but SRWCs should quickly become a net sink for carbon. Hansen (1993) found that soil carbon increased in 12- to 18-year- old hybrid poplar plantations at a rate of 1.6 Mg ha-1 y-1 more than in adjacent agricultural crops. Of course, such increases in soil carbon storage following agricultural conversions to SRWCs will not continue indefinitely. It is likely that a new equilibrium soil carbon level will be reached, with little long-term change under continued SRWC growth and harvest cycles. Grigal and Berguson (*in review*) concluded that changes in carbon storage and soil quality can be slowly changed over a one- to ten-year period by soil management. Johnson (1992) reviewed studies of soil carbon in chronosequences from abandoned agricultural land to aggrading forests. Most of the studies reviewed reported substantial net increases in soil C across a 40- to 50-year period relative to initial soil C under agricultural production.

Hydrology

Growing SRWCs on agricultural lands can change the hydrology compared with typical row crops. Sites are captured by SRWCs after one to three years and produce less runoff than row crops due to higher levels of evapotranspiration and soil cover. SRWCs quickly develop a forest floor after canopy closure that promotes rainfall interception and retention compared to row crops that are tilled at least once annually and thus have extended periods of bare soil each year. SRWCs generally have bare soil only during the first year or two following establishment and so have forest floor cover throughout most of each rotation. Transpiration rates on an equivalent leaf area level may not differ much between row crops and SRWCs, but SRWCs maintain higher leaf area throughout the year due to their perennial nature and so would be expected to transpire more on an annual basis.

A study comparing row crops with SRWCs in Alabama, Mississippi, and Tennessee observed few significant differences in the amount of runoff during the first 14 months following establishment (Thornton et al. *in review*). This is not surprising since there is little difference in canopy cover, rooting depth, and litter layers between these crop systems during the first year. Hydrologic differences should become expressed during the second and subsequent years due to differences between annual and perennial cropping.

Richardson and McCarthy (1994) used a field-scale hydrologic simulation model

(DRAINMOD) to compare hydrology among several alternate land uses in eastern North Carolina. In their simulation they separated pine plantation silviculture into an early period (1-3 years) and closed canopy period (4 years +). A 20-year simulation on a 404 ha area found that young pine plantations had 7% less runoff annually than agriculture, and older, closed canopy pine plantations had 26% less runoff than agriculture. Studies of SRWCs in the southeastern and north-central states are expected to demonstrate similar reductions in runoff as the research plots mature. The reduced runoff can also be tied to improved surface and groundwater quality as nutrients and chemicals applied for weed and pest control are retained on the SRWC sites.

Wildlife

Wildlife implications of conversion of agricultural fields to SRWCs and other energy crop systems have been discussed by Christian et al. (1994), Graham et al. (1995), Tolbert and Schiller (1996), and Tolbert and Downing (1995). Benefits include habitat for early successional species, the potential for improving habitat for interior forest species by connecting fragmented forests with SRWC plantings, and use as linear corridors for wildlife travel in predominantly agricultural landscapes (Schiller and Tolbert 1996). Additionally, forest products companies can use increased production from intensively managed SRWCs to meet their raw material needs while offsetting decreased yields from the portions of their timberland that are managed less intensively, e.g., streamside management zones, ecologically sensitive or unique areas, and other areas managed primarily for wildlife (Hughes 1992).

Christian (*in review*) used snow-tracking to study how medium-sized mammals and deer used small hybrid poplar plantations and adjacent lands in Minnesota, South Dakota, and Wisconsin during winter. Eight plantations, all 3-4 ha in size and 5-6 years old, were studied. Deer used hybrid poplar plantations for travel, but concentrated use was not observed. Medium-sized mammals such as squirrels, rabbits, and hares also rarely used the plantations. Winter use of these SRWCs was similar to adjacent open land. Christian et al. (1994) also found that small mammals using hybrid poplar plantings were more similar to grasslands and row crops than to forested areas.

Use of SRWCs in Minnesota by breeding birds was studied in 12 hybrid poplar plantings ranging in age from 1 to 8 years and in size from 4 to 30 ha. More individual birds and more species were found in these SRWCs than in croplands, but less than in nearby native forest and scrub habitats (Hanowski et al. *in press*). Bird use of these SRWCs was influenced by the structure of the plantation's vegetation, with increased use in more structurally complex habitats. Bird use in these plantations seemed also to be influenced by the plantation's landscape context. However, it is not clear how plantation size, shape, and landscape arrangements influence habitat quality for different species of breeding birds. The relatively new science of landscape ecology is only just beginning to provide land managers with information on alternatives regarding how to configure forest plantations in landscapes containing agricultural fields, roads, towns, and natural forests (Robinson et al. 1995).

The study of wildlife habitat quality in SRWCs planted for bioenergy is relatively recent. Most early bioenergy SRWCs were installed as research plots used to assess performance of different species and clones and are usually small in area (Schiller and Tolbert 1996). Knowledge about wildlife use of these plantings may not be applicable to operational-sized SRWC plantations. Wildlife use of operational-scale plantations grown for pulpwood and solid wood products has been extensively studied (NCASI 1993, Allen et al. 1996). Information on wildlife use of these plantations, at least in young ages, should be useful in assessing how wildlife will use operational-scale SRWCs.

Conclusions

Studies of how soil nutrients and physical properties change with incorporation of short-rotation woody crops into industrial and agricultural landscapes can help assess the environmental effects of these crops produced in different regions of the country. Information on environmental changes associated with conversion of erosive or marginally productive lands to intensive short-rotation tree crop management can help match tree crop species, site characteristics, and nutrient requirements to maximize productivity and both economic and environmental benefits. For forest products companies, SRWCs offer a way to offset the production losses associated with managing a portion of their timberland for non-timber objectives. Documenting how SRWCs managed for fiber and energy can simultaneously provide environmental benefits can increase the value and acceptance of these crop systems for industry, producers, environmental groups, and the general public.

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Agenda 2020 Forest Products Vision

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Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

Like Lynn said, my name is Tom Foust. I'll go over, very quickly, the Agenda 2020 program. It is a joint research program with the Department of Energy (DOE) and the forest products industry represented by the American Forest and Paper Association (AF&PA). I work in the Office of Industrial Technologies (OIT) at the DOE. OIT has three simple goals:

1. Reduce raw material and depletable energy use per unit output
2. Reduce generation of wastes and pollutants
3. Provide advanced science and technology options that dramatically increase the productivity of US industry.

First I'll give you some basic statistics about the forest products industry including pulp and paper products and wood products and statistics about the industrial sector in general. Then I will discuss the Agenda 2020 program.

The forest products industry employs 1.3 million people directly and produces products valued at $230 billion per year, including $130 billion in pulp and paper and $700 million in lumber. The employees earn on average $12/hour. The forest products industry spends about $9 billion per year on capital expenditures, $3.4 billion of which supports pollution abatement. This industry also uses about 3 quads of energy per year.

The OIT focuses on the 7 most energy and waste intensive industries in the manufacturing sector. These industries use 80% of the energy and generate 90% of the waste in the manufacturing sector. The industrial sector uses about one third of the energy consumed in the US. The forest products industry consumes about 15% of the energy in the industrial sector.

Pollution abatement costs in the industrial sector average less than 1% of sales. The forest products industry spends about twice that on pollution abatement. Energy expenditures in the industrial sector average 2% of sales. The forest products industry spends 3.5% of sales on energy, almost twice that of the industrial average. As a result, while research and development spending averages 3% of sales in the industrial sector, the forest products industry spends only 1%. Compounded with that, there has been a shift from 1988 to 1993 away from basic and applied research toward product and process specific, commercialization type research. This leaves very little spending on fundamental research to support the forest products industry. The OIT assists in supporting this area.

Now that I have given you some background information, I'll give you an overview of the Agenda 2020 program, and some examples of the research included in our first year portfolio. The model is actually very simple. First the industry writes a vision of where they would like to be some time in the future to remain globally competitive. Next the industry develops technology roadmaps which guide the industry from the present to their vision of 2020. These roadmaps then become the basis of requests for proposals.

The DOE, as mentioned by a previous speaker, encourages collaborative research. Eleven pulp and paper universities have formed an alliance to work collaboratively on research. The DOE national laboratories have signed a memorandum of understanding to work cooperatively to support the forest products industry in performing research. Fifteen national laboratories have signed the agreement.

The vision, "Agenda 2020", was written by the forest products industry in November 1994. It calls out 6 essential areas for performing strategic research: sustainable forestry, environmental performance, energy performance, improved capital effectiveness, recycling and sensors and control. The research pathways were completed in 1996 and were used to issue the call for proposals in 1996. As an example, I will show you the research pathways for the capital effectiveness area since that is the shortest. It starts with the Agenda 2020 focus area, then describes the results of continuing research, next it describes the future direction for research, then the knowledge and goals that will be delivered from that research, and finally lists the results realized in 2020.

The research pathways were developed by task groups for each of the six technology areas. These groups also evaluate, select and prioritize research and development and make recommendations to the DOE. Typically, these task groups are made up of representatives from industry, national laboratories, universities, federal government agencies, and industry groups such as the National Council for Air and Stream Improvement in the Pulp and Paper Industry (NCASI) and the Technical Association for the Pulp and Paper Industry (TAPPI). Finally the AF&PA is facilitating the process.

This is the second year the DOE has received recommendations from the task groups on research and development efforts. The task groups evaluate the proposals using six criteria: relevance to the topic identified in the request for proposals, clarity of objectives, general technical and scientific quality, probability of achieving the objectives, benefits to industry and innovation. The probability of achieving the objective and benefits to industry are scored higher than the other four criteria.

Again to review the process, each task group reviews the research pathways and develops and issues a request for preproposals or two page idea fact sheets. Preproposals are reviewed according to the six criteria. A selection of the top preproposals is made. Those selected are invited to attend a poster session to assist in the development of final five page proposals and to develop collaborations between investigators and industrial partners. Final proposals are submitted to the task groups and evaluated, again according to the six criteria and another selection is made. Based on this selection, recommendations are forwarded to the DOE where another internal programmatic and technical evaluation is performed to determine final selection and project awards based on available funding. In the environmental area for example, 177 preproposals were submitted. 35 were selected to submit 5 page proposals. 10 were recommended to the DOE for funding, and 10 received DOE funding. Approximately one third of the five page proposals are funded.

This is the second year using this process. 1996 was the first year. So far, the process has worked well. In the first year, 1996, we developed a $7 million research and development program. About $5 million was DOE funds and $2 million industry funds. The projects were recommended to DOE in March and awards were made by September. I will give you examples of the types of projects funded in 1996 in the environmental and the sustainable forestry areas. In the environmental area, 10 projects were funded. The first three projects aim to reduce the volatile organic compound (VOC) emissions from kraft mills and lumber drying. A big problem for the industry is the water discharge associated with the pulping and papermaking processes. The next couple of projects are for removing non process elements from process water to support mill closure and increased water recycling. The last few projects support the basic understanding of the fundamental chemistry of lignin and cellulose to develop more efficient pulping and pollution prevention technologies ultimately reducing the industry's environmental burden. In the sustainable forestry area, 5 projects were funded. These mostly support short rotation woody crop development and soil limitations of loblolly pine and hybrid poplars.

One of the benefits of this program is that linkages are being made between universities and the national laboratories. Consortia are being formed, like I said, the DOE national laboratories, the forest service, and the forest products laboratory all participate in this process. Other industrial groups such as NCASI and TAPPI are also involved. To give you an example of the level of interest in this program, so far in 1997, 664 preproposals have been received. DOE expects to fund about 30 of those year.

Southern Perspective: Boise Cascade's Short-Rotation Woody Crop Operations

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Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

To start, I am not sure "we know" what is working. At this time we are still in the exploratory stage, to determine if SRWC operations are viable. In the latest draft of an SRWC Co-op study, the key questions surrounded basics of production, environmental assessments and management systems. Data surrounding these three factors are linked to the following comments.

SRWC structure in the South will probably never mirror the broad plains of fiber farms on the east side of Washington and Oregon state. Fiber farms of the South will be somewhat similar to the fiber farms on the west side of the states mentioned. Even then they will not be the same due to the difference that is found in how land is valued in the South under a forestry dominant scenario.

SRWC in the SOUTH will have opportunities based upon the objectives of the individuals establishing the crop. (Appendix A) If the rotation is 10 to 20 years still shorter than traditional tree cropping, there will be fewer constraints on obtaining an acceptable biological and economical crop. Intense regimes that include fertilization and competition control will have to be followed to maximize volume gain. Quality assurance programs will have to be in place to ensure correct species deployment and proper genetic material allocation by site. There is less competition from agricultural cropping and urban expansion for long term sites that may not have the highest productivity potential.

Pesticide control is essential as well as irrigation when the rotation age is below 10 years. When these two components are part of the management regime, site location is a key factor. Many locations are not feasible for fiber farming when pesticides and irrigation are part of operations. Irrigation is even a bigger factor when we consider the many ramifications that surround using ground water from wells. Sites that will be crop rotated in 10 years or less are more economical the closer they are located to the user of the fiber. With very few well drained, large, contiguous blocks of land to choose from, SRWC farming with 10 years less rotations will be difficult to justify economically in today's market.

When one views the long term planning horizon with assumptions that reflect an increase in fiber prices, then SRWC of 10 years or less may have a greater role. The biology and processes will have to be fully developed, but that can be accomplished. In the end the economical feasibility of SRWC will determine the role SRWC serves in supplying fiber in the woodbaskets of the future.

APPENDIX A

1. ESTABLISHMENT & ACREAGE

- Most SRWC farms are being established on land that was farmed within the last ten years.
- Most SRWC farm land is well drained and has an acceptable nutrient base.
- Most SRWC farms are small in acreage with most under 100 and few greater than 500 acres.

2. PLANTING STOCK & IRRIGATION

- Most SRWC farms are planted with the best genetic material available.
- Most SRWC farms have irrigation, with drip or micro-irrigation being the most common.
- Lakes, rivers and canals are the primary sources for irrigation, and wells are utilized in some areas.

3. SPECIES

- To date, SRWC farming in the South is more successful for hardwoods than pines.
- The cottonwood is the preferred species, sycamore and sweetgum are frequently used species.
- Numerous other hardwood species are being tried with limited success in growth rates.

4. SPECIES & CROPPING AGE

- Most SRWC rotations range from six to twelve years depending on species, site and cultural
- treatments.
- Conifers are in the mix for SRWC but have limited success at the present.

5. SOILS, NUTRIENTS, & HERBICIDES

- SRWC establishment at this time start with the best soil available.
- Most soils are prepared like farming crops - disking, pre-nutrient screening with nutrients added
- as needed.
- Application of herbicide treatment with follow-up as needed.

6. PESTICIDES & AFTERCARE

- Most SRWC have added insecticide treatments as needed especially with hardwoods and

- especially cottonwood.
- Pesticide treatment for disease is being applied as needed for many species.
- Aftercare (i.e., pruning) is being addressed more than ever within the SRWC concept.

7. WHAT HAS TO BE DETERMINED

- Will SRWC be environmentally acceptable?
- Will SRWC be politically acceptable?
- Currently, all SRWC farms in the South are regulated, taxed, etc. according to forestry industry
- guidelines.
- Harvesting methods for various products.
- Species & clonal for product lines.

Short Rotation Woody Crops Operations Working Group Conference Prologue

Presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

There is increasing interest in short rotation woody crops (SRWC), growing trees under intensive management as an agricultural crop. SRWC can provide high volumes of wood for fiber and/or energy in a relative short time period. Well managed plantations are an environmentally acceptable and potentially economically efficient method of producing wood. Such plantations can help meet the increased demand for hardwood fiber, reduce harvesting of natural forests, improve local rural economic development and ensure sustainable future wood supplies.

Even with a long history in developing genetically superior clones of woody crops and successfully developing intensive-managed plantations across the U.S. and around the world, there is still a need to increase efficiency and improve the management of these plantations. An area that would provide great benefits from substantial enhancements is the entire scope of SRWC operations. The successful commercialization of SRWC depends on a diversity of economical and environmentally- acceptable practices and machines. Since there was no formal organization addressing these needs and much interest, a grass-roots effort was initiated by several interested parties to develop a mechanism for bringing people together to improve operations in SRWC plantations. This effort is being called the **SRWC Operations Working Group** and is the group that sponsored this conference.

In a mutually beneficial and collaborative fashion, the USDA Forest Service, DOE's Oak Ridge National Laboratory (ORNL), and the Electric Power Research Institute (EPRI) established the SRWC Operations Working Group (SRWC-OWG) to consider the efficient development of practices and equipment to culture, harvest and handle large-scale woody biomass plantations. These organizers established an initial steering committee in 1995 that represented a cross-section of potential interested parties. This committee developed a proposed charter and planned this conference. At the 1996 conference, the Working Group was formally established and a SRWC-OWG Steering Committee was formed to finalize the charter and manage the general business of the Working Group. The final charter, current Steering Committee members, and business meeting information is enclosed in the Appendices. The Steering Committee members as well as specific functions of the Working Group will be re-assessed at annual meetings of the Working Group. The SRWC-OWG is opened to all interested persons and has no restrictions on membership.

The mission of the Working Group is to promote collaborative efforts in developing needed operations for SRWC plantations that comply with the principles of economic viability, ecological soundness, and social acceptance. This goal will be met primarily by improving communication and sharing of information among interested parties, and by sponsoring conference and workshops. As a working group, there will not be a formal infrastructure to provide membership services. Success of the Working Group will depend on each member and supporting organization contributing time and effort in fulfilling the group's goals.

The First Conference of the Short-Rotation Woody Crops Operations Working Group was a true success in terms of attendance, participation, support, and in terms of technical sessions and tour content. Hopefully, this precedent-setting meeting will continue into the future and become a fine tradition of offering the best and latest information concerning operating in SRWC plantations.

Many people and organizations were responsible for making this conference successful. Foremost, we must thank all of the speakers for their informative presentations and papers. We appreciate the fine job by the able moderators for the sessions. A special recognition goes to the sponsoring organizations and those who worked so hard to have a great conference, especially Lynn Wright, Bob Perlack, Kathy Ballew, and Wilma McNabb of the Oak Ridge National Laboratory, and Tim McDonald and Janice Jordan of the Southern Research Station, USDA Forest Service. We certainly appreciate the International Energy Agency, Short Rotation Forestry Activity, for supporting the printing and distribution of the proceedings, and to Netafim, CH2M-Hill, and Morbark Industries who provided funding support for the conference. Most of all, we want to express our greatest appreciation to Westvaco Corporation, especially Jim Baer, for co-sponsoring the conference and for providing a most excellent tour.

I want to personally express my appreciation to Lynn Wright, Bob Perlack, and Tim McDonald, who have shouldered the load of turning ideas into reality, and to all the members of the original and current Steering Committees for their support and efforts from the inception of the Working Group, through this conference, and beyond. Lastly, but most importantly, I want to thank each of you for your interest and support of working together to advance operations for short-rotation woody crops.

Finally, if you are not currently a member of SRWC-OWG, please see our homepage for more information. The SRWC-OWG Homepage is http://www.esd.ornl.gov/bfdp/srwcwgrp/index.html

Bryce J. Stokes, Proceedings Compiler and Chair, SWRC-OWG

International & North American Perspective: Short-Rotation Woody Crop Potential and Markets - Industrial/Fiber Perspective

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Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

Abstract

North America is well behind the Southern Hemisphere in development of short-rotation woody crops for commercial purposes. This has placed the Southern Hemisphere in a position of competitive advantage because of the low cost, reliability of supply, and uniformity of biological material represented in the short-rotation crops that have already been widely established. Because of thirty years of wide-scale development of these crops, the Southern Hemisphere has developed technological know-how that gives producers a measure of enduring advantage, likely to last for several decades.

Because of rapid expansion of North American forest products industries (pulp, paper, solid and engineered wood products) over the last half century, and because of dramatically increased pressures from the environmental community, the United States finds itself in a shortage of softwood timber in the Pacific Northwest. An emerging shortfall of commercial quantities of coniferous wood is also developing in the U.S. Southeast. On the other hand, it appears hardwood supplies are in sufficient supply in all regions to meet current volume requirements in North America.

An increasing measure of worldwide pressure on commercial wood resources is coming from another source. Many users of wood fiber-based products are requiring that their purchases contain fiber certified to have been attained from "sustainable" forest resources. There are several such initiatives in the U.S. and other countries. All are having some influence on availability of fiber supply.

These factors all increase the attractiveness of short-rotation woody crops as a potential commercial resource throughout North America. However, there are distinct biological and financial factors that limit the locations in which projects of fast-growing trees make commercial sense. Much the same as for agricultural food crops, there are geographies and climates that are suitable for development of these woody crops, and there are those that are not. Well designed trials of various

species, provenances, and hybrids are necessary to determine the commercial viability of proposed tree-growing projects. With the proper biological information in hand, an effective time-valued financial analysis will define the commercial attractiveness of a proposed project.

This paper discusses the underlying market factors, the biological requirements, the basics of commercial fast-growing tree technology, and the financial implications that must be considered in evaluating potential short-rotation woody crop plantation programs for commercial application. This applies whether the project is for traditional uses of woody crops, or for potential energy related applications.

Market Factors

Long term, the single most important factor driving utilization of the forest resources of the earth is likely to be population growth. As more people arrive on the face of the earth, their requirements for fuelwood, building materials of wood, paper products and the other materials that utilize wood as a resource to bring comfort to humans will all increase significantly. As the economies of third world nations improve and move to a condition where a substantial middle-class emerges, the amount of disposable income available will exponentially drive demand for wood-fiber-based products. According to Colin McKenzie, the chief executive of Groome Poyry Ltd. of Auckland, New Zealand, and the keynote speaker at the International Woodfiber Conference held in Atlanta in May of this year, the world is already "moving forever away from an era of plentiful and inexpensive woodfiber toward stepped-up prices and competition"1

In terms of roundwood demand, more than half the current world requirement of 3.6 billion cum is for fuelwood purposes. Industrial demand stands at 1.6 billion cum, with sawnwood at 54% of that total, and woodpulp at 28% of the primary roundwood demand. However, when primary manufacturing residues are included in global fiber utilization, at present, the woodpulp industry is estimated to be the largest single end-user of wood fiber in the world, accounting for more than 40% of the total industrial roundwood used2. Only 26.5% of the industrial supply actually ends up as sawnwood.

According to Mr. Colin McKenzie, a range of emerging discontinuities in the supply of worldwide timber are projected to continue into the 21st century3. They include:

- Withdrawal or reduction of timber cutting rights.
- Past overcutting and alternative land use impacts.
- Lack of investment to increase productivity and reforestation.
- Lack of infrastructure to cost effectively harvest and transport timber.

Mr. McKenzie suggests that even though "the theoretical cutting potential for the world's forests exceeds the projected demand for timber, the noted limitations will continue to reduce the area of forest land that is economically available for harvesting and will constrain management of timber resources that are available"3.

A further pressure on wood supply has come from the growing environmental sensitivity of the world community. Government initiatives and the actions of non-governmental groups calling for preservation of the tropical forests of the earth (which represent approximately 80% of the earth's biodiversity, while only representing 7% of the earth's land mass) have appropriately slowed the harvest of virgin wood from that resource. Preservation of old-growth virgin forests, protection of ecosystems, and species preservation have all been major issues in many areas of the world, and especially in Europe and in the Pacific Northwestern region of North America. This has led to litigation and new legislation that has taken much of public timberland out of production in the Pacific Northwest and has even restricted harvesting on large areas of privately held land. All of these factors have significantly reduced the forest cover available for commercial utilization.

International pressure from the consuming public has increased the level of recycling of paper products back into the primary paper production stream. During the next decade, recycling is projected to increase from the 20 to 30% range currently practiced to a practical maximum of about 50% of primary production. During that time, there will be short term dilution of demand for wood fiber from forest resources by the world's papermakers. Even so, at present, during the period while this increase in recycling is in full swing, the demand for industrial roundwood continues to grow at an average rate of 0.7% per year2. When recycling equilibrium is reached, the amount of fresh fiber that must be inserted into the product stream will once again increase to higher annual demand rates.

Finally, consumer pressure has increasingly strengthened the requirement that products containing wood fiber be shown by sound documentation to come from resources that can be certified to be operated in a fully sustainable manner. This means the humans associated with management and operation of these forest resources must be trained in and proven to be using sound forest sustainability practices. These requirements are being put into place in North America by agencies such as the American Forest & Paper Association (AF&PA), the Canadian Standards Association, and the Forest Stewardship Council (an international organization, headquartered in Mexico)4. Similar agencies are creating "sustainability" requirements on other continents.

With the exception of the current and short-term bulge in recycling, all of the pressures mentioned above are leading to the shift from plentiful wood fiber supply to local and regional shortfalls in an increasing number of locations. This sets the stage for increased demand for short rotation woody crops.

In the near term, there will not be major disruptions in supply and demand relationships for wood fiber. It is more likely to be a gradual change. As availability of supply shrinks, prices for roundwood and residuals will increase, drawing volumes of wood into the mix that were previously not supplied because of the low to nonexistent profit margins associated with their harvest and delivery into the demand stream. However, as timber available on the stump for harvest approaches the demand in given regions, the areas of shortfall will steadily increase.

In the Southern Hemisphere, development of both hardwood and softwood fast-growing tree crops has been in progress for more than thirty years. The result is a significant and continuing cost and supply advantage over producers in the

Northern Hemisphere. The genera most widely exploited have been various species of Eucalyptus and the tropical pines. Acacia is a lesser genera being utilized in the tropics, most especially in Indonesia. The country with the largest plantation resource is Brazil, where hardwood plantations cover 2.5 million hectares of land and softwood plantations amount to 1.5 million hectares5. Indonesia is vigorously expanding their planted forest resource, with most of the development in Acacia mangium (also known as Racosperma mangium).

In the Northern Hemisphere, the plantation of pines in the U.S. South constitutes the area with the single largest intensively managed fast-growing tree crop in the world. Over 9 million hectares of plantation pine is currently under management in the U.S. South. However, when it comes to fast-growing hardwoods, the Northern Hemisphere has barely gotten started. Portugal and Spain have planted Eucalyptus for most of this century, but the land devoted to this resource is less than 1 million hectares6. In the USA, only nominal amounts of land have yet been devoted to fast-growing hardwood plantations. Less than 40,000 hectares have been planted to hybrid Populus, and only about 5,000 hectares has been successfully planted in Eucalyptus. There were extensive trials of Eucalyptus in the U.S. South in the 1970's, but they all failed due to severe temperature depressions which killed all growing stock. These periods of low temperature inevitably occur, even if only once in a decade, and will occur again, making large scale plantation of Eucalyptus in that region infeasible.

In North America, the opportunities for fast-growing tree projects will increase as shortages of timber from traditional resources increase. From research done over the past twenty years, it is clear that hybrid Populus species will be those of most interest to commercial growers. While small scale trials have pointed the way to other species possibilities, the greatest emphasis in research and in actual commercial scale plantation development has been with Populus. This wood will be attractive in both pulp manufacture for paper products and for composite products, such as oriented strand board (OSB).

Clearly, the most attractive softwood plantations continue to be the pines in the U.S. South. As shortages increase, large companies will have increased incentive to acquire additional land base for their plantations. They will utilize the full benefit of contemporary technology and management practices to develop productive stands. This will almost certainly be an outcome, as small producers tend not to manage their timberlands in as aggressive fashion as the large companies. In northern areas, there have been limited trials of hybrid Larch that suggest potential benefit to the aggressive producer. Hybrid larch has potential to reach pulpwood maturities within 20 to 25 years, and should be pursued with well planned trials by timber producers with need for short-rotation softwood supply in more northern climates of North America. Additionally, Rhinelander, WI-based Forgene has a patented white spruce hybrid, sold under the trademark "Forgene Elite". It is projected to be ready for first pulpwood harvest in 20 to 25 years versus 35 to 40 years for conventional white spruce. At least six companies are reported to be field testing these trees7.

Keys to Fast-Growing Tree Project Success

It is clear that fast-growing trees are not a panacea that will solve all the wood resource needs of humans in the future, but they can be a much more important resource than is currently the case. This is especially true in the Northern Hemisphere for projects such as the manufacture of kraft pulp, chemithermomechanical pulp (CTMP), and panelboard products, such as OSB.

I may be "lecturing to the choir," but I feel it important to describe my view of the critical steps that must be taken to assure a successful fast-growing tree project. They are sufficiently important in my mind that I feel they bear repeating.

In order to determine what will constitute a successful project, a series of steps must be carefully taken. Most important of these is site selection. To be commercially successful, a project must be placed on a site that is properly suited to the growing potential of the species selected. Such considerations as rainfall, temperature ranges, soil conditions, land cost, and various environmental factors should be studied. Because of the rapid growth of the trees, plentiful rainfall, distributed over a substantial portion of the year is a key requirement. The species must be able to tolerate the greatest range of temperature that will occur over at least a one hundred year span. The failure of the Eucalyptus trials in the U.S. South is a tribute to that requirement. Soil fertility is necessary to feed the rapid creation of biomass. Even with good initial fertility, it is likely that fertilization of the land will be required in the first one to two years to properly launch the crop. Finally, the geography of the site and its proximity to the location at which the timber will be utilized is of considerable importance, as harvest and transportation costs can have significant bearing on the financial viability of the project.

At the same time that site selection is being considered, an interested grower should begin to think about development of scientifically designed trials to properly define the best growing stock and proper growing conditions. To manage such trials, best results are likely to be achieved by employing the services of one or two professional persons who have had experience in these developments elsewhere. For the most part, this means utilization of people who have experience in fast-growing tree projects in the Southern Hemisphere. Unfortunately, there are very few people in the Northern Hemisphere who yet fully understand the requirements of this technology.

In the trials, it will be important to examine the following:

- Various species and provenances of those species that are likely to be successful on the chosen site. This will include a range of hybrids as well as pure species. For these selections, it will be important to acquire the highest quality seed and/or seedlings available for planting.
- Soil preparation variants.
- Tree spacing trials.
- Evaluation of various fertilizer regimes.
- Evaluation of various weed control strategies. (Clean weeding may turn out to be the single most important factor in an effective project. The presence of phytotoxins in other plant material is likely to restrict the full growth potential of the chosen tree crop. Once the crown of the tree crop is closed, and photosynthesis of understory competition is eliminated, the need for additional weed control will be overcome.)

The amount of land devoted to these trials can be quite small. The important ingredient is that a full range of the above variants be incorporated in a statistically sound trial plan, and that excellent data collection be made during the years of the trials.

Closely following on the heels of any successful trial program, it is important to launch a well designed tree breeding program. It is very clear that some of the world's best fast-growing trees are hybrids that have been developed in breeding programs. Often, hybrids will perform at much better levels than the pure species from which they are derived.

For any program aimed at selecting the most desirable trees, it is important to give advance thought to the factors of greatest importance. It is appropriate to prioritize and to even give weight to these factors. They might include such things as:

- Straightness of the tree stem.
- Annual growth rate.
- Wood density.
- Disease resistance.
- Insect resistance.
- Tolerance to herbicides.
- Crown structure.
- Fiber morphology.
- Cellulose/lignin balance.
- Bark to solid wood under bark relationships.
- Ease of bark removal.
- Ease of conversion into the final end product.
- Effectiveness in optimization of the value stream associated with production of the end product.

There may very well be other factors. This list is just intended as a thought provoker.

One of the highly desirable factors in making tree selections is their ability to be clonally reproduced. This includes both the ability to produce vigorous coppice regrowth from the stump after harvest, and the readiness with which cuttings from a clonal hedge can be stimulated to produce plantable seedlings

If it is clear that the site is right and that selections have been made that will deliver an attractive return to the grower, it is time to develop a high quality nursery. Getting the growing of seedlings right can make or break a program. Selection of the growing medium, seedling containers, physical makeup of the nursery structures and supporting equipment, and methods for propagation of the seedlings can have strong bearing on the level of success in the field. Generally, one should expect that 95% survival rate in the field will be assured by choices made in the trials, in the nursery, and in the techniques used in preparing the field, planting the seedlings, and managing the crop thereafter.

If the program turns out to be successful at the beginning, the next step is to continually upgrade the growing stock. This means development of hybrids that grow at faster rates, have better and more productive utilization in downstream operations, and have better fit with the whole value chain to bring improved profitability and value to both the producer and the end use customer. Beyond traditional tree breeding activities, it may be of value to genetically alter the growing stock with gene splicing techniques. Genetically altered Populus is now being experimentally grown. It has been generated so as to be sexually sterile to prevent unwanted propagation of material that might turn out to be undesirable.

When utilizing clonal material for a plantation, it is critical that a series of clones be developed that are substantively different than one another. This is to protect against an outbreak of disease or an insect attack that would wipe out the entire growing stock. Even with tightly managed plantations, genetic diversity is necessary to assure an enduring and sustainable fiber resource.

Environmental considerations are paramount in this day and age. First, there is substantial opposition to any sort of plantation of trees by various environmentally sensitive individuals and groups. My thoughts on this issue are that new plantations should be on land already cleared, and not in place of biodiverse forests that have been harvested to make way for the plantations. Probably the least sensitive sites from a political perspective are those that would make use of former agricultural land that is no longer in food production. To generate the most environmentally acceptable projects, it may even be desirable to plant blocks of biodiverse forest species commingled with the monoculture.

Issues such as the protection of watersheds, animal habitat, and provision for recreation possibilities for humans are other matters that fall into the broad environmental category. Those organizations that choose to follow the guidelines for planted forests as established by the Forest Stewardship Council will likely have little to no trouble from the environmental community, recognizing there will always be those who will object to planted forests of any kind.

Finally, in order for a project to be successful, a high quality financial analysis should be conducted. It should show that a return better than the cost of capital will be forthcoming from the investment. The analysis should incorporate time value methodology and incorporate conservative assumptions.

Factors that must be included in such an analysis include:

- Land cost: Capital or annual rental.
- Infrastructure capital: Nursery, roads, buildings, vehicles, etc.
- Planting costs: Seedlings, weed control, site preparation, fertilizer, outplanting.
- Silviculture costs: Weed control, fertilizer, insect control, disease control, fire prevention and suppression, etc.
- Harvest cost.
- Transportation cost.
- Expected growth rates and wood densities.
- Selling price projections over time.
- Timing of capital investments.
- Headcount expectations and labor costs.
- Maintenance expenses.
- General and administrative costs.

- Species trial and tree breeding program costs.
- Interest on borrowed funds.
- Depreciation expense.

These are the most significant elements of cost and revenue streams, but are not meant to be all inclusive. From analysis of these elements, a net present value for the investment can be calculated, as well as an internal rate of return and other financial indicators of project vitality and robustness. It must be realized that the up front investment required to create this resource is much greater than traditional forestry cost. Positive cash flow is not likely to occur within the first ten years, so the project must be able to withstand a negative flow during all of that time and still show positive net present value. It is because of these considerations, that siting successful projects is a somewhat challenging process.

Recommendations

With the emerging shortfall of harvestable timber to resource the needs of all timber using populations in the U.S. it is time for the establishment of significant new short-rotation plantations. The most obvious of these should be in Pinus and Populus species. For Populus, the rather outstanding hybrids that have already been developed should be employed.

The most likely locations for new hardwood plantations are in river bottoms along the Pacific Coast, in the areas of best rainfall between the Cascade and Rocky Mountain ranges, where terrain is suitable, throughout the Northeast and North Central states, and in areas of more arid land where possibilities exist for carefully metered irrigation. In the U.S. South, cottonwoods can be propagated effectively in sandbank locations along river systems, where the trees can have their root structures under water during the spring floods, but these locations are highly limited. For hardwood species in the South, it is more likely that Sycamore, Willow, or other fast-growing indigenous species will prove effective.

Increased ownership of timberlands by large commercial organizations is likely to be needed to significantly increase the acreage of well managed pine plantations in the U.S. South. Only about one-quarter of the land in the hands of private owners is replanted and properly cared for after harvest at current levels of practice.

The other fast-growing softwood resource worth consideration is hybrid Larch. I have given my thoughts on that potential resource earlier in this paper.

With regard to the development of short-rotation woody crops for energy production, I offer the following thoughts.

1. Pulp mills with biomass boiler capabilities are likely to increase the utilization of biomass from various sources. It may well be that densely spaced short-rotation tree crops will be shown to be commercially attractive as feed sources for these operations. If so, it is likely that public utility companies will be able to justify development of such crops. A great deal will depend on what happens to the cost and availability of fossil fuels.
2. The single most available alternative energy resource for the U.S. is biomass.

Because of our growing dependence on foreign sources for our fossil fuel needs, national policy should be established to create significant biomass resource in the form of short-rotation woody crops and appropriate annual grass crops. How to bring proper attention to that cause should be the subject of other studies.

3. There is a significant environmental issue in shifting the country to more biomass resource for its fuel (either solid or liquid) and other hydrocarbon product needs. The acquisition of these resources from renewable crops will cause shift to a carbon cycle that is more in equilibrium. The carbon dioxide given off by combustion of the biomass will be the Q building block for the growing stock on the stump or in the field. In this way, less of the anciently stored carbon of fossil fuels will find its way into our atmosphere and the likelihood of problems from global warming will be attenuated.

The most likely areas for new projects are in pulp manufacturing (especially for potential new mills of CTMP), and for panel board production in products such as OSB. Bleached hardwood CTMP is proving to be an attractive low cost replacement for hardwood kraft pulps. The capital cost of a proper scale OSB plant is approximately $80 MM. The cost for a new greenfield kraft pulp mill is upwards of $1 billion.

For those who have the courage and determination to launch new fast-growing tree projects, I say start soon. Also, it is appropriate to start small, with well planned trials to prove the assumptions made in the preliminary analysis. Before starting, make sure you have a person well experienced in managing the technology leading the trial program, and a business leader with drive and entrepreneurial spirit heading the project. Once the best growing species stick their heads above the other trees, and appropriate strategies have been selected for successful future propagation, it will be possible to get a much clearer fix on the returns possible from the project. If it then is clear that attractive returns are possible, it is time to move ahead. Those who locate the sites, do the homework to create outstanding projects, and put the resource into the ground have the potential to become the low cost producers on the American scene.

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Proceedings

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Agriculture's Perspective of Short-Rotation Forestry

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From the farmer's perspective, does it make sense to get involved in short rotation forestry? Will we just get going to get knocked out of the saddle in a few years by South American competition, especially if we are operating in a part of the United States which is not terribly efficient in growing trees? I was asked to talk about the perspective of farmers on short rotation woody crops. Frankly I don't believe the farmers have a great deal of perspective right now. It is so new in terms of farming that there isn't much to look at in order to gain a perspective. However, in the past few years the value of fiber to be harvested whether it be in field or forest has increased to a level which should cause farmers to take a closer look.

There is as much variety among farming personalities and motives as is found in any other segment of our society. What we need to do is categorize the basic motivations behind farming in order to determine how this type of crop may fit in. In this exercise we can quickly recognize two distinct purposes in farming. One consists of farmers working at that profession day in and and day out as a means of putting groceries on their table. In other words, its their way of making a living. If I came home and said to my wife "Gee, I've heard there is a good return in raising trees. I'm going to put all the whole farm into trees. By the way, would you mind going to town and getting a job so we can buy groceries for the next ten years?" I think not! At this point in time we have had just one experimental project of some 2500 acres in Minnesota which provides an annual cash flow for the participants. By in large the users of fiber are not ready to provide a cash flow over a ten year period in order to support a farmer in raising trees. This will need to change if our first category of farmers is to get involved.

There is a second category of farmers which could be more aptly called investors.. This group includes a large number who farm but earn their living doing something else as well as an elite group of large successful farmers. Whatever the situation, if the returns for raising SRWC appears promising enough, some in this category can be enticed into devoting land and resources toward such an effort.

I want to share with you a strategy that may be beneficial in the future if you are going to be dealing with farmers. This is a concept every good farm machinery salesman understand and most certainly will come to play as you begin to bring farmers into SRWC.

As we look at the general bell shaped curve of all farmers, there is a small slice of the population way over on the left that we might term the innovators of the industry. They are not necessarily the most successful farmers, but they will try new concepts. These are the folks who will take that piece of land that doesn't work for much of anything and try planting trees.

A little larger group to the right on the curve is known as the early adaptors. This group represents many of the elite in American farming and they keep a close eye on the innovators. When the concept is proven they are quick to adapt. Since this group comprises the largest and most recognizably successful in farming they are eventually followed by the large numbers of farmers under the curve to their right. As a grain dryer salesman, I learned that selling a Farm Fans dryer to one of the early adaptors would earn then or twelve additional sales around the area over the following three to five years. In Minnesota the innovators have been playing with Hybrid Poplars for several years and now I am seeing some early adaptors taking up the cause on a considerably larger scale. The process seems to be evolving.

Since we are going to be dealing with farmers on the basis of investment rather than cash flow, we need to focus on the aspects of SRWC as they pertain to return on investment. Some of the terms used by forestry will need to be translated to the vocabulary of farming in order to do this effectively. To this end I struggle as I attempt to glean answers to my many questions about SRWC in an agricultural setting. One point is very clear. The cost of establishing and maintaining a SRWC can be very high and tat affects return.

A second item that is extremely important is land value. When determining land value we need to consider the various options available for use of that land. It never ceases to amaze me when a farmer continues to raise corn next to a shopping center year after year when he could sell that land and invest the money at a much higher return. Often times farmers tend to forget to evaluate all the options for their land. If irrigation is to be used, then the cost of that system needs to be added to the land value.

An important third factor that affects our return on investment is the length of time involved. I envy you folks in the western part of the country when you talk of raising a crop of Hybrid Poplars in six years while we look at ten. However, when I consider the cost of your irrigation systems and their management the return on our respective equations may equalize considerably.

When we put actual figures into our equation, we determine what return can be projected on our investment. By projecting a yield of 40 cords per acre to be sold at $50 per cord, on land costing $400 per acre, all happening over a ten year cycle at an initial establishment cost of $300 per acre, we end up with a projected return in the 13 to 15 percent range.

The risks involved are many. Can we achieve 4 cords per year growth? Will stumpage prices allow $50 per cord ten years from now? how likely is a crop failure for whatever reason several years down the line? I am a little nervous about a wind storm 7 or 8 years down the road.

My feeling is that a return in the 20 to 30 percent range may be necessary while such major questions remain unanswered. As the results of SRWC become more firmly established, the required return for getting involved will come down. It is clear for now that it will be restricted to a more marginal land proposition in Minnesota. Our formula pretty well eliminates competing with sugar beets on $1500 to $2000 land. For that matter, at current commodity prices, corn and soybeans on $800 to $1200 land look like a far better alternative also. However, there exists a large amount of marginal agricultural land in Minnesota with values of $500 and less on which SRWC may prove to provide the best alternative return on investment.

Proceedings

Utility's Interest in Using Wood for Power Production

Evan Hughes, Electric Power Research Institute, Palo Alto, CA

Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

[Transcribed from tape of presentation]

Abstract

Short Rotation Woody Crops are a way to capture solar energy, especially in places where water is abundant. There is much enthusiasm for using short rotation woody crops as a way to get a very high yield at low cost and have a competitive solar energy resource.

When looking at wood as a potential major source of energy, biomass energy today is mostly wood residues. Although it is an important source of energy, it can't grow to be a very major part of electricity supply. To get a major electricity supply from biomass we have to use land that would otherwise be idle farm land to specifically grow trees for energy.

The major objectives of our studies are to increase the yield in order to reduce costs, develop methods to irrigate at low cost to eliminate the dependency on a natural water supply, improve chipping operations, and drastically reduce the cost of harvesting. To reduce harvesting costs, specialized methods for crops that are uniform in size and shape should be incorporated instead of using methods utilized in natural forests.

There are possibilities for R & D to reduce costs, especially through collaboration. Since there are common interests among forest companies, collaboration is very important. In addition, it is important to prioritize and see where the biggest payoff will come.

There is also the area of collaboration or competition in the commercial arena. The price and value for pulp is so much higher than the value for fuel. With that kind of price differential it would appear that any woody crop would have a much higher likelihood of being used within the pulp industry. To cut the cost from both perspectives, a crop should be grown until its reached its most profitable potential, either for pulp or a higher value product. By moving to short rotation woody crops, this source of fuel would be much less costly.

Three important keywords to consider are residue, co-products, and co-firing. Using residues might be a basis for collaboration. With co-products, the value of one product, such as wood or pulp, subsidizes the price of fuel. Electric utilities are looking at co-firing, where a small amount of wood is burned along with coal using their existing equipment. The field price payed is very low, so there is a low incentive for growing a crop unless there is a breakthrough on the cost. Three factors that could result in a cost breakthrough would be high yield, low cost harvesting, and taking advantage of a subsidiary through a co-product or through the agriculture subsidiary that exists.

File posted on March 17, 1998; Date Modified: February 21, 1999

next

TABLE OF CONTENTS

Proceedings

The Role of Short-Rotation Woody Crops in Sustainable Development

Jim Shepard, National Council of the Paper Industry for Air and Stream Improvement, Gainesville, FL

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Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

Abstract

Trends in wood demand are closely correlated with population growth. While forest acreage in the United States has been essentially constant since 1930, the fraction of forest available for timber harvesting has decreased, particularly on public timberlands. National policies regarding the role of publicly-owned timberland have been changing toward ecosystem management, in which timber harvesting is an incidental consequence of management rather than an objective. Litigation, primarily concerning threatened and endangered species, has dramatically reduced planned harvests of public timber, particularly in the Pacific Northwest. The result is that total U.S. National Forest harvest volumes over the next 50 years are forecast to be half the levels of the previous several decades. National consumption of pulpwood is forecast to increase by 47% and lumber by 31% over the next 50 years. In addition, use of wood for bioenergy may increase substantially during this time period. How will these wood demands be met?

One answer is to increase wood production by increasing management intensity on existing timberland, especially in plantation forests. Another is to convert land currently in agriculture to timberland. Short- rotation woody crops can be used in both cases. But, what are the environmental consequences? Short- rotation woody crops can provide a net improvement in environmental quality at both local and global scales. Conversion of agricultural land to short-rotation woody crops can provide the most environmental quality enhancement by reducing erosion, improving soil quality, decreasing runoff, improving groundwater quality, and providing better wildlife habitat. Forest products companies can use increased production from intensively managed short-rotation woody crop systems to offset decreased yield from the portion of their timberland that is managed less intensively, e.g. streamside management zones and other ecologically sensitive or unique areas. At the global scale, use of short-rotation woody crops for bioenergy is part of the solution to reduce greenhouse gases produced by burning fossil fuels.

Incorporating short-rotation woody crops into the agricultural landscape also increases storage of carbon in the soil, thus reducing atmospheric concentrations. In addition, the use of wood instead of alternatives such as steel, concrete, and plastics generally consumes less energy and produces less greenhouse gases.

Cooperative research can be used to achieve energy, fiber, and environmental goals. This paper will highlight several examples of ongoing cooperative research projects that seek to enhance the environmental aspects of short-rotation woody crop systems. Partnerships between government, industry, and academia are conducting research to study soil quality, use of mill residuals, nutrients in runoff and groundwater, and wildlife use of short-rotation woody crop systems. Such research is vital to assure the role of short-rotation woody crops as a sustainable way of meeting society's needs.

Keywords: environment, energy crops, bioenergy, biomass crops, wildlife, breeding birds, small mammals, soil, water quality, erosion, soil quality, hydrology, carbon sequestration

Introduction

Trends in wood demand are closely correlated with population growth. Between 1950 and 1991 world population increased from 2.5 billion to 5.2 billion; meanwhile, wood consumption increased from 1.5 to 3.5 billion cubic meters (Sutton 1994). Forest area in the United States has been relatively constant since about 1920 (Powell et al. 1993). However, the fraction of forest area available for timber harvesting has decreased, particularly on public forests in recent years (Haynes et al. 1995). National policies regarding the role of publicly-owned timberland have been changing toward ecosystem management, in which timber harvesting is an incidental consequence of management rather than an objective. Litigation, primarily concerning threatened and endangered species, has dramatically reduced planned harvests of public timber, particularly in the Pacific Northwest. The result is that total U.S. National Forest harvest volumes over the next 50 years are forecast to be half the levels of the previous several decades, while national consumption of pulpwood is forecast to increase by 47% and lumber by 31% over the same period (Haynes et al. 1995). In addition, the use of wood for energy may increase substantially during this time period (Moore 1996). How will these wood demands be met?

One answer is to increase wood production by increasing management intensity on existing timberland, especially in plantation forests. Another is to convert idle or marginally productive agricultural land to timberland. Short-rotation woody crop (SRWC) systems can be used in both cases. But, what are the environmental consequences? Production of SRWCs can provide a net improvement in environmental quality at both local and global scales. Preliminary results are showing that shifting from production of row crops on marginal or erosion-prone agricultural land to SRWCs can reduce erosion, improve surface and ground water quality, provide better wildlife habitat, and reduce carbon dioxide emissions.

Erosion and Water Quality

A study to assess the environmental effects of converting conventional agricultural lands to SRWCs is ongoing at sites in Alabama, Mississippi, and Tennessee (Joslin and Schoenholtz *in press*, Thornton et al. *in review*). During the first few months of the first growing season, few differences in runoff water quality were observed between row crops and SRWCs because both still had substantial amounts of bare soil (Joslin and Schoenholtz *in press*). By the end of the first growing season, and during the following winter and spring of the second year, substantial differences in sediment lost via runoff were observed. In Mississippi, 16.2 Mg ha-1 of sediment was measured in runoff from conventionally-tilled cotton (*Gossypium hirsutum*) compared with 2.3 Mg ha-1 observed in runoff from cottonwood (*Populus deltoides*) over a 14-month period (Thornton et al. *in review*). Sediment loss from no-till corn (*Zea maize*) was three times that from sycamore (*Platinus occidentalis*) at the Tennessee site, although rates were much lower than at the Mississippi site (Thornton et al. *in review*). At the Alabama site, the sweetgum (*Liquidambar styraciflua*) SRWC treatment had greater sediment in runoff than no-till corn when a cover crop was not used in the SRWC treatment. With a fescue (*Fescue elitor*) cover crop, there were no differences between the row crop and SRWC (Thornton et al. 1996, Green et al. 1996, Tolbert and Wright *in review*). Nutrient concentrations in runoff were related to fertilizer applications and were generally higher from row crops than from SRWCs. Ground water nitrate concentrations exceeded EPA's maximum contaminant level of 10 mg l-1 nitrogen in several instances in the row crops but not in the SRWCs (Thornton et al. *in review*).

Soil Quality

Studies of small-scale planting of hybrid poplar in the north-central states have shown that over time significantly more organic matter built up under the SRWCs than under row crops or grasslands (Hansen 1993). Investigators assessing the environmental effects of converting land from row crops to SRWCs hypothesize that soil quality in different regions will be improved (Grigal and Berguson *in review*, Joslin and Schoenholtz *in press*). Improvements in soil porosity, bulk density, aggregate stability, soil organic matter, and infiltration are expected. These improvements may take several years to be detectable, however. Ongoing studies of SRWCs will identify the extent of differences in soil quality improvements over time for different soil type and regions.

An ongoing study in South Carolina is addressing the use of mill waste and residues as amendments to improve soil quality. Results to date are showing that paper mill residues provide more rapid and stable pH adjustment than agricultural residues alone (Camberato 1996, Tolbert and Schiller 1996). Field studies beginning in 1997 will verify these preliminary greenhouse results and will determine application rates that consider existing soil quality and SRWC nutrient requirements to enhance growth while minimizing the potential for soil and water quality impacts.

In the Tennessee study mentioned above, soil physical properties associated with soil quality were investigated in no-till corn, 1-year-old SRWCs, 12-year old sycamore and loblolly pine (*Pinus taeda*) plantations, and a 50-year-old forest (Bandaranayake et al. 1996). Findings generally confirmed the hypothesis of improvement in soil quality following replacement of row crops with SRWCs. Soil quality, as assessed by measurements of steady state infiltration, bulk density, and soil organic carbon, was highest in the 50-year-old forest and least in the corn crop. The 12-year-old sycamore and loblolly pine plantations had intermediate values for these soil parameters.

Carbon Storage

Use of SRWCs for bioenergy either for production of transportation fuels or for direct combustion has the obvious effect of reducing the amount of fossil fuel burned and thus reduces atmospheric CO2. Additional benefits can be gained when marginally productive or erosive agricultural cropland is replaced by SRWCs through carbon stored both in the soil (Hansen 1993) and in long-lived wood products (Marland and Marland 1992). Soil carbon may be lost in the early years of SRWC establishment due to mineralization of organic matter in the upper soil profile, but SRWCs should quickly become a net sink for carbon. Hansen (1993) found that soil carbon increased in 12- to 18-year- old hybrid poplar plantations at a rate of 1.6 Mg ha-1 y-1 more than in adjacent agricultural crops. Of course, such increases in soil carbon storage following agricultural conversions to SRWCs will not continue indefinitely. It is likely that a new equilibrium soil carbon level will be reached, with little long-term change under continued SRWC growth and harvest cycles. Grigal and Berguson (*in review*) concluded that changes in carbon storage and soil quality can be slowly changed over a one- to ten-year period by soil management. Johnson (1992) reviewed studies of soil carbon in chronosequences from abandoned agricultural land to aggrading forests. Most of the studies reviewed reported substantial net increases in soil C across a 40- to 50-year period relative to initial soil C under agricultural production.

Hydrology

Growing SRWCs on agricultural lands can change the hydrology compared with typical row crops. Sites are captured by SRWCs after one to three years and produce less runoff than row crops due to higher levels of evapotranspiration and soil cover. SRWCs quickly develop a forest floor after canopy closure that promotes rainfall interception and retention compared to row crops that are tilled at least once annually and thus have extended periods of bare soil each year. SRWCs generally have bare soil only during the first year or two following establishment and so have forest floor cover throughout most of each rotation. Transpiration rates on an equivalent leaf area level may not differ much between row crops and SRWCs, but SRWCs maintain higher leaf area throughout the year due to their perennial nature and so would be expected to transpire more on an annual basis.

A study comparing row crops with SRWCs in Alabama, Mississippi, and Tennessee observed few significant differences in the amount of runoff during the first 14 months following establishment (Thornton et al. *in review*). This is not surprising since there is little difference in canopy cover, rooting depth, and litter layers between these crop systems during the first year. Hydrologic differences should become expressed during the second and subsequent years due to differences between annual and perennial cropping.

Richardson and McCarthy (1994) used a field-scale hydrologic simulation model

(DRAINMOD) to compare hydrology among several alternate land uses in eastern North Carolina. In their simulation they separated pine plantation silviculture into an early period (1-3 years) and closed canopy period (4 years +). A 20-year simulation on a 404 ha area found that young pine plantations had 7% less runoff annually than agriculture, and older, closed canopy pine plantations had 26% less runoff than agriculture. Studies of SRWCs in the southeastern and north-central states are expected to demonstrate similar reductions in runoff as the research plots mature. The reduced runoff can also be tied to improved surface and groundwater quality as nutrients and chemicals applied for weed and pest control are retained on the SRWC sites.

Wildlife

Wildlife implications of conversion of agricultural fields to SRWCs and other energy crop systems have been discussed by Christian et al. (1994), Graham et al. (1995), Tolbert and Schiller (1996), and Tolbert and Downing (1995). Benefits include habitat for early successional species, the potential for improving habitat for interior forest species by connecting fragmented forests with SRWC plantings, and use as linear corridors for wildlife travel in predominantly agricultural landscapes (Schiller and Tolbert 1996). Additionally, forest products companies can use increased production from intensively managed SRWCs to meet their raw material needs while offsetting decreased yields from the portions of their timberland that are managed less intensively, e.g., streamside management zones, ecologically sensitive or unique areas, and other areas managed primarily for wildlife (Hughes 1992).

Christian (*in review*) used snow-tracking to study how medium-sized mammals and deer used small hybrid poplar plantations and adjacent lands in Minnesota, South Dakota, and Wisconsin during winter. Eight plantations, all 3-4 ha in size and 5-6 years old, were studied. Deer used hybrid poplar plantations for travel, but concentrated use was not observed. Medium-sized mammals such as squirrels, rabbits, and hares also rarely used the plantations. Winter use of these SRWCs was similar to adjacent open land. Christian et al. (1994) also found that small mammals using hybrid poplar plantings were more similar to grasslands and row crops than to forested areas.

Use of SRWCs in Minnesota by breeding birds was studied in 12 hybrid poplar plantings ranging in age from 1 to 8 years and in size from 4 to 30 ha. More individual birds and more species were found in these SRWCs than in croplands, but less than in nearby native forest and scrub habitats (Hanowski et al. *in press*). Bird use of these SRWCs was influenced by the structure of the plantation's vegetation, with increased use in more structurally complex habitats. Bird use in these plantations seemed also to be influenced by the plantation's landscape context. However, it is not clear how plantation size, shape, and landscape arrangements influence habitat quality for different species of breeding birds. The relatively new science of landscape ecology is only just beginning to provide land managers with information on alternatives regarding how to configure forest plantations in landscapes containing agricultural fields, roads, towns, and natural forests (Robinson et al. 1995).

The study of wildlife habitat quality in SRWCs planted for bioenergy is relatively recent. Most early bioenergy SRWCs were installed as research plots used to assess performance of different species and clones and are usually small in area (Schiller and Tolbert 1996). Knowledge about wildlife use of these plantings may not be applicable to operational-sized SRWC plantations. Wildlife use of operational-scale plantations grown for pulpwood and solid wood products has been extensively studied (NCASI 1993, Allen et al. 1996). Information on wildlife use of these plantations, at least in young ages, should be useful in assessing how wildlife will use operational-scale SRWCs.

Conclusions

Studies of how soil nutrients and physical properties change with incorporation of short-rotation woody crops into industrial and agricultural landscapes can help assess the environmental effects of these crops produced in different regions of the country. Information on environmental changes associated with conversion of erosive or marginally productive lands to intensive short-rotation tree crop management can help match tree crop species, site characteristics, and nutrient requirements to maximize productivity and both economic and environmental benefits. For forest products companies, SRWCs offer a way to offset the production losses associated with managing a portion of their timberland for non-timber objectives. Documenting how SRWCs managed for fiber and energy can simultaneously provide environmental benefits can increase the value and acceptance of these crop systems for industry, producers, environmental groups, and the general public.

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Woody Crops
TABLE OF CONTENTS
Proceedings

next

Agenda 2020 Forest Products Vision

Tom Foust, Department of Energy, Office of Industrial Technologies, Washington, DC

Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

Like Lynn said, my name is Tom Foust. I'll go over, very quickly, the Agenda 2020 program. It is a joint research program with the Department of Energy (DOE) and the forest products industry represented by the American Forest and Paper Association (AF&PA). I work in the Office of Industrial Technologies (OIT) at the DOE. OIT has three simple goals:

1. Reduce raw material and depletable energy use per unit output
2. Reduce generation of wastes and pollutants
3. Provide advanced science and technology options that dramatically increase the productivity of US industry.

First I'll give you some basic statistics about the forest products industry including pulp and paper products and wood products and statistics about the industrial sector in general. Then I will discuss the Agenda 2020 program.

The forest products industry employs 1.3 million people directly and produces products valued at $230 billion per year, including $130 billion in pulp and paper and $700 million in lumber. The employees earn on average $12/hour. The forest products industry spends about $9 billion per year on capital expenditures, $3.4 billion of which supports pollution abatement. This industry also uses about 3 quads of energy per year.

The OIT focuses on the 7 most energy and waste intensive industries in the manufacturing sector. These industries use 80% of the energy and generate 90% of the waste in the manufacturing sector. The industrial sector uses about one third of the energy consumed in the US. The forest products industry consumes about 15% of the energy in the industrial sector.

Pollution abatement costs in the industrial sector average less than 1% of sales. The forest products industry spends about twice that on pollution abatement. Energy expenditures in the industrial sector average 2% of sales. The forest products industry spends 3.5% of sales on energy, almost twice that of the industrial average. As a result, while research and development spending averages 3% of sales in the industrial sector, the forest products industry spends only 1%. Compounded with that, there has been a shift from 1988 to 1993 away from basic and applied research toward product and process specific, commercialization type research. This leaves very little spending on fundamental research to support the forest products industry. The OIT assists in supporting this area.

Now that I have given you some background information, I'll give you an overview of the Agenda 2020 program, and some examples of the research included in our first year portfolio. The model is actually very simple. First the industry writes a vision of where they would like to be some time in the future to remain globally competitive. Next the industry develops technology roadmaps which guide the industry from the present to their vision of 2020. These roadmaps then become the basis of requests for proposals.

The DOE, as mentioned by a previous speaker, encourages collaborative research. Eleven pulp and paper universities have formed an alliance to work collaboratively on research. The DOE national laboratories have signed a memorandum of understanding to work cooperatively to support the forest products industry in performing research. Fifteen national laboratories have signed the agreement.

The vision, "Agenda 2020", was written by the forest products industry in November 1994. It calls out 6 essential areas for performing strategic research: sustainable forestry, environmental performance, energy performance, improved capital effectiveness, recycling and sensors and control. The research pathways were completed in 1996 and were used to issue the call for proposals in 1996. As an example, I will show you the research pathways for the capital effectiveness area since that is the shortest. It starts with the Agenda 2020 focus area, then describes the results of continuing research, next it describes the future direction for research, then the knowledge and goals that will be delivered from that research, and finally lists the results realized in 2020.

The research pathways were developed by task groups for each of the six technology areas. These groups also evaluate, select and prioritize research and development and make recommendations to the DOE. Typically, these task groups are made up of representatives from industry, national laboratories, universities, federal government agencies, and industry groups such as the National Council for Air and Stream Improvement in the Pulp and Paper Industry (NCASI) and the Technical Association for the Pulp and Paper Industry (TAPPI). Finally the AF&PA is facilitating the process.

This is the second year the DOE has received recommendations from the task groups on research and development efforts. The task groups evaluate the proposals using six criteria: relevance to the topic identified in the request for proposals, clarity of objectives, general technical and scientific quality, probability of achieving the objectives, benefits to industry and innovation. The probability of achieving the objective and benefits to industry are scored higher than the other four criteria.

Again to review the process, each task group reviews the research pathways and develops and issues a request for preproposals or two page idea fact sheets. Preproposals are reviewed according to the six criteria. A selection of the top preproposals is made. Those selected are invited to attend a poster session to assist in the development of final five page proposals and to develop collaborations between investigators and industrial partners. Final proposals are submitted to the task groups and evaluated, again according to the six criteria and another selection is made. Based on this selection, recommendations are forwarded to the DOE where another internal programmatic and technical evaluation is performed to determine final selection and project awards based on available funding. In the environmental area for example, 177 preproposals were submitted. 35 were selected to submit 5 page proposals. 10 were recommended to the DOE for funding, and 10 received DOE funding. Approximately one third of the five page proposals are funded.

This is the second year using this process. 1996 was the first year. So far, the process has worked well. In the first year, 1996, we developed a $7 million research and development program. About $5 million was DOE funds and $2 million industry funds. The projects were recommended to DOE in March and awards were made by September. I will give you examples of the types of projects funded in 1996 in the environmental and the sustainable forestry areas. In the environmental area, 10 projects were funded. The first three projects aim to reduce the volatile organic compound (VOC) emissions from kraft mills and lumber drying. A big problem for the industry is the water discharge associated with the pulping and papermaking processes. The next couple of projects are for removing non process elements from process water to support mill closure and increased water recycling. The last few projects support the basic understanding of the fundamental chemistry of lignin and cellulose to develop more efficient pulping and pollution prevention technologies ultimately reducing the industry's environmental burden. In the sustainable forestry area, 5 projects were funded. These mostly support short rotation woody crop development and soil limitations of loblolly pine and hybrid poplars.

One of the benefits of this program is that linkages are being made between universities and the national laboratories. Consortia are being formed, like I said, the DOE national laboratories, the forest service, and the forest products laboratory all participate in this process. Other industrial groups such as NCASI and TAPPI are also involved. To give you an example of the level of interest in this program, so far in 1997, 664 preproposals have been received. DOE expects to fund about 30 of those this year.

Southern Perspective: Boise Cascade's Short-Rotation Woody Crop Operations

Steve Coleman, Boise Cascade, DeRidder, LA

Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

To start, I am not sure "we know" what is working. At this time we are still in the exploratory stage, to determine if SRWC operations are viable. In the latest draft of an SRWC Co-op study, the key questions surrounded basics of production, environmental assessments and management systems. Data surrounding these three factors are linked to the following comments.

SRWC structure in the South will probably never mirror the broad plains of fiber farms on the east side of Washington and Oregon state. Fiber farms of the South will be somewhat similar to the fiber farms on the west side of the states mentioned. Even then they will not be the same due to the difference that is found in how land is valued in the South under a forestry dominant scenario.

SRWC in the SOUTH will have opportunities based upon the objectives of the individuals establishing the crop. (Appendix A) If the rotation is 10 to 20 years still shorter than traditional tree cropping, there will be fewer constraints on obtaining an acceptable biological and economical crop. Intense regimes that include fertilization and competition control will have to be followed to maximize volume gain. Quality assurance programs will have to be in place to ensure correct species deployment and proper genetic material allocation by site. There is less competition from agricultural cropping and urban expansion for long term sites that may not have the highest productivity potential.

Pesticide control is essential as well as irrigation when the rotation age is below 10 years. When these two components are part of the management regime, site location is a key factor. Many locations are not feasible for fiber farming when pesticides and irrigation are part of operations. Irrigation is even a bigger factor when we consider the many ramifications that surround using ground water from wells. Sites that will be crop rotated in 10 years or less are more economical the closer they are located to the user of the fiber. With very few well drained, large, contiguous blocks of land to choose from, SRWC farming with 10 years less rotations will be difficult to justify economically in today's market.

When one views the long term planning horizon with assumptions that reflect an increase in fiber prices, then SRWC of 10 years or less may have a greater role. The biology and processes will have to be fully developed, but that can be accomplished. In the end the economical feasibility of SRWC will determine the role SRWC serves in supplying fiber in the woodbaskets of the future.

APPENDIX A

1. ESTABLISHMENT & ACREAGE

- Most SRWC farms are being established on land that was farmed within the last ten years.
- Most SRWC farm land is well drained and has an acceptable nutrient base.
- Most SRWC farms are small in acreage with most under 100 and few greater than 500 acres.

2. PLANTING STOCK & IRRIGATION

- Most SRWC farms are planted with the best genetic material available.
- Most SRWC farms have irrigation, with drip or micro-irrigation being the most common.
- Lakes, rivers and canals are the primary sources for irrigation, and wells are utilized in some areas.

3. SPECIES

- To date, SRWC farming in the South is more successful for hardwoods than pines.
- The cottonwood is the preferred species, sycamore and sweetgum are frequently used species.
- Numerous other hardwood species are being tried with limited success in growth rates.

4. SPECIES & CROPPING AGE

- Most SRWC rotations range from six to twelve years depending on species, site and cultural
- treatments.
- Conifers are in the mix for SRWC but have limited success at the present.

5. SOILS, NUTRIENTS, & HERBICIDES

- SRWC establishment at this time start with the best soil available.
- Most soils are prepared like farming crops - disking, pre-nutrient screening with nutrients added
- as needed.
- Application of herbicide treatment with follow-up as needed.

6. PESTICIDES & AFTERCARE

- Most SRWC have added insecticide treatments as needed especially with hardwoods and

- especially cottonwood.
- Pesticide treatment for disease is being applied as needed for many species.
- Aftercare (i.e., pruning) is being addressed more than ever within the SRWC concept.

7. WHAT HAS TO BE DETERMINED

- Will SRWC be environmentally acceptable?
- Will SRWC be politically acceptable?
- Currently, all SRWC farms in the South are regulated, taxed, etc. according to forestry industry
- guidelines.
- Harvesting methods for various products.
- Species & clonal for product lines.

Central/Southern Perspective - Westvaco's Short-Rotation Operations

Gail Simonds, Westvaco-Timberlands, Wickliffe, KY

Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

Management of shorter-rotation hardwood plantations in the Central region consists of a six-part program. The intensity level of the management program varies with economic investment and potential productivity. The spectrum ranges from fertigated fiber farms to a variety of upland plantations. Regardless of intensity, the following components must be included, land classification, planting stock, competition control, soil amendments, disease and insect control, and monitoring and evaluation.

Land classification is the cornerstone for management shorter-rotation hardwood plantations. Answering the basic question, of what species to plant on what site, requires the synthesis of information from a variety of sources. Land classification maps are derived from NRCS and USGS maps and Landsat and DEM imagery. Field soil mappers verify and modify map information. Site indexes, both present and historical are included in productivity estimates. These land classification maps are used in the establishment of new plantations.

There are two areas of importance in selecting planting stock. First, the best genetics available must be used. Cottonwood, sycamore and sweetgum have established genetic bases from which superior stock is being selected. Hybrid aspens are currently under study in the Central region. Selections of yellow- poplar are currently based on phenotype and planting stock availability. The second concern is the quality of planting stock. Requirements such as minimum basal diameters, seedling height, top pruning and handling procedures, must be communicated to nursery owners. Higher premiums have been found to encourage production of stock with a greater potential for survival.

Competition control is an integral part of plantation survival and initial growth. Research in loblolly pine has shown that growth rates were greater in years one through three with chemical control of hardwood competition. That difference in growth increment was maintained throughout stand development. Chemical control in hardwood stands is hindered by the susceptibility of chosen species to herbicides. Until biotechnology can provide trees that are resist to the herbicides of choice and can pass societal scrutiny, chemical control is being accomplished by a variety of pre- and post-emerge treatments in conjunction with mechanical site preparation. In the Central region, chemical control is usually an intensive management tool rarely used beyond the third year of stand development.

Soil amendments come in three types, water, fertilizers and biological agents. In the Central Region, water is reserved for the high-end technology of fertigated fiber farming. However, that does not preclude the occasional, emergency application on newly planted stock. Fertilizer applications include lime, macro- and micro-nutrients. Amounts, timing and delivery systems are designed for each species and site combination. Biological agents include rooting hormones, nitrogen-fixing bacteria and mycorrhizal fungi.

Disease and insect control includes both biological and chemical treatments. A wide variety of agents are available for treatment of disease and insect problems. Efficacy, economics and societal pressures are considered in choosing agents. A effective control program requires a thorough scouting program. Proper monitoring and evaluation of tree health will determine if and when controls are necessary and how effective those controls are.

Monitoring and evaluation are the most important parts of managing shorter-rotation plantations. Height and diameter data are being collected and comparisons between actual and predicted growth evaluated. Growth data coupled with soil and foliar analyses determine if amendments are effective. Additionally, water sampling is being done for determinations of nutrient leaching in susceptible plantations. Competition control is being monitored and evaluated for efficacy and changes in competitive populations. Effectiveness of controls are evaluated on the basis of tree growth. Disease and insect controls are evaluated by the same criteria.

This management program outlines the main points in developing successful shorter-rotation hardwood plantations. It also includes the unmentioned need for commitment by all involved parties. Off-site plantations, poor survival and less than desirable growth, seedlings overtopped by vines, ill-timed fertilizer applications, and losses due to insects and disease can be avoided if each part of the program is maintained at the highest levels possible.

Western Perspective: Boise Cascades Short Rotation Operations in Washington and Oregon

Steve Pottle, Boise Cascade, Wallula, WA

Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

Abstract

There are approximately 50,000 acres (20,000 hectares) being actively managed for Short Rotation Woody Crops in California, Oregon, Washington and British Columbia. These crops are primarily of Populus and Eucalyptus species grown for pulp and paper production.

Boise Cascade began developing its Fiber Farm in the Columbia Basin in Washington and Oregon in 1991. It currently manages 17,000 acres (7,000 hectares) in cottonwood plantations ranging from 1 to 6 years of age.

These plantations are established on large blocks of irrigated farmland. Planting stock consists of dormant cuttings grown in contract stool beds. The primary challenges to plantation establishment and development are weed and pest control and irrigation system maintenance. The farm block design coupled with integrated MIS/GIS and accounting systems allows for detailed tracking and reporting of inventories, costs, and farm conditions.

Harvesting operations will begin in the months ahead and will utilize conventional logging equipment and in-field debarking and chipping. Replanting will closely follow the harvest, making effective stump and residue disposal a necessity.

Boise Cascade's Cottonwood Fiber Farm will supply clean pulp chips, hog fuel, and fiber for corrugated medium to company owned paper mills in Wallula, Washington and St. Helens, Oregon.

Introduction

In the past decade there has been a considerable reduction in the amount of available timber in the Western United States and Canada. This loss of timber is well recognized and is related to environmental and political issues that have reduced harvests on both public and private lands.

While there has been a reduction in the amount of raw material available for forest products manufacturing, the demand for these products has remained strong. Many manufacturing facilities in the Pacific Northwest have been forced to close because of the reduction in fiber supply (at least 240 mills have closed since 1989, primarily solid wood facilities). This fiber shortage however, has also prompted the exploration of alternative sources of raw material. One of these alternative sources has been Short Rotation Intensive Culture of Woody Crops.

There are currently at least ten companies in California, Oregon, Washington and British Columbia that are either conducting Short Rotation operations or are planning to do so. Some of these efforts began in the early 1980s, so short rotation forestry is well established in the Pacific Northwest. There are now a total of 50,000 acres (20,000 hectares) in Short Rotation plantations in this region. The primary crops are hybrid cottonwood and Eucalyptus grown for paper production although there is interest in energy and specialty products use as well.

Presentation

Boise Cascade began developing its Fiber Farm in an area known as the Columbia Basin in Southeastern Washington and Eastern Oregon in 1991. The Columbia Basin is an area along the Columbia River bordered on the West by the Cascade Mountains and on the East by the Blue Mountains. It is in the rain shadow of the Cascades and thus has an arid climate that is uncharacteristic of the Pacific Northwest.

The area receives only 8 to 12 inches (20 to 30 cm) of precipitation a year, less than half of which falls as rain during the growing season. While the natural vegetation consists of sage brush and steppe grass, the sandy, alkaline soils and 200 day per year growing seasons combine to create very good growing conditions when water is made available.

As a result of the development of elaborate irrigation systems beginning in the 1950s the Columbia Basin has become one of the premiere agricultural areas in the United States. Locally grown crops include wheat, alfalfa, a variety of vegetables, fruit, and now cottonwood trees.

Boise Cascade has approximately 17,000 acres (7,000 hectares) in cottonwood plantations. These plantations have been developed on established farms with existing irrigation systems.

Site Preparation and Planting

The steps involved in establishing a cottonwood plantation on an active farm include conversion of the irrigation system to drip irrigation, site preparation and planting. This process begins months before the trees are actually put into the ground.

Planting stock consists of dormant cuttings of hybrid clones from three different species of cottonwood. These include Populus trichocarpa, P. deltoides, and P. nigra. The trees on Boise Cascade’s farm are planted by hand because they need to be adjacent to an emitter on the drip irrigation lines. A mechanical planter cannot sense where the water is and deposit a tree in the right spot.

Fertilizer Applications

Boise Cascade's objective in fertilization is to maintain nutrient conditions that correspond to optimum cottonwood growth. Nutrient levels are measured through soil tests and foliage samples. Foliage sampling is the preferred method once the plantations are established because it gives an indication of the amount of the various nutrients that the trees are actually able to utilize and overcomes some of the micro-site variation that is inherent with irrigation.

Over the past six growing seasons, Boise Cascade has developed a standard recipe for fertilizer that meets most of the annual needs of cottonwood trees growing in the Columbia Basin. This recipe consists of a mix of nitrogen, phosphorus and zinc and is applied to the fields through the irrigation system over the course of the growing season.

Because of the sensitivity of the irrigation system to sediment, there are filter stations set up on each irrigation block. Fertilizer tanks are connected to the irrigation system at these filter stations. The fertilizer, in liquid form, is pumped into the main-lines that lead to the farm blocks. There it is mixed with the irrigation water and dispersed to the trees.

Phosphorus and zinc are fairly stable in the soil and are applied early in the growing season. Nitrogen on the other hand tends to leach and is thus applied at slower rates over several months.

The plantations are continually monitored for such problems as nutrient deficiency. If a condition does arise, it is addressed as soon as possible. Intermittent fertilizer treatments, over and above the standard recipe, are usually applied with aerial equipment. When additional fertilizer is needed it is generally in an isolated area rather than over an entire irrigation block. Therefore it is more effective to carry out spot treatments from the air than to apply extra fertilizer through the irrigation system.

Pest Management

Weeds

Pest management including weed management is a critical consideration in the production of short rotation woody crops. When excellent conditions for growing trees are created, those same conditions benefit other plants as well.

There are three primary reasons for weed control when growing cottonwood on a short rotation in an arid climate:

1. Cottonwood trees are very intolerant to shade and sensitive to competition. Until they grow beyond the reach of the various weeds, control is necessary for optimal development. Cottonwood trees also may have an allelopathic

reaction to some weeds, in particular Canadian thistle and cocklebur.

2. The irrigation lines must be regularly maintained. For the farm workers to monitor the condition of the lines and to find and correct problems excess vegetation must be controlled.
3. Grasses and other weeds provide cover for rodents and other animals that can damage the trees or the irrigation lines.

Boise Cascade's weed control program extends from before the trees are planted until the canopy closes between the rows. This usually takes two growing seasons. Methods of weed control consist of mechanical, chemical, and a combination of the two.

Before the trees are planted a combination of mechanical and chemical control is used. Trifluralin is rotovated (rototilled) into the soil. After the trees are established, but before they have developed extensive root systems, weeds are controlled mechanically by tilling or mowing between the rows. Prior to leaf out in the second growing season, any early emerging weeds can be controlled with broadcast spray. After leaf out, a hooded sprayer is used. The hood prevents the herbicide from coming into contact with the sensitive trees.

We have tried using a wicking device to apply herbicide but have had marginal results. For this method to be successful, the weeds must be at least 12 inches (30 cm) tall. Plants that are shorter than this may not be exposed to enough herbicide.

Insects

There are several insects that pose a continual challenge to Boise Cascade's short rotation program. There are leaf beetles, moths, caterpillars, leaf rollers, grasshoppers, and stem borers. Although we have used systemic insecticides applied through the irrigation system, our primary control has been with aerial application. Aerial application has the advantage of being fast and effective, and it can used in isolated patches rather than over an entire irrigation block.

Animal Damage

There have been continual problems with several different animals. Deer browse on the youngest trees and can cause multiple tops and reduced growth. Where they have been a particular problem, hunting is allowed to control their numbers. Because of the intensity of the farming activities however, and the poor visibility in the younger trees, the extent of this hunting is extremely limited.

Mice and voles girdle the trees at the ground line, usually in the winter with a snow cover. This problem is generally associated with a buildup of grass and weeds and is best controlled through a good weed control program. Poison baits can be used as well.

Gophers eat tender tree roots and chew on irrigation lines. Gopher populations are directly related to the crop that was growing on the field before the trees were planted. Alfalfa, for instance is one of their favorites. They are controlled with poison baits.

Coyotes chew on irrigation equipment and beaver and porcupines chew on the trees. They each need to removed from the farm when their populations become too high.

Harvesting

Boise Cascade will begin harvesting its Cottonwood plantations early in 1997 producing three products: clean paper chips, hog fuel and low grade chips for corrugated cardboard. Harvesting will take place on a year-round basis according to mill needs.

Felling and bunching will be carried out with small and efficient wheeled harvesters and forwarding will be done with grapple skidders. With the soil types in the Columbia Basin and Boise Cascade's farming practices, soil compaction is not a concern.

Delimbing, debarking, and chipping will be carried out in the field. The trees will be forwarded directly to the chipper minimizing field storage and handling. This will require that felling and skidding operations be balanced with debarking and chipping.

Transportation of the chips will be carried out in trucks for the Wallula Mill and a combination of trucks and barges for the St. Helens Mill. St. Helens is some 200 miles from our farm but on the Columbia River. Barge transportation on the river is an economical option when long distances are involved.

The bark and limbs will feed directly from the debarker/chipper unit into a tub grinder and be prepared for hog fuel use. The boiler at the Wallula Mill is sensitive to dirt so it will be necessary to keep this material as clean as possible. No on site storage will take place.

For various reasons it will be advantageous to remove stumps and large roots from the fields after the harvest. Boise Cascade is currently experimenting with several methods of stump extraction and processing. While extraction has been fairly easy, cleaning and processing have been a challenge. Stumps can be removed with either an oversized nursery lifter or a Rockwell Roto-Lifter. Both of these machines are able to operate in excess of 2 mph (3 km/hr). The stumps will be transported to the processing area and will be split, tumbled and screened before they are chipped. A second screening is likely to follow the chipping as well. If this process is successful, the material will then be transported to the Wallula Mill and used for corrugated medium.

Organization and Planning

The organizational structure of Boise Cascade's short rotation project lends itself quite well to operations, planning, and record keeping. The project is spread over six farms that are managed as separate operating units. Each has farming and irrigation technicians assigned to it who oversee and carryout daily activities and monitor farm conditions. These people are familiar with all aspects of the respective farms and are instumental in insuring that the trees are well cared for.

The farms were established over several planting seasons, thus there are several age classes on each. This Farm by Age Class breakdown is the level at which long-term strategic planning for irrigation system development, planting, power and water requirements, and harvesting takes place. Boise Cascade's primary strategic planning tool is a model that operates similarly to the Forest Service's FORPLAN model and optimizes yields against costs and projected mill needs. It provides harvest schedules as well as farm development plans.

Each age class on a farm was planted over several irrigation blocks. These blocks are from 80 to 1400 acres (30 to 550 hectares) in size and each has its own independently operating irrigation system. Because the irrigation system is designed to water all of the trees within an irrigation block at the same rate, and the trees water needs vary by age, there will never be more than one age class within a single irrigation block. Because of this characteristic, harvesting and replanting will only take place on whole (not partial) irrigation blocks in a given year. The irrigation block level therefore, is the tactical planning unit. Harvest contracting and irrigation scheduling are conducted by irrigation block.

Each irrigation block is further divided into a number of planting blocks from 25 to 125 acres (10 to 50 hectares) in size. Planting blocks are clearly defined in the field and have a road or ATV trail on all four sides. This is the primary record keeping unit. Inventory data, MIS/GIS and the accounting systems are all maintained by planting block giving Boise Cascade the ability to do in-depth analysis on such factors as growth rates, ground conditions and treatment costs.

Summary

Boise Cascade has been managing short rotation woody crops in Washington and Oregon for six growing seasons. It has a total of 17,000 acres (7,000 hectares) of cottonwood trees planted on irrigated agricultural land.

The primary challenges to growing short rotation crops include irrigation system conversion and maintenance, site preparation and planting, and weed and pest control. A very intense level of management is necessary to address these issues.

Boise Cascade will complete its first rotation early in 1997 when it begins to harvest and replant its oldest fields.

Results from these short rotation operations have been excellent. The oldest trees average more than six and a half inches dbh (diameter at breast height) and 70 feet in height.

Short Rotation Management of Woody Crops has given Boise Cascade a new stable source of fiber in a region that has an increasingly limited supply.

Western Perspective: SRWC Operations - Field Conversion and Plantation Establishment

Jake Eaton and John Finley, Potlatch, Boardman, OR

Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

Abstract

Potlatch Corporation is in the third year of converting 22,500 acres (9000 hectares) of Northeast Oregon center-pivot irrigated farmland to hybrid poplar Conversion of this acreage will take place over a six year period with approximately 3,800 acres (1500 hectares) of new plantations established annually. The farm will provide a sustainable annual production of fiber beginning in the year 2000 and furnish 208 of the chip fiber for Potlatch's Pulp & Paperboard operations located at Lewiston, Idaho.

The Columbia River provides a stable source of irrigation water that in combination with the area's long sunny days, sandy loam soils, and 190 day frost-free growing season, creates an ideal environment for intensive poplar culture. Drip irrigation allows efficient delivery of water, fertilizer, and some pesticides to individual trees.

With three-year-old trees as our oldest operational age class, the Potlatch western perspective will focus on field conversion to drip irrigation, site preparation, selection and development of planting stock, and plantation establishment. State-of-the-art filtration, pumping, and water delivery systems are used to run the 200,000 gallon per minute irrigation system. Site preparation involves field leveling, soil ripping, and incorporation of pre-emergent herbicide. A rigorous clonal testing program from breeding new material to selections for operational deployment results in new clonal material that is mass propagated at contract stoolbeds. Dormant cuttings are processed and stored until spring planting. Post-planting activities include herbicide and manual release, cultivation, and pest monitoring.

Currently, 8500 acres (3400 hectares) are under management and construction is underway on the 3900 acres (1600 hectares) scheduled for planting in 1997 Early tree performance is meeting expectations, and production levels of a minimum of 40 bone dry tons of clean pulp chips per acre are realistic with a six-year rotation.

Introduction

Potlatch Corporation has acquired two contiguous center-pivot irrigated farms totaling 22,500 acres (9000 ha) near Boardman, Oregon for intensive farming of hybrid poplar. A declining supply of economically available residual chips motivated Potlatch to aggressively develop hvbrid poplar to augment its fiber supply. The decline has resulted from constraints on the Pacific Northwest timber supply brought about by environmental activism and a change in relative priorities of timber harvest versus other uses of public forest lands.

The Northeast Oregon location was selected for its optimal climate for intensive poplar culture. Long sunny days and a 190 day frost-free growing season provide abundant solar radiation. The soils are sandy, extremely well drained and allow year-round operability. The Columbia River provides a secure and dependable long-term source of clean irrigation water. Both farms have well-developed irrigation infrastructures with relatively senior water rights allowing application quantities of 4.5 acre-feet per year. The location also has excellent barge, rail, and truck access.

Ground was broken on the hybrid poplar program in 1993 with the conversion of the first 800 acres (320 ha) to drip irrigation. This acreage was planted in 1994. The 1995 and 1996 plantings were approximately 3800 acres (1500 ha) each and development will continue at this pace through 1999. Beginning in the year 2000, the farm will provide a sustainable annual production of high quality fiber and furnish 20~ of the chip fiber needs for Potlatch's Pulp & Paperboard operations at Lewiston, Idaho. Hybrid poplar fiber will mainly be used in bleached paperboard and tissue based consumer products.

Field Conversion

Potlatch purchased center-pivot irrigated agricultural land developed in the early 1970's. Prior to growing trees the farm land was used to grow a variety of crops including potatoes, onions, corn, wheat, and alfalfa in rotation. Conversion to drip irrigation is a requirement for poplar farming in our desert environment. Drip systems reduce system pressure requirements thus saving electricity, minimize water wasted by evaporation, minimize competing vegetation by reducing the area irrigated, and enable injection of necessary nutrients and some pesticides during the rotation cycle.

The existing center-pivot system presently waters crops in irrigated circles. This leaves corners of native desert outside of the circles that have never been farmed. The corners are very uneven from small sand dunes formed by years of blowing sand collecting around existing sagebrush plants.

Conversion to drip irrigation, inside and outside of the circles, occurs in two separate time frames. Corner conversion activities occur while crops are still maturing in the circles, 18 months before trees are planted. First, corners are mowed and large dunes leveled with a bull dozer. If there is a good grass cover and the ground is reasonably smooth, the area is left undisturbed. Disturbed corners are very susceptible to wind erosion. To prevent erosion, these areas are covered with straw. Specialized equipment shreds straw bales and spreads it evenly over the ground. Following this a grain drill is used to seed a winter wheat cover crop that will hold the soil through the following year. The drill also tucks the straw into the soil, helping to hold it until rainfall germinates the wheat and a cover crop is established. This process is generally completed by December, and these areas are ready for the final site preparation the following August.

Conversion activities inside the farmed circles begin the August prior to planting, when the final crops are being removed. Several activities occur in quick succession. The crop preceding hybrid poplar influences what happens next. Because of strong winds in our area, cover crops to prevent blowing sand and wind erosion are critical. The best crop to follow with hybrid poplar development is wheat. In this case the stubble is left and the fall and winter rains sprout the volunteer wheat resulting in a good cover crop. Potatoes or other row crops leave the field bare. In these instances winter wheat is sown and watered with the center-pivot.

Once the cover crop is established and able to exist until the onset of fall rains, the center-pivots are removed. Pivots are sold to buyers that are responsible for their removal. A quarter-mile long pivot with several towers can be removed in about two days. In coordination with the pivot removal, surveyors are brought in to layout the underground portion of the new drip system. In addition to staking the locations of new pipelines, the fields are surveyed and a grid system of check rows are located to ensure that tree rows are laid out straight.

When the surveying is completed a tractor mounted soil ripper is brought into the field to mark out the tree rows. This equipment rips two rows at a time, 10 feet (3m) apart to a depth of 24-30 inches (60-75cm). The operator works off of the surveyed grid of check rows and uses a marker bar to help locate the next row. If necessary, adjustments are made at the check rows to maintain straight rows ten feet apart. Consistent row spacing is critical to insure adequate space for tractor operation between tree rows. Once ripped the field is ready for irrigation construction.

Irrigation Construction

With 19,000 miles (30,400km) of drip tube and 26 million emitters, clean irrigation water is a must. Water from the Columbia River is moved to the plantations through mainlines and an irrigation canal. Screen filters are installed at pumping stations along the canal. Primary filtration for silt and organic matter takes place here. These filters automatically clean themselves when the sediment load reaches a predetermined level. Down stream of the filters, chlorine is injected into the irrigation stream to control algae.

The drip irrigation system uses the infrastructure of mainlines that supplied water to the old center-pivots. A manifold system is installed at the old pivot point that distributes water, fertilizer, and pest control products to four similar sized blocks. The underground construction begins with trenching and laying pipe on three sides of the block. The submain system is three sided to allow irrigation to be supplied from both ends of the block and facilitate automatic flushing of sediment and other contaminants from the system. Blocks are approximately one-quarter mile square. Flexible hose risers are attached to the below ground submains at the block ends, and serve to bring the water back to the surface. Drip hose will eventually be attached to the risers. Risers are lined up with the rip marks to get the correct row spacing along the pipeline.

Once the submains and riser lines are installed, the manifolds are assembled. The manifold consists of all the hardware necessary to distribute water to each of the four blocks. A master valve regulates mainline pressure to prevent excessive pressure on the drip lines. The manifold has an injection port for fertigation and chemigation. A final filter is installed after the injection port to prevent drip tube contamination from mainline breaks. Electronic valves regulate the flow to each block. Sensors for pressure and flow are also located at the manifold. Irrigation, injection, and system monitoring are all automated and controlled by a central computer.

Site Preparation

All of the field conversion activities take place between August 1 and November 1 of the year prior to planting. Beginning around the first of November, or as soon as soil moisture is adequate, rototilling begins. The rototillers are six feet wide and till 3-4 inches (7-l0 cm) deep. The tillers center on the rip mark and as they till, leave two groove marks on the soil. These marks are one foot apart and indicate where the soil was ripped. Tilling in this pattern leaves a 4 foot (3.2m) strip of cover crop between each tree row. This is done to provide wind protection to the young trees. Installed on the tillers is a sprayer that applies a preemergent herbicide right in front of the tiller. Presently, products with the active ingredient Trifluralin are used. Tilling takes place throughout the winter months as weather allows and is completed by March 1st.

Installation of the drip hose begins in January and is completed by the first of April. The hose arrives from the manufacturer in rolls of predetermined lengths, with emitters or drippers attached along the hose at preset spacings. These emitters are pressure compensating and will put out a constant 0.75 gallons (31) per hour over a range of pressures. These rolls are spooled out by a specialized implement mounted on a tractor. It uncoils three rolls at a time as the tractor moves down the row. Care is taken to lay the hose between the groove marks left by the tiller. This assures that the tree will be planted at the rip mark. Drip hoses and submains are flushed thoroughly before final connections are made. At this point the field is ready to be irrigated.

Clonal Testing

Potlatch's clonal testing program begins with acquisition of new plant material. Our strategy has been to do some breeding of our own and acquire additional clonal material through the research cooperatives we are active in. Further, we are constantly looking world-wide to secure possession of material that has not been tested in our environment. The hybrids we are working with are crosses between four poplar species, including *P. trichocarpa*, *P. deltoides*, *P. niqra*, and *P. maximawiczii*.

Newly bred clones enter a two-year screening trial, where the top 10-15%, based primarily on volume growth, are selected to move forward to the refinement phase. This three-year trial will begin to evaluate clone suitability to the Boardman environment, wood quality, and also expand our growth analysis work. Again the top 10% move ahead to the final verification test. It's 5-6 year duration is designed to thoroughly evaluate volume growth (including stem form), en-vironmental suitability, wood quality, disease and pest resistance. Current operational clones are included in the test and serve as the basis for comparison. Exceptional material can be identified at any time during the testing sequence and moved to clone banks to facilitate rapid scale-up.

Crosses between *P. trichocarpa* and *P. deltiodes* (TxD) and *P. deltoides* and *P. nigra* (DXN) have been used operationally. The TXD crosses generally produce the greatest biomass, but may not be as cold hardy as the DxN hybrids. The *P. trichocarpa* by *P. nigra* (TxN) crosses have shown great potential in testing and will be included in future operational plantings. To date, crosses between *P. trichocarpa* and *P. maximawiczii* (TxM) have not proven suitable to our hot and cold extremes, and our windy environment.

Clone testing is an ongoing process with new material entering different phases of the testing program each year. Many years are needed to confidently select new clones for operational use. Work underway in the Poplar Molecular Genetics Cooperative hopes to compress the testing period by identifying genes for desirable traits at an early age. Marker aided selection would also be valuable to select parents for future breeding.

In spite of long deliberate clonal testing programs, all of the risks associated with deploying new clones can not be eliminated. Extreme environmental conditions or disease and pest adaptations can result in failures. Long-term risks have to be balanced against productivity gains in a comprehensive clonal testing program.

Planting Stock Development

Clonal material is mass propagated at contract nursery stoolbeds. Plant material for stoolbed development comes from company clone banks or outside purchases. Single-bud cuttings, cut from clone bank whips, are greenhouse propagated for stoolbed starter material. More rapid scale-up using a controlled green wood propagation technique is also possible. Extreme care is taken to assure clonal integrity is maintained during scale-up. Suspicious greenhouse and stoolbed material is discarded to avoid contamination.

Depending on the level of scale-up desired, smaller stoolbed cuttings can be saved when processing production cuttings for additional stoolbed development. Stoolbeds are generally planted at a 1 x 1 ft. (30 x 30cm) density and intensively managed to assure proper nutrition and irrigation. The goal is to maximize yields by growing branchless wands with very little taper. Insects and disease are monitored continuously and controlled promptly. At full production one acre of stoolbed will yield around 150,000 operational cuttings.

Wands are processed when dormant. Crews harvest wands in the field and transport them to a processing facility. Most processing is done by hand. Cutters have lopping shears with length and caliper guides to aid in size determination. Generally accepted cutting size specifications for planting East of the Cascade Range are 8-9 inches (20-23cm) in length and 3/8-7/8 inch (lcm-2cm) in caliper. Processing is a labor intensive activity and accounts for 60% of the cutting production cost. Cuttings are double bagged to prevent moisture loss, boxed, and placed in dark cold storage at 28 degrees F.

Plantation Establishment

An average of six different clones are planted each year. Plantations are established in monoclonal blocks. Generally, all four irrigation blocks in a 160 acre (64ha) field are planted with the same clone.

In Northeast Oregon planting begins in early April. Just prior to planting, the fields are sprayed with herbicide. The two tank spray rig eliminates weeds that have escaped in the tilled strips and treats broadleaf weeds in the cover crop strips. All planting is accomplished by contract crews that can hand plant up to 240 acres (96ha) per day. wet spots along the drip tube indicate where to plant. Care is taken to plant the cutting with buds pointing up, the top bud flush with the ground, and within a few inches of the emitter. Planting is completed by late May. After the cuttings have been out for about six weeks, crews go through the plantations to replant any failed cuttings, move the drip tube to the west side of each tree, single multiple stems, and check emitter operation.

The first year after planting is critical to plantation establishment and performance. Hybrid poplar is not a shade tolerant plant. In areas where pre-emergent herbicide activity has been weak, new trees can be rapidly out competed by weeds. Grass competition can be controlled by any of the Fluazifop herbicides (e.g. Fusilade) without damaging the poplar. Unfortunately, at a young age poplar is not compatible with most of the common herbicides. Because of this, manual release may be the only option to remove unwanted vegetation next to the trees. Once trees are established, tractor operated cultivation does occur between tree rows to remove vegetation strips, left to provide wind protection for new trees.

Pest monitoring begins soon after planting. Grasshoppers, wire worms, cut worms, and ants can damage young plants. Although damage from these insect pests is seldom economically significant, grasshoppers can cause defoliation and have been managed with Carbaryl insecticides. Other insect pests monitored for and controlled when necessary during the first year are the cottonwood leaf beetle and various caterpillars. Mammalian pests include deer, gophers, voles, and indirectly coyotes. Deer browse is generally local and tolerated. Gophers eat tree roots and voles can girdle stems. The rodents seem to concentrate damage in local areas and can be held in check by poisonous baits and thorough weed control. Coyotes chew through drip tube resulting in leaks and moisture stress on the trees.

Summary

The level of activity in the plantations decreases after the first year. Irrigation, fertigation, and pest monitoring form the basis of plantation management until harvesting activities begin. Annual stand inventories are conducted on each age class to assess performance and identify problem areas. To date, average growth rates of 40 plus feet (12m) in height and 4-5 inches (10-13cm) DBH have been observed on trees nearing the end of their third growing season. It appears that our target tree size of 6570 feet (20-22m) tall and 8-9 inches (20-23cm) in DBH is realistic with a 6 year rotation.

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next

Proceedings

Northeast Energy Perspective: Willow Biomass - Bioenergy Industry Development

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Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

Abstract

Biomass-for-energy cropping and production systems based on willow planted and managed at high densities and short (3 to 4 year) coppice harvest cycles, providing fuel for co-firing with coal can be economically, ecologically, and environmentally sustainable. These issues are crucial to the successful commercialization of this biomass-bioenergy system. Current knowledge and ongoing research and development indicate that the production and utilization systems involved are environmentally and ecologically acceptable. Attempts are being made to adopt the European planting and harvesting system for North American conditions. The other major issues that need development are the economic viability based on cost of production and use, the value of environmental externalities (such as atmospheric emissions), and potential government/public policy actions to promote this system of providing a locally produced and renewable farm crop and fuel. Development needed to overcome the economic constraints are known, and should be bolstered by the environmental and ecological quality of the system.

Introduction to the Salix Consortium Project:

Willow biomass farm crops grown as a Dedicated Feedstock Supply System

(DFSS) in Northeastern USA has been analyzed and found to be a feasible means of augmenting current coal resources for power generation. This project is focusing on the technology, equipment and infrastructure required to grow willow crops and integrate them with existing pulverized coal electric generation facilities in central and western New York.

The most promising near-term commercial biopower business scenario involves independent growers, a DFSS planting/harvesting/processing cooperative, and a co-firing utility market. Business expansion in the future includes markets for new generation capacity based on biomass-fired integrated gasification power systems as well as production of liquid and gaseous fuels. The “Salix Consortium” was formed in New York (by four principle partners with the cooperation of about 30 private, government, and research institutions) and supported by the US Departments of Energy and Agriculture plans to commercialize this system in Central and Western New York with future expansion in Central/Northeastern USA and Eastern Canada.

The principle partners in the Salix Consortium are all involved in various aspects of development of biomass resources for energy applications. New York State Electric and Gas Corporation (NYSEG) is among a handful of utilities in the US to actively co-firing biomass fuels with coal. Several years of tests and operations at the NYSEG stoker-fired Jennison and Hickling Stations have produced encouraging results. This includes trouble-free and economic use of these fuels when the feedstock costs are comparable to coal on a per-BTU basis. Modifications for co-firing biomass with coal at the pulverized coal Greenidge Station have recently been completed for sustained co-firing. Further, NYSEG has a research program with the State University of New York College of Environmental Science and Forestry (SUNY ESF) establishing biomass dedicated feedstock supply systems (DFSS) on company land. Niagara Mohawk Power Corporation (NMPC) has had an active research program in renewable energy for many years. Niagara Mohawk has sponsored, since 1988, research for energy feedstocks from biomass at SUNY ESF, and is committed to the SUNY ESF biomass program with a 12-year contract (through 2004). SUNY ESF has been a leader in the development of experimental methods for evaluation of high yield woody crops since 1983. SUNY ESF has conducted plant development and cultivation trials for hybrid poplars and willow in soils of the Northeast, achieving experimental yields over 13 dry tons per acre per year. The New York State Energy Research and Development Authority (NYSERDA) has supported biomass energy research at SUNY ESF since 1983, and a range of other efforts to evaluate the availability and environmental acceptability of the use of DFSS biomass and residue resources for power generation and process heat applications. These Consortium members have long-standing interests in renewable energy, environmental quality and rural development.

The willow cropping system is based on 15 years of research at SUNY ESF. Research has ranged from hybrid poplar clone-site trials at wide spacings (435 trees/ acre) and anticipated 10-year rotations, to willow clone-site trials at extremely high densities (43,560 trees/ acre) and 1-year rotations. The system adopted is based on this research and extensive work in Sweden, the United Kingdom and Canada. Its basic characteristics are: "Swedish" double row mechanical planting of 6,200 trees per acre, mechanically harvested on 3- to 4-year coppice cycles. There are more than 40,000 acres of willow DFSS in this system established in Europe, and commercial planting and harvesting machines are available. Research and scale-up at SUNY ESF and the University of Toronto have further validated the system for North America. The proposed near-term conversion technology, namely co-firing biomass with coal, is well established in stoker and more recently pulverized coal boilers. Advanced conversion technologies, such as direct biomass gasification, alcohol production, and fuel cell technologies are in various stages of pilot-scale development, and the Consortium is well positioned to access them for testing and eventual deployment.

Under the umbrella of the Salix Consortium, these organizations have combined their respective strengths to further the development of high yield energy crops to a pre-commercial demonstration and commercial production stage. The Consortium partners, in conjunction with other sponsoring agencies, are currently scaling-up clone-site trials, establishing a commercial scale demonstration farm, securing acreage for large scale plantings, co-firing 5-15% wood residues on a sustained basis, and continuing co- firing pilot trials. The combining of a long-term funding base for sustained research by SUNY ESF, an active role by progressive electric utilities, politically favorable federal/state governments and a demonstrated need for rural development has resulted in one of the first successful near-term commercialization opportunities for willow as a short rotation dedicated feedstock supply system for electric energy production in the USA

Willow Energy Business Development - the Vision for the Enterprise:

The business enterprise being developed by the partners of the Consortium combines the strengths of entrepreneurial farmers and forward-looking utility companies in New York and the Northeastern United States. As partners in the enterprise they will forge a long term business relationship that will provide the necessary capital and expertise to develop an energy crops market and infrastructure in the Northeastern US The business is built around three entities distinct in their responsibilities but integrated by their common interests in developing a profitable business.

- The Grower - growers (farmers) within a 50-mile radius of the power plant will grow willow crops, developed by SUNY ESF and others, on 20- to 300-acres of land. Landowners will get paid for the feedstock commodity and/or land rent. Income generated by the crop will diversify farm products, and yield up to a 6% internal rate of return on the growers' investment in the energy crop, and allow the land to stay in productive use.
- An Associated Farmer/Utility Cooperative - investment in specialized planting and harvesting equipment will produce income through fuel sales to the utility and service fees charged to regional growers for planting, harvesting, processing and transport services. The cooperative will procure biomass residues in the region and deliver a blend of residues and dedicated feedstocks to the fuel market.
- Associated Utilities - the utilities associated with the Consortium will be able to receive favorable terms on fuel purchases from the Cooperative. Fuel prices for a 50-50 blend of energy crops and residues will be competitive

with coal. The utilities will be able to bank the emission reductions (SO_x and NO_x , and potentially CO_2) due to biomass fuel substitution. The emission credits are an additional incentive provided through biomass fuel purchases that confer a competitive edge to power companies making the biomass fuel switch.

To ensure profitability, the Consortium will establish regional cooperatives that serve a minimum of 2500 acres. The first would be established to serve NYSEG's Greenidge Generating Station in central New York. Greenidge production acreage will eventually grow to 5000 acres capable of supporting 15% co-firing with a 50-50 blend. The second regional cooperative would be established to serve NMPC's Dunkirk generating station. Within 10 years, production is projected to reach 120,000 dry tons per year dedicated biomass fuels grown on 13,000 acres and 336,000 tons of residue fuels serving four co-fired coal generating stations in NYSEG and NMPC territory.

Anticipating the development of greenfield Integrated Gasification Combined Cycle (IGCC) power stations fired entirely by biomass fuels, nearly 30,000 acres are projected to be planted in willow energy crops by 2010 in New York. With annual fuel sales projected to approach $20 million in New York alone, electricity sales at 5 cents per kWh would generate $135 million in revenues from biomass generated power. Sales of emission credits could substantially increase these revenues. Other enterprises modeled after these pioneer operations and associated with the Consortium could be constructed throughout the Northeast.

Project Feasibility and Business Plan Development:

The analytic approach to determining the potential for successful development of biomass resources as a profitable venture for both fuel suppliers and users rests on the ability to quantify, within comfortable ranges, the price and availability of the resource and the economic value that can be realized by the utility and fuel producers in the process of utilizing biomass-derived fuels. Beyond these basic considerations, an array of issues and factors will determine public and regulatory agency acceptance of the changes in land and fuel use. These issues will influence resource supply and demand, and are being addressed as risks with potential impacts on both cost and schedule for project development. Approaches to resolving or mitigating the potential impacts are being evaluated.

The Salix Consortium has prepared a preliminary plan for the development of biomass as a utility fuel resource in the Central and Western regions of New York State, and adjoining areas where utility partners are located and co-firing experiments have been conducted. The primary reasons for developing the biomass resource are both economic and environmental. The goals for the project are multiple.

- Establish the technical, economic and environmental viability of willow biomass as an alternate farm crop for the region serviced by the Salix Consortium utilities and potential expansion to other regions.
- Demonstrate the environmental benefits and operability of co-firing biomass and coal in existing coal-fired PC boilers in the region.

- Determine the regional economic development benefits of creating a biomass power infrastructure.
- Demonstrate the environmental benefits and economic advantages attributable to the use of existing by-products and residues from the wood products industries and raw materials from good forest management practices in the region.

A phased approach to development of the resource is embodied in the Salix Consortium plan. In the initial phases that have been ongoing, field tests were conducted for willow clones that would become the foundation of a DFSS. Clones with proven yields have been developed and are uniquely available to the Consortium through a long-standing association between SUNY ESF and the University of Toronto and the Ontario Ministry of Natural Resources. Combustion of wood by-products and residues in utility boilers has been conducted to evaluate their compatibility with coal firing as well as their environmental and economic characteristics. In the commercialization Phase that the Consortium is now entering, scale- up and expansion of the early experiments is being conducted as a prelude to the first commercial operation of a fully integrated biomass fuel system. Success in the first commercial plant conversion to co-firing biomass and coal will be a stepping-stone to expansion of the use of the fuel in co-firing applications and scale-up of DFSS production capability. It will serve as an infrastructure development model for application in other regions.

In the future new biopower capacity will be considered as power demands change and older generating facilities are retired. The introduction of high efficiency biopower systems is expected to occur near the turn of the century. Based on demonstration of the effectiveness of these systems in pilot plant facilities, the Consortium plans to eventually identify potential repowering or greenfield plant sites for capacity expansion.

Description of Region:

The potential biomass supply within a 50-mile hauling radius of NMPC's Dunkirk Station, and NYSEG's Kintigh, Greenidge, and Milliken Generating Stations, in west-central New York was evaluated. Dunkirk and Kintigh Generating Stations are located on the Lake Erie-Ontario Plain of New York. Most of the Kintigh area possesses highly productive soils. The valley floors of this region are some of the most productive agricultural lands in the state, and the hillsides in this region are primarily used for pasture and hay land, or are uncultivated. Although the Dunkirk Station is located within the Lake Plain region, most of the study area falls in the Allegheny Plateau. The northwestern portion of this plateau is cultivable, although soil drainage is restricted. The Dunkirk area encompasses some of the largest timber-producing areas in New York. Kintigh is located between the large population centers of Rochester and Buffalo. The Dunkirk study area encompasses Buffalo. Both of these areas have access to well-developed transportation systems.

The Greenidge and Milliken Generating Stations are both located in the Finger Lakes region of the Lake Erie-Ontario Plain. Greenidge and Milliken have access to the timber producing counties in the southern portion of the state, and the agricultural lands of the Finger Lakes. These areas are not as densely populated as the Dunkirk and Kintigh areas. The transportation systems are not as well developed in the Greenidge and Milliken areas but are adequate for agricultural industries.

Agriculture in New York State is annually a $2.6 billion industry and one of the state's most important sectors. Data from the US Census Bureau and Cornell University's College of Agriculture and Life Sciences quantifies land use and farming trends readily visible throughout the state. Changes in the industry, beginning in the 1930s, and accelerated over the last decade, have made significant amounts of land potentially available for willow DFSS production in support of biopower industry. For example, between 1987 and 1992 the number of farms declined by 14%, and the number of acres farmed by 11%. Slightly less than half of all farmed acres are cropped, the remainder being in pasture and support areas. Average farm size increased during this period by 7 acres, to 200 acres. Of all farms (32,306) reporting, only 52% earned a profit in 1992. However, 33% of the reporting farms accounted for fully 92% of all agricultural sales. Thus, most small farms are in need of economic revitalization, such as from the introduction of willow biomass as a new cash crop. Steady increases in New York's forested area since the 1930s (the state is now 63% forested) indicate that land removed from agriculture is generally abandoned and returns to forest. Willow biomass is likely to be a socially acceptable alternative for recently retired and unprofitable farmland, and economically welcomed as markets develop.

Willow biomass is not recommended for establishment on currently forested areas. These areas are best managed as forests and it is unacceptably difficult and costly (environmentally and economically) to convert them to DFSS. New York's forests do, however, have great potential to supply wood biomass for biopower, particularly during the scale-up phases of DFSS deployment, as a long-term component of the industrial fuel mix, and as an "insurance" resource to smooth out unanticipated fluctuations in willow biomass production.

Willow Biomass Cropping:

The willow biomass cropping system upon which this project is founded can be summarized as follows: land with appropriate soils (medium textured, moderate drainage, pH 5.0-8.5, depth 18 inches) that is currently open (idle, brush, pasture, cropped) is suitable for producing willow biomass for bioenergy. Other species adapted to the cropping system may also be used (i.e., hybrid poplar). Currently forested land (dominated by trees of sufficient stature to resist brush-hogging) is not to be converted to willow biomass crops. Suitable land is prepared using agricultural practices (clean and/or conservation tillage), trees are mechanically spring planted at 6,200 per acre (using the "Swedish" double-row system; cuttings planted 2 feet apart within each double row that are 2 1/2 feet apart, with the double rows being 5 feet apart), managed on coppice cycles of three to four years (three years normally, except for the 1-year cutback after the establishment year to promote multiple stems), weed control is extremely important the year of establishment, nutrients (chemical fertilizers and/or organic sources) are applied the spring and/or early summer after cutback and each coppice harvest, and mechanically dormant season harvested with modified agricultural machines. Approximately 7 coppice harvests over 21 to 28 years are expected following establishment. The willow crop can be reestablished whenever tree vigor-health-survival declines substantially and reduces productivity, or new-improved clones become available and it is economically justified to replant. Alternatively, the crop can be abandoned or the land can be converted back to other uses.

All harvesting is done during the dormant (winter) season. This maximizes tree nutrient and carbohydrate allocation to roots during the autumn, thus promoting vigorous coppice regrowth the following spring, and ensures that leaves have fallen and will enter the site's nutrient cycle. In addition, leaves with their relatively high nutrient contents may be problematic in some conversion processes. Winter harvesting ensures that the ground is hard and trafficable, and does not interfere with normal farm harvesting operations in the summer and autumn.

Winter harvested material (which is immediately chipped) must either be stockpiled during harvest months (November to March) for use throughout the year, creating inventory management challenges, or be a "cold-season-only fuel" (six months). In this case, during the "warm-season" (April to November) alternative fuels would be required since chipped material can only be stored for one to four months with proper management. In co-firing operations, willow biomass crops might not be used in the warm- season; other biomass may be used. Alternatively, if willow biomass harvesting is done with a whole- stem harvester machine, the cut stems can be stored up to several years, drying while in storage, and then used as fuel during cold or warm-season months. In co-firing, coal-only fuel can be used as required. In advanced biopower conversion systems, 100% dependent on biomass, alternative biomass resources in addition to willow biomass crops may have to be used. These could include biomass from forests and wood processing industries, as well as seasonally available agricultural residues. Warm-season harvested DFSS crops, such as the alfalfa stem biofuel project in Minnesota, might also be attractive options.

Willow DFSS is an agri-forestry system of production, using agricultural practices and equipment to produce wood biomass. By analogy, the willow biomass crop system is established like a corn crop, but managed like a hay crop with multiple harvests from a single planting. In addition to the use of agricultural type site preparation techniques and equipment, planting and harvesting machines and operations are more similar to agriculture than traditional forestry. Commercial planting equipment developed in Sweden for willow biomass crops includes an automated tractor-drawn and powered two- and four-row planters.

Automated willow DFSS harvesting machines have been developed in Europe and are commercially available in the US Two basic types of machines have been developed: the harvester-chipper and the whole-stem harvester. The harvester-chippers are modified corn (Claas Jaguar 695 - CLAAS Corporation) or sugarcane (Austoft 7700 - Austoft, Inc.) harvesters, which cut, chip and blow the chips into a dump wagon following alongside or pulled by the harvester.

Two Swedish companies, Rosenhalls gard Energi AB (Empire 2000 - self propelled) and Froebbesta, Inc. (Froebbesta Harvesters - both self propelled and tractor pulled), have developed whole-stem harvester machines. These cut whole stems and then pile them in the field, which are moved by grappling equipment for on-site storage, direct transport, or chipping and transport.

Summary:

In summary, the Consortium's biomass energy plans must consider the current economic factors, present future energy consumption level, and the environmental constraints on the electricity-producing industry. It is clear that New York is currently gearing its efforts towards improving its electricity-producing market capabilities. However, further work and planning is necessary to ensure New York's existence in this highly competitive market.

- The most important innovations that could change the commercial prospects for biomass to energy technology are: the development of high-yield willow energy crops and economical, high capacity planting and harvesting equipment; willow yields 50% above current yields are possible but will take time to achieve in field conditions. Commercial harvesters and planters for willow are in a first production run stage in Europe. Improvements to the productivity of this equipment and broader use would significantly reduce production costs.
- Improvements in fuel handling and fuel preprocessing technology will ease the introduction of biomass as a co-fired fuel in existing coal-fired boilers. NYSEG is investigating improvements to fuel-handling equipment.
- Introduction of integrated gasification combined cycles will increase efficiency and output by as much as 30%, reducing fuel costs and potentially capital investment.

All of these factors would provide leverage for market entry for a biopower enterprise and were evaluated in terms of their potential effects upon the business viability.

Fortunately, a strong potential exists for the growth of New York's energy market through the use of energy efficiency programs, the continued use of coal and natural gas, and the future use of renewable energy resources (such as the willow biomass crop described here) found in New York.

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next

Proceedings

Intensive Culture of Hybrid Poplars in Minnesota

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Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

Intensively cultured poplar plantations are well known in the Southern and Northwestern United States where they have made significant contributions to industrial fiber supplies. Intensively cultured plantations are less well known in the North Central United States, with interest historically centered on production of alternative fuels. But, several driving forces have recently combined to increase interest in intensively cultured plantations in the North Central region, especially in Minnesota. In response, about 6,000 acres of hybrid poplar plantings have been established as of 1996. A few operational scale plantings are as old as age six years, but most are three-years-old or younger. Support for research on cultural methods, site selection, genetics, and other areas has increased with the formation of the Minnesota Hybrid Poplar Research Cooperative. In the following sections we describe the forces that have caused increased interest in intensively cultured plantations, current cultural methods, current acreage and expected yields, and our current research emphases.

Driving Forces

Increased attention to the need for intensively cultured poplar plantations in Minnesota has been catalyzed by three driving forces. First, increased needs for non-timber resources on public forests has resulted in reduced harvests, the perception that harvests will be reduced in the future, or both. Second, industrial expansion in paper and oriented strand board (OSB) production has increased demand for aspen and other species that can be substituted for aspen. Third, the supply of natural aspen is unevenly distributed throughout all age classes and reduced availability is anticipated within the next 20 years or so. The aforementioned forces have combined within the last 10 years to drive the average price for aspen stumpage in Minnesota from about $3.50 per cord in 1986 to about $20.00 per cord in 1996 (Figure 1). In fact, some recent aspen sales in northern Minnesota have gone much higher, in excess of $40.00 per cord. The combined effects of all forces has made intensively cultured poplar plantings an attractive alternative wood supply.

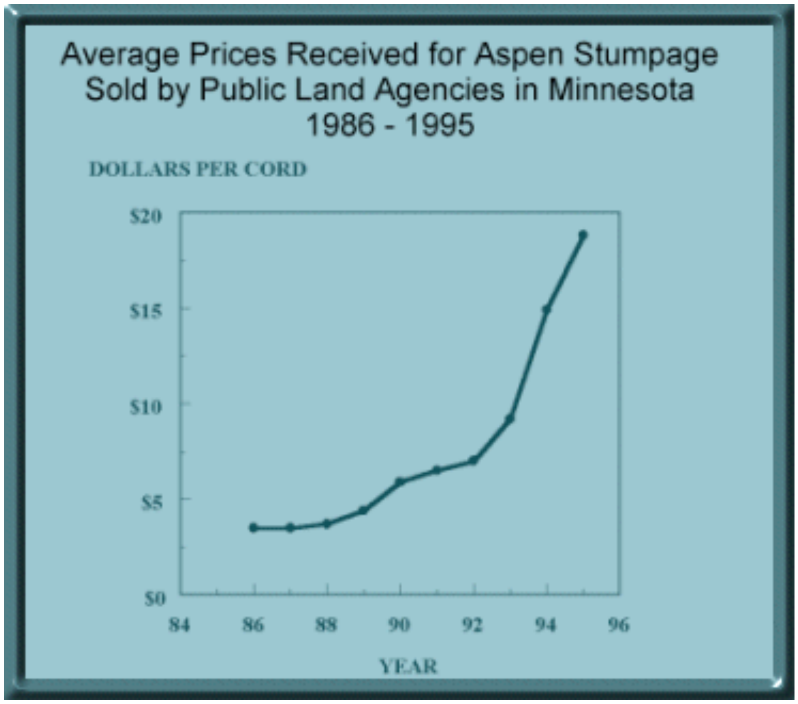

Figure 1. Average price of aspen stumpage in Minnesota over the last ten years (Data courtesy of Mr. John Krantz, Minnesota Department of Natural Resources, St. Paul, MN.

Current Cultural Practices

Cultural methods almost always involve the use of herbicides. Some of the uses described in the following are for research purposes only and therefore subject to categorical exclusion. The reader should always ensure that a proposed commercial application is within the label. Site preparation protocols involving herbicides differ by region within the State of Minnesota. Initial site preparation is a good example. Fall tillage, marking planting rows by mechanical scribing, and the application of preemergent herbicides such as Oust™ or Lorox™ is common in the Alexandria area. Spring tillage is less acceptable, but is sometimes the only choice if access to sites in the fall is not possible. Chemicals can be applied in the spring prior to planting but application rates, especially for Oust™ , must be reduced. Lorox™ is commonly applied immediately after planting.

Further north, sites enrolled in the CRP often have deep sod layers and sites benefit from prescribed burning before tillage. Cultivation in the spring is often necessary in the north because heavier northern soils can be seriously compacted over the winter. There is some debate regarding universal herbicide prescriptions across Minnesota. But, Lorox™ is commonly applied after planting in the north. In any case, an aggressive combination of chemical and mechanical vegetation management strategies is most commonly practiced to achieve a completely weed-free condition prior to planting in the spring. One possible exception to this rule is a minimum tillage strategy with poplars following a soybean crop. Some success using single trench tillage has been observed in this scenario.

Current clone selection is limited and the most commonly planted clones are DN-

34 (*P. deltoides* x *P. nigra* cv. *Eugenii*) and NM-6 (*P. nigra* x *P. maximowiczii*). Other recommended clones are DN-2, DN-5, DN-70, DN-182, NE-222 (*P. deltoides* x *P. caudina*) and I-45/51 (*P. deltoides* x *P. nigra*) (Hansen et al. 1994). Nursery supplies of all clones is increasing although current demand is high in relation to supply especially as planting season nears. The scarcity of suitable clones has lead us to place a high priority on state and regional breeding efforts (see subsequent section).

Dormant stems are harvested from stool beds, usually in December, then cut into 10 inch cuttings and stored either frozen or refrigerated until shipment. Cutting quality guidelines are currently limited to size categories with an acceptable caliper range of 3/8" (~1.0 cm) to ¾" (~1.9 cm). Shipment by refrigerated transport is recommended. Cuttings are soaked in water at room (ambient) temperature to stimulate root growth. Soaking lasts for about 5 days, but cuttings should be observed frequently so they can be planted before adventitious roots are fully emerged and subject to damage.

Cuttings are mostly planted by hand in Minnesota. Fields can be scribed in two directions using a variety of mostly custom-built tractor-drawn tools. Two-directional scoring yields even spacing in both directions which eases cultivation throughout the first growing season. One-directional scoring often yields uneven within-row spacing that can limit cultivation to one direction, especially when cuttings are planted by machine. Then, weed growth within the row is more difficult to control. Poor within-row weed control can, in turn, increase reliance on chemical strategies. The most serious noxious weed problem in our plantings has been various species of thistle that are unaffected by Oust™ . We have controlled thistle (*Cirsium* spp.) by mid-season spot application of Stinger™ . Actively growing poplar trees are not killed by Stinger™ but we have observed some transient stem and leaf deformation, perhaps as a result of the chemical possessing limited auxin activity.

Proper use of chemicals usually results in a weed-free plantation through mid-July of the first year. Then, aggressive mechanical tillage is required because weeds will inevitably outgrow newly planted trees through this part of the summer. We have observed that, in some plantings, as much as 2/3 of total first year growth in height, stem caliper, and leaf number occurs after August 1, thus it is important to continue cultivation throughout the first growing season.

Cultural practices in years 2 and 3 are much the same as in year 1. Fall application of Oust™ and/or Roundup™ is recommended after leaf drop. Spring application at reduced rates prior to flushing, or even greening, of the buds is an alternative. Mechanical cultivation continues throughout year 2. Crown closure occurs late in year 2 or during year 3 at which time weed control treatments may be suspended. Mechanical cultivation for non-weed management objectives such as soil aeration may be continued, however we have little solid research that documents whether such cultivation is beneficial.

Plantations are not commonly irrigated in Minnesota. But, we are aware that corporate interest in this practice is surfacing. Whether the marginal benefits of irrigation, which can be manifold considering the ease with which mineral nutrients and pesticides can be applied in addition to water, outweigh marginal costs has yet to be determined.

Acreage and Expected Yields

Minnesota now contains approximately 6,000 acres of intensively cultured hybrid poplar plantations, mostly attributable to three activities. First, almost 2,000 acres have been planted in the vicinity of Alexandria, Minnesota with support from the Biofuels Feedstock Development Program of Oak Ridge National Laboratories (ORNL) and with landowner assistance from the Minnesota DNR and WesMin RC&D. Plantings are up to three years old and new plantings have been established as recently as 1996. Lands are predominantly enrolled in CRP, with landowner costs partially subsidized by the CRP, Minnesota DNR tree planting incentives, and operational support from ORNL. Second, an additional 2,000 acres have been established in the vicinity of Crookston, Minnesota. Landowners in the Crookston project are mostly under long-term contract with Minnesota Power and Light and receive technical assistance from the University of Minnesota, Crookston and the Agricultural Utilization and Research Institute, Crookston. Lastly, about 2,000 acres have been planted by various fiber-using companies. Land ownership in this class mostly includes acreage that has been under long-term corporate ownership or that has been recently acquired specifically for the deployment of intensively cultured plantations. Some uncontracted plantation establishment by individual landowners is found in addition to the aforementioned activity. The ultimate grower-consumer relationship is difficult to define at this time. A mosaic of many different strategies involving land ownership, risk sharing, and cash flow agreements may be the most likely outcome.

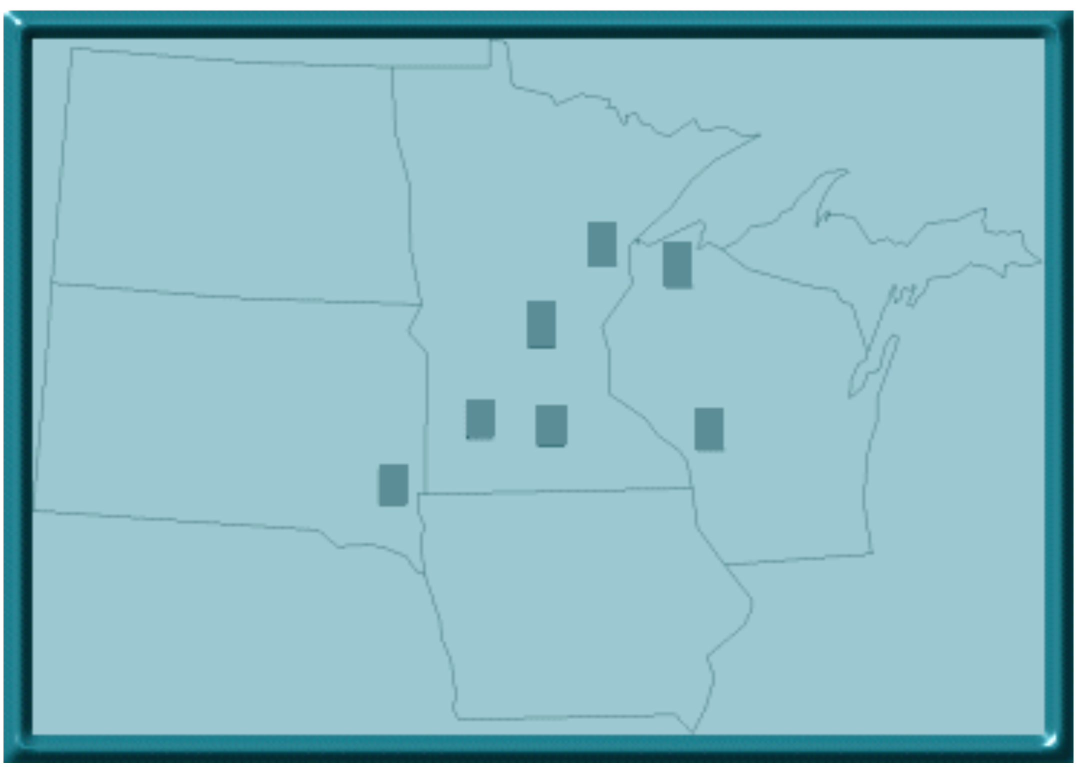

Figure 2. Location of test plantations in the plantation network.

Most intensively cultured plantings in Minnesota are three years old or less. However, some large-plot yield trials were established in 1987 and 1988 (Figure 2) and limited yield estimates are available (Table 1). Data demonstrate the importance of both site selection and clone selection (Table 1). Indications are that choice of the proper site can be as important as selection of the proper clone (Table 1). Mean annual increment shows indications of culmination in some plots at the end of age 8 or 9 years. However, we believe that additional study is required for three reasons. First, analysis has shown that leaf nitrogen content in most plots has declined to about 2%, which may be insufficient to sustain rapid growth past mid-rotation. None of the studies described here have been fertilized after year four, but mineral fertilization is planned in the future, after which growth increment will be reevaluated. Second, our equations relating tree diameter and height to total above-ground biomass have not been recently re-calibrated. Experience has shown that biomass equations developed in our region inevitably underestimate biomass when the calibration population is younger than the population of current interest. Sampling is now being done to develop new equations. Last, culmination of mean annual increment in our research plots appears to be both site and clone dependent. Knowledge of the true regional range in culmination, and thus the ability to forecast yields and construct prudent silvicultural recommendations, can only be determined after culmination has been clearly demonstrated over a wide range of sites and clones. Overall, current research has demonstrated that yields based on the use of best practices can approach 5 dry tons per acre per year (Table 1).

Table 1. Mean annual increment at age eight and nine years of hybrid poplars in a network of plantations over North Dakota, South Dakota, Minnesota, and Wisconsin. Clones included in the calculations were DN- 17, DN-34, DN-182, NE-308, and Siouxland.

Basis	Yield (dry tons per acre per year)
All clones over all sites	3.0
Best clone over all sites	3.3
All clones on best site	3.9
Best clone on best site	4.7

Current Research Emphasis

Landowners and industry in Minnesota are fortunate because a research infra-structure has been in place in Minnesota for many years. In fact, much of the intensive culture technology that has been deployed in the Northwest and South was originally developed by USDA Forest Service, North Central Forest Experiment Station and cooperators at the University of Minnesota with support from various programs at ORNL.

A new hybrid poplar research cooperative has been organized with funding from the Minnesota State Legislature and Minnesota wood-using industries. Current research, supported by the new cooperative and ORNL, has several emphases.

First, we are developing new clones through breeding and selection. Over 10,000 new clones of eastern cottonwood, F1 hybrids between eastern cottonwood and other species, and advanced generation backcross populations have been produced with the objective of increasing the genetic diversity of hybrid poplar production populations. Selection criteria include growth potential, adventitious rooting ability, and resistance to Septoria canker. Studies of rooting ability are of special interest because a large component of our selection program is devoted to pure eastern cottonwood, which roots erratically in our region under commercial planting conditions. Resistance to Septoria canker is also critical because that disease limits deployment of our fastest-growing selections. Early selections from nursery tests are entered into an ORNL-supported regional clone trial program with test locations in Minnesota, Wisconsin, Iowa, and Michigan.

Second, we are studying new vegetation management strategies that include use of more effective and environmentally benign chemicals, along with mechanical tillage methods. Third, we are revisiting previously established guidelines for planting stock quality and planting methods with the objective of increasing early growth while reducing planting costs. Fourth, we continue to monitor growth and yield of large plot clonal trials established as early as 1988. Research partners in this cooperative include University of Minnesota, Crookston; The Agricultural Utilization and Research Institute, Crookston; The Natural Resources Research Institute, Duluth; The University of Minnesota, Department of Forest Resources, St. Paul, and the USDA Forest Service, North Central Forest Experiment Station, St. Paul.

Summary

Deployment of intensively cultured hybrid poplar plantations is feasible in Minnesota. Yields are lower that those achieved with similar methods in the North West and South, but costs are lower as well. We have demonstrated that a combination of wise site and clone selection can produce potential yields of 4.7 dry tons per acre per year. A combination of factors including competing forest uses, industrial expansion, and the age distribution of native aspen stands has caused increased interest in the deployment of intensively cultured plantations to increase fiber supply. Several groups have established approximately 6,000 acres of plantations, mostly three years old or less, in Central to North Western Minnesota. A substantial research infrastructure exists to support the sustained development of intensive culture technology. Current research emphases include genetics, cultural improvements, vegetation management strategies, and growth and yield studies.

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Guidelines for Drip Irrigation and Fertigation of Pines and Hardwoods

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Introduction

Drip irrigation technology is relatively new to the forestry industry. As with any new technology, the objective of drip irrigation is to maximize profits through optimizing tree growth, resulting in higher yields and better quality. For that purpose, drip irrigation is considered as a system to grow short rotation woody crops rather than just a method of irrigation. In order to use this technology to its fullest potential, the basic principles that constitute a drip irrigation system need to be understood.

The concept of drip irrigation is to create a continuous wetted strip along the tree line. This wetted strip should be homogeneous and uniform thus providing even distribution of water and nutrients to the trees. The even supply of water and nutrients directly to the root zone creates an optimal environment for the roots to efficiently absorb the soil solution in order to maximize growth.

Drip irrigation delivers precise amounts of water in a very uniform fashion directly to the root zone without runoff, wind drift, leaching below the root zone or wetting the canopy. Furthermore, the dripperline applies water only to a portion of the surface thus maintaining high moisture within the root zone without water logging due to dry surroundings. These facts permit the use of "marginal water" such as wastewater, mill effluent and brackish water. Marginal water can be used through drip without the risk of injuring the canopy, building-up high concentrations of salts or leaching contaminants into the groundwater. However, only the careful selection of a dripperline will bring the full expression of the aforementioned benefits.

Dripperline Selection

The selection of the most effective dripperline is comprised of determining the best type of dripper, dripper discharge (flow rate) and spacing. The continuous wetted strip consists of individual wetted "bulbs" which, to a certain degree, overlap each other. The size and shape of the "bulbs" are determined by the dripper's discharge, soil type and duration of the application.

- Dripper Discharge – The higher the flow, the better the lateral movement.
- Soil Type – The heavier the soil, the better the lateral movement.
- Duration of Application – The longer the application, the better the lateral movement, to a certain degree.

The distribution of water into the soil profile from a point source is very different compared to overhead irrigation. In overhead irrigation, the water moves through the soil like a piston. The upper layer is saturated before the water reaches the lower layer. As the water progresses downward, it forces the air out of the wetted soil profile.

In drip irrigation, the soil moisture created by a point source includes all of the various states of moisture from saturation to dry soil. By providing this array of different moisture levels within the root zone, we enable the roots to "choose" the optimum combination of water, oxygen, and nutrient absorption.

There is a differentiation in soil moisture dependent on the distance from the point water source in drip irrigation. This has a detrimental affect on the placement of soil moisture metering devices and their ability to represent the true fluctuation of moisture related to consumptive use and application. For example, placement of such devices within the saturated zone will result in relatively high, flat moisture readings.

The following table will help new users to select the appropriate dripper discharge and consequently, the resulting spacing as related to the specific soil type. Please note there is a trade-off between discharge and spacing on a given soil type and between these two, on different soil types.

Dripper Discharge (ltr/hr) and Recommended Spacings (m)			
SOIL	2.0 ltr/hr	4.0 ltr/hr	8.0 ltr/hr
Light	0.4 x 0.4	0.8 x 0.8	1.2 x 1.2
Medium	0.8 x 0.8	1.2 x 1.2	1.6 x 1.6
Heavy	1.2 x 1.2	1.6 x 1.6	2.0 x 2.0

There is a minimum coverage, expressed as a percentage of the wetted strip from the total available tree's surface, for the drip system to be operable under real world conditions.

P=Available Wetted Area/Available Tree Area x 100
P greater than or equal to 35 – 40% Relatively Low Rainfall
P greater than or equal to 25 – 30% Humid Area

The minimum coverage under rainy conditions should be 25 – 30%. The coverage will depend on the type of tree, root zone characteristics, soil type, and climate. Certain trees will be less sensitive to changes in root structures than the others. Some trees have wide and superficial root systems as opposed to a deep, tapered root system. Eventually, trees in a lighter soil will benefit from a wider wetted strip. Frequent rains can always compensate for a narrower wetted strip. Other factors that affect the selection of the dripperline include topography, water quality, and agro-economics.

The only way to use drip irrigation economically (or at all) on a rolling terrain is to use a pressure compensated dripperline. Even on flat ground where it is not hydraulically necessary to use a pressure compensated dripperline, selecting such a line will permit longer runs resulting in overall lower costs as well as extremely accurate and reliable performance.

Not all drippers are alike in terms of accuracy, clogging resistance and durability. On some fiber farms, the water source may be surface water (creek, pond) or mill effluent. These water sources contain numerous contaminants and organic slime. Only years of field tested and proven dripperlines which are equipped with a self-flushing mechanism and, if needed, an internal algae control device, should be selected.

Agro-economical factors should also be considered. In some instances, the drip systems may have to retrofit to an existing infrastructure. This obviously limits the flexibility of the system selection and design. Automated systems are normally less expensive because the flows can be reduced on the expense of time.

The most common spacings and flows which are being used in forestry are listed below.

- 40" -42" @ .92 gph
- 36" @ .92 gph
- 24" @ .92 gph
- 36" @ .61 gph
- 42" @ .42 gph

Irrigation Scheduling

There are several methods used to schedule irrigation. We have selected what is commonly referred to as the bookkeeping or budget approach. The peak demand is estimated based on prior experience, available case studies, literature, and weather data from universities and agricultural operations. For example purposes, we will use a stand of 500/trees/acre which is considered average for short rotation woody crops in the Southeast.

Estimating the peak demand of water consumptive use in various stages.

- Peak demand for a mature forest in the Southeast is 1.25"/week.
- Peak demand at first year is ~ 0.5"/week.
- *Assuming 500 trees/acre=approximately 3.5 gallons/tree/day.*

In the Southeast, most soils under short rotation woody crops (SRWC) are sandy loam soils. The total water retention capacity of a typical sandy loam soil is 1.3"/ft. Therefore, assuming a root zone diameter of 5' and 12" depth, the total water holding capacity in the first year is approximately 16 gallons. The maximum depletion of the available water is established at 50% to prevent any stress to the trees. That equates to eight gallons of allowable depletion. Consequently, the irrigation interval would be every other day at eight gallons/tree/application. The duration of the application will depend on the characteristics of the drip system. A dripperline spacing of 40” at 0.92 gph on a tree spacing of 12’ x 7’ will result in a flow of approximately 2 gph/tree or four hours of irrigation every other day.

Based on all of the above, the following table depicts a tentative irrigation schedule for SRWC first year in the Southeast. Some species of fast growing hardwoods like cottonwood may require a slightly higher water application.

	April	**May**	**June**	**July**	**August**	**September**
Gal/Tree/Day	2	2.5	3.5	3.5	3.5	2.5
Interval (days)	4	3 – 4	2	2	2	3
Hours of Run	4	4 – 5	4	4	4	4

Fertigation

Fertigation is the essence of drip irrigation. Drip irrigation should actually be viewed as a method of growing crops and not simply as a method of irrigation. Many times people tend to compare drip irrigation to overhead irrigation (pivots, sprinklers, mini-jets) or flood irrigation. This is not an accurate comparison because the latter methods are viable mainly for irrigation while in drip irrigation, fertigation is a very integral part of the system. Fertigation is a must in order to realize the full potential and benefits of the system. Drip irrigation can be used solely for irrigation and would still be the most efficient method, but the foremost benefits are lost.

In many cases, depending on the year and location, the drip system is used predominantly as a fertigation system. In seasons or climates with abundant rainfall, there is many times no need to irrigate, but there is an obvious need to fertilize due to significant leaching conditions. Applying the seasonal amount of fertilizers in small doses at high frequency (spoon-feeding) will ensure a continuous and stable supply of nutrients. Moreover, this method meets the tree’s growth requirements without leaching the fertilizers below the root zone.

The advantages of fertigation are:

- Less labor, equipment and energy needed for receiving, storing and fertilizer application.
- Reduced soil compaction.
- Prevents damage to crop during delivery.
- No restrictions or limitation on application timing.
- Accurate and uniform distribution for superior efficiency.
- Application restricted to most active root zone which reduces waste.
- Adaptability of nutrients supply to the growth curve resulting in better crop

response.

- Split applications for better control of run-off and leaching into groundwater.
- Extremely efficient method of accurately delivering uniform, minute quantities of minor elements.
- Complete adaptability to automation.
- Can be used for other purposes, i.e. pestigation, soil amendments, maintenance.
- Can overcome negative effects of saline/waste water.

Fiber farms are already using systemic insecticides through the drip system to control the cottonwood leaf beetle. Chlorine and acid can also be injected to maintain the cleanliness of the dripperline. Furthermore, certain nutrients can be injected into wastewater, that may contain toxic elements, to counteract their negative effect on tree growth. In many cases, the water contains relevant nutrients such as calcium and magnesium. These elements should be considered as a part of the Fertigation program, in addition to their clogging potential.

In an attempt to determine a formula for Fertigation of SRWC, we collected data from several studies that concentrated on the removal of nutrients by pines and hardwoods. There is not much information in this field due to the fact that, until recently, fertilization of stands was not a common practice. One of the studies suggests the following formula which was put together by Dr. Claus Steinbeck.

Element	N	P	K	Ca	Mg	Mn	Zn	Cu
Lbs/ac/yr	150	30	60	60	20	0.5	1.5	0.3

Another study suggests the following ratio:

N P K Ca Mg
7 : 1 : 7 : 7 : 2

Based on the latter formula, we recommend the use of 8:2:8 as a complete liquid fertilizer that might be enhanced by adding some minor elements like B and S. In some cases along the East Coast and Southeast, phosphorus levels are notably high and therefore the phosphorus can be omitted and calcium and/or magnesium may be added if needed. It is always preferable to apply calcium and magnesium pre-plant as part of the liming or, if pH adjustments are not required (pines), to utilize land plaster and K-Mag.

The underlying concept of Fertigation is to build an adequate level of P, K, Ca, Mg using pre-plant applications which will be always significantly less expensive compared to liquid fertilizer. And then maintain these levels using Fertigation. To summarize Fertigation:

1. Pre-plant applications might include P, K, Ca, Mg, S, Lime and minor elements – all based on soil analysis.
2. It is preferable to use a complete liquid fertilizer containing N, P, K and minor elements especially in very sandy soil. In medium to heavy soils, only N and K might be used on a continuing basis.

3. Sources of N may include: A.N., urea, A.S., Urea + A.N.
4. Sources of P may include: H_3PO_4, A.P.P, M.A.P., M.K.P.
5. Sources of K may include: KCl, KNO_3, M.K.P.
6. Minors should be chelated.

Conclusion

The success of drip irrigation in forestry will depend on the capacity and the ability of the system to optimize distribution of water and nutrients thus resulting in high yields and better quality.

The prerequisites necessary to ensure optimum performances are:

- High quality products with years of field proven results.
- Appropriate selection of spacing and flows based on soil, water and tree types.
- Complete fertigation program based upon soil and water analysis.
- Irrigation scheduling based on crop demand, soil characteristics and system features.
- A fundamental maintenance program.

Water Resource Planning Considerations for Irrigated Short Rotation Intensive Culture Projects

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Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

Implementing a large-scale short rotation intensive culture (SRIC) project requires a significant quantity of water. In order for the project to be successful and profitable, the right mixture of water resources must be identified and acquired. Careful planning is essential.

How Much Water?

For the purposes of discussion, we have estimated the water demands of a generic largescale SRIC project in the eastern United States. Using generalized water uptake rates for poplars, sweet gums, and sycamores, we have estimated peak-month irrigation demand and the annual water usage. The quantities shown in Figure 1 provide a rough indication of the amount of water that is needed for an SRIC project, based on 1.33 inches per week peak month water use at 90 percent efficiency and 40 inches per year irrigation requirement. In actuality, it would vary according to the types of trees planted and an assortment of site specific factors such as soil moisture, groundwater levels, and climatic conditions. Nevertheless, these estimates give an idea of what is meant by "significant quantities." For a 1,000-acre plantation, for example, approximately 5 million gallons per day (mad) would be needed. For the year, that plantation would need about 1 billion gallons. Five thousand acres would need 26 mad, which is equivalent ta the daily usage of a city with a population of 200,000.

Potlatch Corporation's hybrid poplar SRIC plantation in the desert near Boardman, Oregon, provides another example of the kind of water demand that can be encountered. The plantation is planned for 22,000 acres, about half of which are currently planted. The total projected water demand for the plantation is over 200 mad. The rate is high because of the hot, dry climate, with 10 inches of rain annually and a long growing season, but the production rates from this area are among the highest in the country. Depending on its location and other factors, the associated water demand of an SRIC project can range from impressive to astonishing.

Water Use Trends

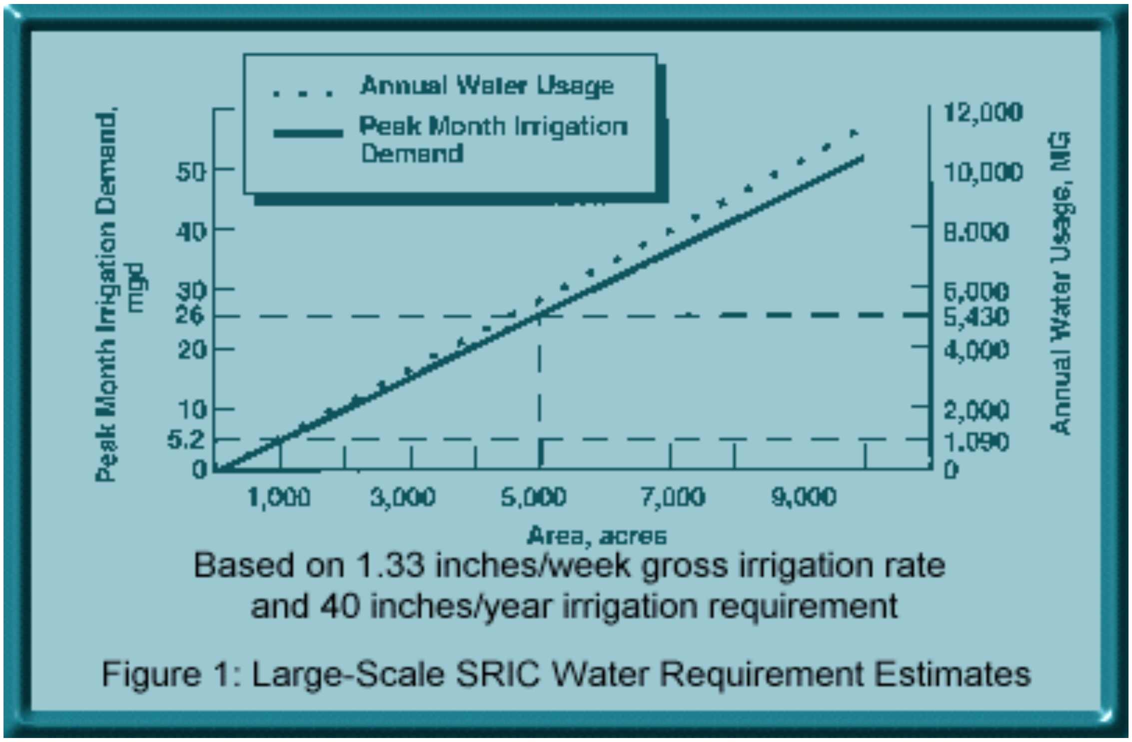

Figure 1: Large-Scale SRIC Water Requirement Estimates

Irrigated SRIC plantations represent a relatively new phenomenon in agriculture that has developed in the last decade. In the east, many forest products companies are determining the feasibility of developing SRIC plantations ranging in size from 1,000 to 10,000 acres. In the west, companies such as Potlatch, James River, MacMillan Bloedel, and Boise Cascade have already implemented large-scale irrigated SRIC projects. Water demands for SRIC projects will have a significant impact on water resources in the given area. Even without additional water use by SRIC projects, the water withdrawals and consumptive use of agriculture are higher than any other sector, as illustrated in Figure 2. The thermo/electric power sector used comparable volumes, but returned most of what it took; whereas irrigated agriculture consumed a high percentage of what it took—via evapotranspiration. In 1990 all sectors consumed approximately 105 million acre-feet of water. Irrigated agriculture accounted for 81 percent of that. Clearly, irrigated agriculture is a substantial water user.

Current and projected trends point to increased competition for water resources. This competition has been at the forefront in the western states, but is beginning to arise in the eastern states as well. Irrigated agriculture or silviculture are increasingly facing a tug of war with other interests for the limited supply of water available. Other interests include public and domestic users, industry, environmentalists, and regulators.

For example, Tampa Bay and north Florida are contending for control of the Suwannee River water supply. Tampa Bay wants to pipe water from north Florida to meet its water demands because of dwindling local sources. Also in Florida, environmentalists are attempting to reduce agricultural uses of water to provide more water to the Everglades. Another example of the current trend is the battle that the states of Georgia, Florida, and South Carolina are having about over-pumping of the Floridan aquifer, which is causing salt intrusion along the coast. Similarly, concern about mill wastewater discharges is increasing.

The public's concern about environmental issues is heightened, but its concern about agricultural needs is relatively flat. Urban industrial demands are increasing in certain areas of the country, especially in the southeast, in Florida, South Carolina, and Virginia. Moreover, regulatory

limitations on surface and groundwater withdrawals have become stricter. In some states, for example, the regulatory agencies require permits for the consumptive use of water. In Florida or South Carolina and in most western states, an SRIC project would need such a permit.

Planning is Critical

Because of the large water requirements, multiplication of contending water users, and tighter regulatory constraints, a comprehensive water resources management plan is critical to the long-term success of any SRIC project. The planning should be done for full-scale operations, not just for the prototype or demonstration project. Full-scale planning activities help to identify pitfalls early in the process. A long-term perspective also helps the participants to identify the least cost mixture of water supply alternatives. In general, development of a comprehensive water resources management plan is done in three steps:

1. Determine current and future irrigation demands.
2. Appraise all possible sources of water to meet the estimated demands.
3. Select the most economic approach for satisfying the projected demands.

While straightforward in concept, the planning process may become complex in practice. Depending on the size and nature of a particular project, several detailed investigations and studies could be required to develop a viable plan.

An important element of the planning process is the collection of information. This includes stream flows, meteorological data, well capacities, water quality data, types of soils, and topography. Important decisions will be made on the basis of this information. The water demands of the project must be projected and consumptive use permitting constraints identified. Also, the project should be examined to see how the water demand will vary throughout the year, during the irrigation season, and as the trees mature. Average day and maximum day demands should be projected.

After the prevailing circumstances and the projected water demand characteristics have been identified, then the search for water supply sources can begin. This analysis should include consideration of all potential sources, how available they are, the timing of their availability, and how their capacities will vary throughout the year. How will the supply vary diurnally and seasonally? Is the water quality compatible with the proposed crops and soil types? The long-term reliability of each viable source should be determined. The investigation of water resources will probably entail careful review of the water rights permitting involved. On many projects in the western United States, water rights are an important component of the project.

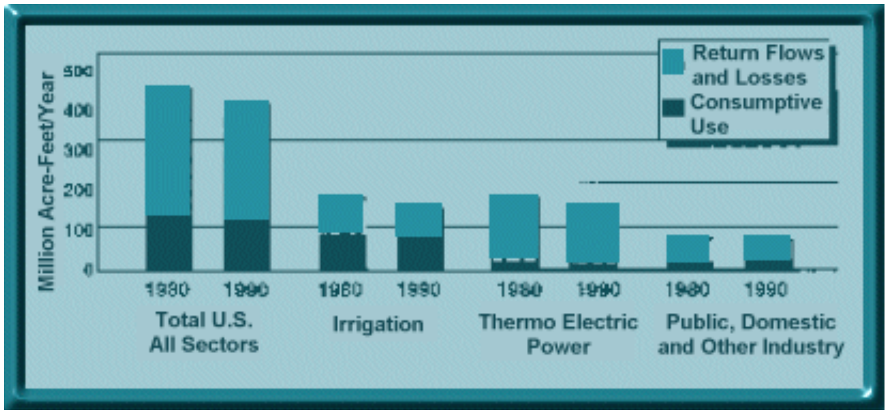

Figure 2: Water Withdrawal and Computer Use in the United States

When the sources have been reviewed, the different ways to regulate their flows can be analyzed. The required storage capacities need to be determined based on the locations, quantities, and occurrences of the various water supplies. Will surface or subsurface storage be required to meet irrigation needs? Typically, if groundwater is the main irrigation source, then additional storage is not required because the aquifer serves as a storage component. When required, surface storage reservoirs are normally adequate for most projects. If land is not available for surface storage facilities, or it is cost-prohibitive, alternative storage strategies, such as aquifer storage recovery (ASR) could be considered. ASR is a water management technology in which water is stored underground in a suitable aquifer through a well during times when the water is available and recovered from the same well when needed. Three principal criteria that govern ASR applicability are as follows:

- Variability in the water supply that does not match demand.
- A minimum scale of development exists, below which ASR may not be cost-effective. The development costs for the first well can be considerable. Subsequent wells can usually be brought on at a lower cost. As a preliminary guide, water supply and demand should be such that a minimum of 1 mad ASR recovery capacity should represent a useful addition to assist in meeting peak or emergency system demands. For most SRIC systems, this requirement is normally achieved.
- A storage zone that meets hydrogeologic, hydraulic, geochemical, water quality, and regulatory criteria must exist at the site.

As part of the comprehensive water resources management plan, it is important to identify the transmission system components needed and the best routes for the pipeline to the potential SRIC site.

Economic considerations are, of course, paramount in such enterprises. Typically, it is worthwhile to perform a least cost analysis that looks at various combinations of the alternatives. This should include present worth and annual cost estimates. The analysis should address anticipated capital costs (i.e., planning, permitting, design, and construction) and operating expenses for each alternative. Within this analysis, an evaluation of the benefits that will result from the implementation of each alternative should be conducted. Also, while conducting the financial analysis, project phasing should be considered with respect to annual cash flow limits for the project. Appropriate phasing can be an important factor in determining the economic viability of the project.

Additionally, the planning effort should address operations and maintenance requirements and establish the level of redundancy that is acceptable, which will significantly affect the costs associated with the project. Reasonable and sound operating budgets should be formulated, and energy and water efficient irrigation systems should be considered to make it a cost-effective project. Recently, CH2M HILL designed an automated drip irrigation system to precisely deliver filtered, chlorinated, and fertilized water to the root zones of 12 million trees at the Potlatch Corporation poplar plantation in Oregon. The plantation draws water from the Columbia River and delivers it through nearly 500 miles of main lines, 19,000 miles of drip irrigation tubing, and 24 million drip emitters. The pumping systems will cost over $1 million per year to operate. Maximizing the efficiency of water and energy use was crucial to controlling production costs and making the project feasible.

Alternative Irrigation Water Sources

An essential element of the planning process will be determining whether the native groundwater and surface water sources available will be adequate for the project. If they are not, or they are not affordable, then it is worthwhile to consider alternative sources. The types of sources available will presumably be different for each location. Some common alternative sources are:

- Mill effluent
- Domestic wastewater and biosolids
- Stormwater runoff and irrigation return flows
- Food processing wastewater
- Other industrial wastewaters

Pulp and paper mills produce approximately 4.2 billion gallons per day of effluent in the United States. Only 0.1 percent of that is currently land applied—and reuse is done at only nine mills in the nation. This yet-to-be-exploited water source could be very valuable to an SRIC project. Moreover, the pulp and paper industry will probably be under pressure from environmental groups to increase their reuse percentage to reduce waste loads to receiving streams.

If a city is close to the project site, then it would be an oversight not to consider application of reuse water or biosolids from domestic wastewater treatment plants. Stormwater runoff from cities, industrial areas, and irrigation return flows could be other potential sources. A site with well drained sands will not generate much runoff, but in some states, particularly in Florida, large irrigation projects are required to have stormwater management systems for pollution abatement. If it is already necessary to construct such a system, then it may be feasible to take advantage of the collected runoff as an irrigation source. Food processing wastewater and other industrial wastewaters in the vicinity should not be overlooked as potential sources.

Water quantity will be the factor that initiates the search for alternative sources, but water quality may be the factor that determines their suitability. Example water quality values for effluents from kraft mills, secondary treatment plants, and beverage distillation facilities are summarized in Table 1. The values for kraft mills are typical of those found in the southeastern United States. The values for secondary treatment plants are from EPA guidance documents. The values for the beverage distillation facility are taken from a CH2M HILL project performed several years ago. The groundwater quality standards for Florida are shown for comparison.

Table 1: Comparison of Selected Water Quality Parameters for Alternative Water Sources (Concentrations in mg/L, except as noted)

Parameter	Typical Kraft Mill Effluent	Typical Domestic Secondary Effluent	Beverage Distillation Process Wastewater	Groundwater Standard
Biochemeical Oxygen Demand	19	25	4,522	None
Total suspended Solids	26	25	5,875	None
Total Dissolved Solids	1,533	100	1,050	500
Total Nitrogen	7	20	877	None
Nitrate	1	18	1	10
Total Phosphorus	0.71	10	65	None
Total Potassium	NA	10	3,691	None
Sodium	404	50	145	160
Chloride	370	45	1,600	250
Color, APHA Units	873	5	750	15
Cadmium	0.005	0.015	0.14	0.005
Iron	0.42	0.1-4.3	10.5	0.30
Lead	<0.9	0.1-0.3	0.83	0.015
Zinc	0.046	0.2-0.44	0.14	5.0
Copper	0.034	0.07-0.14	24.9	1.0
APHA=American Public Health Association				

Biochemical oxygen demand (BOD) and total suspended solids (TSS) concentrations are similar for kraft mill effluent and domestic secondary treatment plant effluent. These values are acceptable for irrigation. Most food processing effluents, however, require additional treatment to reduce the high BOD and TSS concentrations. It is difficult to apply food processing effluents without installation of special filtration systems.

Mill effluent is low in nutrients, so it must be supplemented with nutrient applications. In contrast, secondary treatment effluent is an excellent source of nitrogen and phosphorus. At 20 milligrams per liter (mg/L) nitrogen, it provides about 167 pounds of nitrogen per million gallons (approximately 3 acre feet). At 10 mg/L phosphorus, it provides about 85 pounds per million gallons. The rates of application need to be controlled so that groundwater standards are not violated. This is more likely to be critical on very sandy soils with low water holding capacity. Most food processing effluents provide too much nitrogen, phosphorus, and potassium, and must be treated or diluted.

For mill effluent, the significant parameters to examine are total dissolved solids, sodium, chloride, and color. Compared with the groundwater quality standards, these parameters are typically two to three times higher. That does not mean that mill effluent cannot be used for SRIC irrigation, but it does indicate that the long-term plan must address operational modifications to protect groundwater and surface water quality in the area. Very little information is available to help establish appropriate application rates for long-term salt load management. Pilot projects are recommended to establish loading rates, leaching requirements, and dilution needs. Metals concentrations need to be looked at to see if they might limit the amount of water that can be applied to the crop. For most soils, however, they do not present a problem.

A summary of the benefits and challenges of our four examples of alternative water resources are summarized in Table 2. These include mill effluent, domestic wastewater treatment plant effluent, stormwater runoff, and food processing effluent. Some of the techniques that have been employed to deal with lower quality irrigation water include:

- Multiple, staged filtration systems
- Control valve manifolds for automated irrigation, and frequent flushing of all drip tubes
- Micro sprinklers to distribute high solids wastewater

Table 2: Summary of Benefits and Challenges of Alternative Water Sources

<table>
<tr><th></th><th>Benefits</th><th>Challenges</th></tr>
<tr><td>Mill Effluent</td><td>Water sources typically closer to SRIC site
Large, reliable water source
Reduces or eliminates surface discharge of effluent
Utilizes available nutrients in effluent
Minimizes use of native water sources</td><td>Industrial land application permit typically required
Higher level control of application rates required
Additional land required for on-site storage
Regulatory monitory and reporting</td></tr>
<tr><td>Wastewater Treatment Plant Effluent</td><td>Medium nutrient content; reduces or eliminates N & P</td><td>Domestic wastewater permit typically required
May not be close to SRIC</td></tr>
</table>

	fertilizer • Large, reliable water source; no consumpitve use restrictions • Best water quality • Potential for partnering and cost sharing • Minimizes use of native water sources	sites • Pathogen limits may limit application methods • On-site reservoirs required for seasonal use of year-round source
Stormwater Runoff	• On-site water resource • Recycles nutrients in runoff wter • Also controls other nonpoint source poluution	• Increased cost for reservoirs and stormwter pump station • Low nutrient values; N, P, and K applications required • Loss of area for retention reservoir • Supply varies year to year, not reliable in drought years • High in silt and algae
Food Processing Effluent	• Large, reliable water source • Potential for partnering and cost-sharing • Low concentrations of metals and organic pollutants • High nutrient content	• High BOD and TSS; typically requires additional pretreatment • Stepped filtration systems may be required because of high TSS • May not be close to SRIC sites • Increased wter quality management • Regulatory monitring and reporting

Time domain reflectometry (TDR) or other automated technologies for soil moisture monitoring

- Modifying the irrigation cycle to maximize root zone depth
- Water source blending for water quality control

Alternative Water Source Partnerships

Several good reasons present themselves for a forest products company to establish a partnership with a wastewater generator. Foremost is the possible acquisition of a free, unrestricted water source. Additionally, the wastewater generator may be willing to help defray the costs of the irrigation system infrastructure, because it has been saved the cost of purchasing land for a water reuse application program or additional treatment to meet stream standards. Depending on the nutrient concentrations of the wastewater, fertilizer expenses and operations and maintenance costs could be reduced for the project. The forest products company may also be able to secure a hardwood source through forward contracting with a wastewater generator that has a reuse system and grows trees.

Wastewater generators will be interested in such a partnership because it will help them reduce their wastewater disposal costs. Not only will it reduce their land purchase costs, but it will also establish technical assistance from the forest products company and secure a market for the wood.

A recent present worth evaluation of disposal options for a municipal wastewater treatment plant (WWTP) in southeastern United States serves as an example of how the costs that wastewater generators face may render them especially receptive to discussions about implementing water reuse projects with forest products companies. In this instance, it was going to be necessary for the WWTP to upgrade to incorporate advanced wastewater treatment (AWT) or somehow eliminate its current effluent discharges to the river in order to meet more stringent permitting conditions. CH2M HILL analyzed a variety of options including AWT, wetlands treatment, public-access-level reuse, and land application using an SRIC hardwood tree plantation. The AWT and SRIC costs are illustrated for comparison in Figure 3. The graph shows that the estimated present worth cost for AWT was $46.7 million, whereas the present worth cost for a 1,800-acre SRIC project was $30.7 million. If land salvage costs are considered, the SRIC project cost is reduced to $25.2 million. One of the advantages of the SRIC project is that revenue can be produced in 6 to 7 years to help reduce the overall present worth cost of the option. The AWT had capital costs similar to those of the SRIC, but much higher annual operations and maintenance costs and zero revenue generating potential.

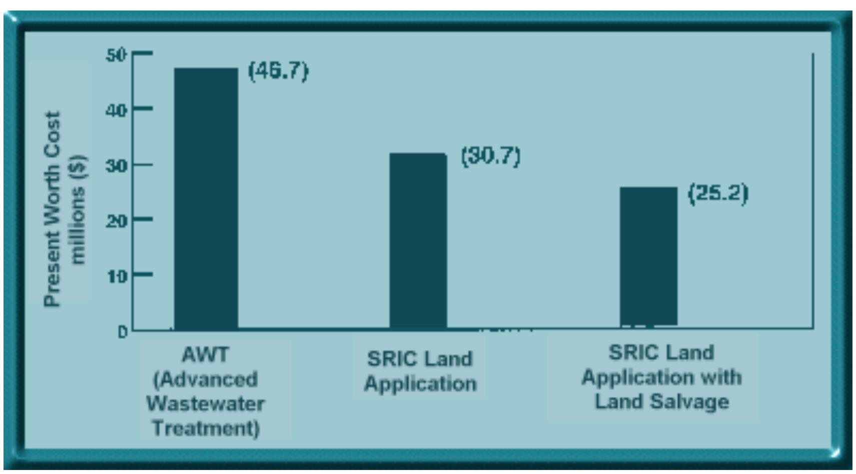

Figure 3: Present Worth Comparison of AWT and hardwood SRIC Land Application Options

Summary

Given the increasing competition for water resources, it is probable that an SRIC project will need to obtain water from multiple sources to meet its irrigation needs. Adopting a "big picture" planning approach will help to ensure the development of a reliable, least cost system. If available, mill effluent and municipal wastewater can be excellent water sources. Water quality usually becomes an issue when using alternative water sources instead of native groundwater or surface water sources, but by employing the appropriate techniques and technological advances in irrigation and monitoring equipment, it is possible to protect the environment and cultivate trees profitably. We encourage forest products companies to investigate partnering opportunities with wastewater generators. Both parties are apt to benefit significantly by the association.

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Weed Control Strategies for SRIC Hybrid Poplar Plantations: Farmer's Perspective

Bill Schuette and Chuck Kaiser, James River, Clatskanie, OR

Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

Several speakers during this conference have mentioned the importance of weed control to their programs when growing SRWC species. Westvaco aptly demonstrated the need during the excellent field tour of both their river bottom and irrigated plantations. From a farmer's perspective the whole topic can simply be stated as "Weeds are Bad".

Why is weed control so necessary for short rotation woody crops such as hybrid poplar? One clue may be found in the ecological mechanisms which lead to establishment of native cottonwood stands. These stands are often established from seed and vegetative material deposited on freshly scarified riparian areas. Native stands are also subjected to repeated flooding that can limit herbaceous growth during the establishment period. Secondly, much silvicultural research has been conducted throughout the United States confirming the ecological effects of weed competition on hybrid poplar. A review of this research verifies that stand growth and yield can be improved significantly by controlling weeds during the early years of establishment. Figure 1 demonstrates the effect of four levels of weed control on a hybrid poplar stand in the Pacific Northwest. Finally, protection problems can be dramatically increased when weed control is not done in poplar plantations. Unwanted vegetation can become habitat for pests such as rodents, slugs and insects.

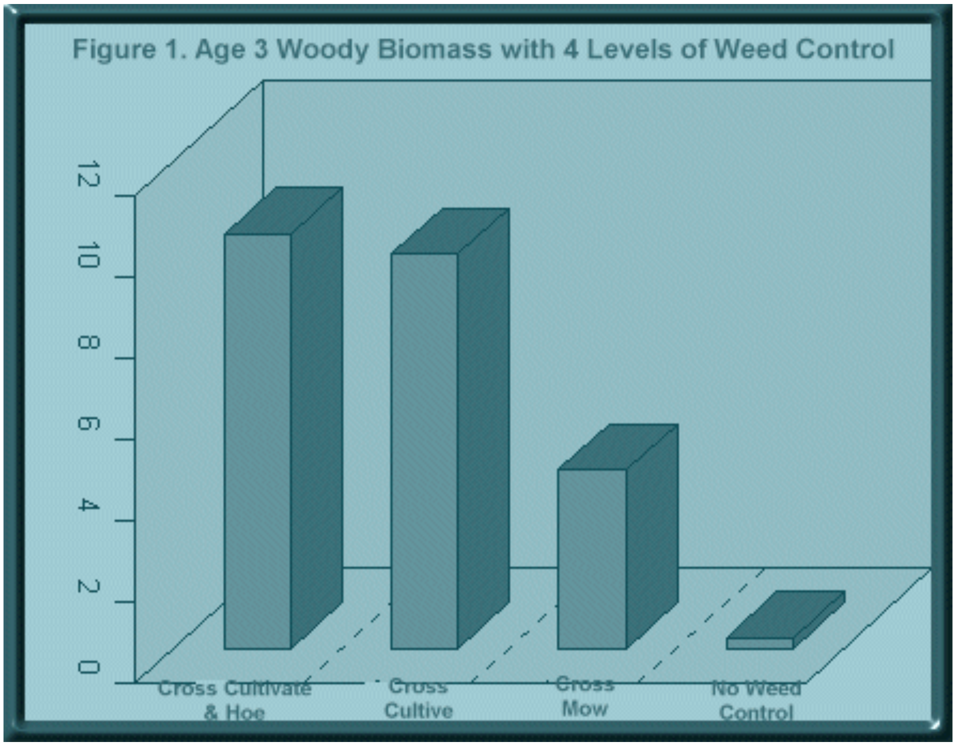

Figure 1: Age 3 Woody Biomass with 4 Levels of Weed Control

Most agronomic strategies for controlling weeds begin at site preparation and continue during the first two to three years of plantation establishment. The machines and methods for accomplishing this strategy may vary from region to region but usually consist of mechanical, chemical, and manual cultivation, or a combination of all three. Intensive site preparation begins with mowing or flailing to remove tall grasses and broad leaf weeds and to stimulate new growth. When new vegetation begins to flush, the field can then be sprayed with an emergent herbicide (glyphosate or 2,4-D) and allowed to sit until the weeds begin to breakdown. The field is then disked or ripped twelve to fourteen inches deep to prepare a proper seed bed for planting. Variations of this strategy include the sowing of cover crops between tree rows to stabilize soil or provide wildlife forage. This site preparation is essential for controlling existing weed rhizomes. It also stimulates the germination of the “seed bank” that has accumulated over the years especially if the ground had been in a less intensive cultivation regime prior to plantation establishment. At the same time, controlling the existing vegetation also acts to reduce production of new weed seeds. James River Corporation in the Pacific Northwest will prepare raised beds 24 inches wide by 18 inches high as a final operation in the fall prior to planting the following spring. This “hill”, besides providing a guide for hand planting also stimulates earlier spring growth by warming the soil faster and elevates the cutting out of detrimental field conditions such as standing water. Other operations will rip planting slits to mark tree rows and facilitate planting.

Herbicides are applied again just prior to planting often using combinations of emergent and pre- emergent chemicals. The emergent herbicide is needed to control winter annuals that have grown since the cessation of fall site preparation and the pre-emergent is used to control any spring annuals germinating from the existing “seed bank”. Herbicide applications are often applied as a band along the tree rows when mechanical cultivation is expected to follow during the growing season. Herbicide bands are typically between four and five feet wide to allow for a complete weed free zone around the trees and enable mechanical cultivators to remove the between-row vegetation in one pass. A dormant season application of both emergent and pre-emergent chemicals is often applied in one year old stands to control winter annuals that grow after mechanical and manual cultivation cease in the fall. Some herbicides are available for use during the growing season but often are restricted to highly selective chemicals which go after one type of weed. Normally these very expensive chemicals are used as a last resort when conventional methods have failed.

A combination of both chemical and mechanical operations are critical in the early stages of plantation establishment. Figure 2 represents a field study conducted by James River which evaluated options for plantation establishment in western Oregon. A combination of chemical and mechanical techniques provided the best survival and tree growth during the first year of establishment. Chemical and mechanical techniques together often provide the operator more options and more flexibility to adjust to seasonal conditions.

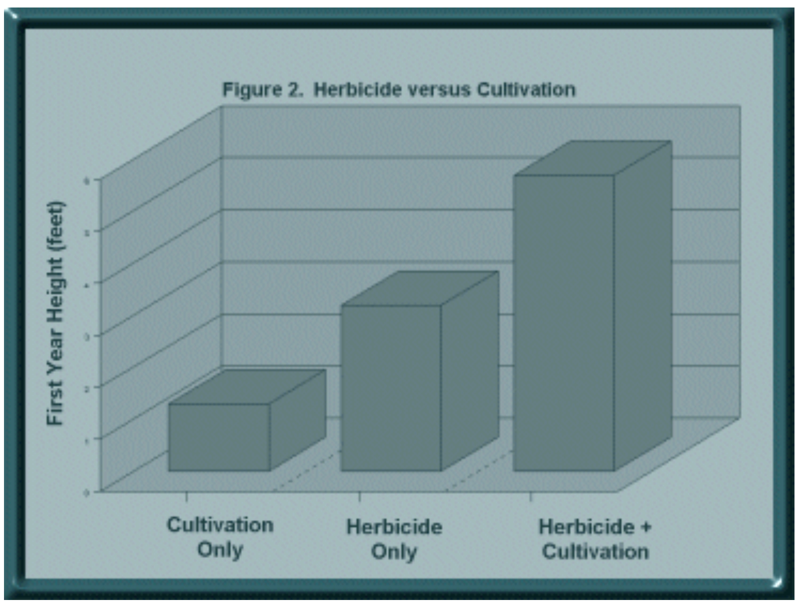

Figure 2: Herbicide versus Cultivation

Mechanical weed control can take many forms. Typical between-tree cultivation is accomplished by either rototilling or disking. Both have their strengths and weaknesses. Rototilling gives you better weed control closer to the trees and provides a "soil mulch" for better moisture retention in heavier soils. However, it is much slower than disking and requires multiple sets of machinery to be able to cover a large acreage. Disking has the benefit of using less energy and covering more ground per day but can also dry out the soil. Disking has an added benefit that it can be used on ground having woody debris from post harvest site preparation and can handle higher amounts of vegetation without clogging. Other methods that have successfully been used on first rotation fields are within-the-row cultivators originally designed for the grape industry and manual cultivation (hoeing). Hoeing is sometimes needed to control weeds close to the first year trees when pre-emergent herbicides do not function as intended and mechanical cultivators risk damage. Cross cultivation can reduce some need for hoeing but requires that plantations be planted on a perfectly square spacing. Cross cultivation can increase the chance of mechanical injury. Mowing between trees has benefits when soil loss is a concern but often does not provide the same growth benefits as mechanical cultivation (Figure 1).

Weed control in hybrid poplar stands will continue until the stand has closed canopy and "captured" the site. This may take two to three years in the Pacific Northwest depending on the initial spacing, site quality and clone used. Some stands of eastern cottonwood may never fully close canopy allowing for a permanent understory to develop. Weed control in these stands will often occur until the trees are established and free to grow.

The farmer did a good job of controlling weeds during the first rotation, but now he has a post harvest field consisting of woody debris, limbs, broken pieces of trees, and a few hundred stumps to the acre. Unfortunately, most farmers did not count on this and are unprepared for handling these conditions. Can the same equipment be used as on the first rotation? Probably not. James River Corporation in the Pacific Northwest has chosen to treat second rotation fields as an agricultural operation but has altered the farm equipment to handle the debris and stumps. The large, four-wheel drive tractor used to pull the site preparation disk has had its agricultural tires replaced with forestry, skidder tires. One-half inch steel plates have been welded on to armor the under side of the tractor. Two plastic fuel tanks normally found on each side of the tractor have been replaced with one steel tank mounted over the rear drive wheels. The large break down disk used during the first rotation has been replaced with a heavier, tougher forestry type disk capable of handling stumps and woody debris. Another method that is being employed by both Crown Vantage at Fitler Managed Forest and Westvaco includes using a large bulldozer to shear the stumps just below ground level. A wood rake is then used to wind-row the debris. Bulldozers fitted with brush rakes push the wind-rows into piles which are then burnt. Other methods include the use of orchard flails to grind larger woody chunks into smaller more manageable pieces and the Merricrusher used by MacMillan Bloedel in the Pacific Northwest. Work is also continuing to develop stump grinders that will grind the debris and stump and reincorporate them into the soil. Herbicide and mechanical treatments continue as described previously with the exception that disks are more often used for mechanical cultivation for their ability to handle woody debris. Why go to such great measures to do site preparation? First, the weed bank is still there and needs to be handled. Second, stumps are hard on tractors, equipment, and the people needed for cultivation.

So what's new? A program is now underway to genetically engineer hybrid poplar clones for resistance to some insects and herbicides. Many SRWC companies have joined the Tree Genetic Engineering Research Cooperative based at Oregon State University to work on developing and licensing these clones for operational use. Studies are on-going and some exciting results with glyphosate resistance have already been achieved. If successful, costs associated with hoeing and mechanical cultivation will be greatly reduced. New herbicides are being marketed and tested for compatibility with SRWC species. Many of these chemicals have lower active ingredient rates, less mobility in the soil and better weed control spectrums. In addition, labeled chemicals for poplars are being re-evaluated in different combinations to specifically target certain soil types and environmental conditions. Weed barriers currently being used in vegetable production are also being evaluated for use with hybrid poplar and other SRWC species. The film can be mechanically laid down to form rows with trees being planted directly through the plastic. The film will suppress most of the weeds around the tree and help conserve moisture during the drier parts of the growing season. Cost is a big concern with this technology, however, but it may have application to some situations. There is also concern that some of the plastic residue may find its way to the mill if the trees are processed in the field.

In summary, weed control in hybrid poplar and other SRWC species is essential for plantation success. The methods and intensity of weed control can vary by site, previous land use, tree spacing, clone, and equipment availability. This paper has examined some of the strategies which are successfully being employed to grow poplars in North America, however, any weed control strategy should be refined to the local conditions. Significant alterations in weed control can occur from the first to the second rotation due to post harvest field conditions. New technologies show promise for reducing weed control costs but applications may vary across regions.

Environmental Impacts of Converting Cropland to Short-Rotation Woody Crops

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Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

[Transcribed from tape of presentation]

Abstract

A few years ago the TVA and the Oak Ridge National Laboratory Biofuels Feedstock Development Program decided to look at the feasibility of growing short rotation woody crops to co-fire with coal in TVA's (Tennessee Valley Authority) power plant. Such an effort would require converting thousands of hectares of crop land to grow short rotation woody crops. An environmental impact of converting the land to SRWC would need to be considered first.

Comparing non-woody crops to woody crops was the major focus, but also evaluating an entire rotation of short rotation woody crops to quantify sediment production, nutrient runoff, wildlife impact, groundwater impact, and soil quality impact was also an important concern. This is not only a comparison between crops and trees but a quantitative look at what is happening to a rotation.

The program is sponsored by TVA, the University of Tennessee, Alabama A&M University, Mississippi State University, the Oak Ridge Biofuels Feedstock Development Program, and Agenda 2020, which is funded by DOE along with AF&PA and some of the forest products companies in AF&PA.

Three sites were chosen based on portions of the Tennessee Valley Region that economic analysis showed short rotation woody crops might, at some point, be able to compete with other crops. At each site, species were chosen that were appropriate for that particular site given soil resources, the land, whether it was bottom land or upland, and compared to an agriculture row crop that was typical to that region.

Cultural practices that were typical to the region included no-till for corn, silage corn, sycamore, sweetgum, and cottonwood, and till for cotton. Herbicides were used on all sites. Nitrogen/ phosphorus fertilizer was applied to the corn and cotton during the first year. The second year all crops received nitrogen/phosphorus fertilization.

Experimental setups consisted of pentagons pointing down slope to a flume so the amount of flow of runoff water could be measured and water samples collected. Four hand lysimeters were installed 4.5 ft below the surface to collect gravitational water moving into the groundwater table. Water flow was monitored in the flumes. At each site there are berms around the plots to make sure the water was diverted to the flumes. Soil samples were collected before initialization of the study to evaluated the baseline chemistry and physical properties of the soil.

For the goundwater portion at 4.5 ft, which is considered to be approximately the bottom of the rooting zone, lysimeters were installed to catch water percolating down, which is collected in a bottle and pumped back to the surface.

Erosion crops are generally more erodible than tree crops, with spring and fall being a vulnerable period for erosion. Some surface protection is important on any amount of slope that exists. Cover crop strips of 4 feet in width were effective on sweetgum in controlling erosion and they do not compete for moisture and nutrients the first two years.

Runoff of nitrate, ammonium and bio available phosphorus occurred after fertilization in the spring. Nitrate runoff was higher under the agricultural crops and ammonium runoff was higher under the trees. Phosphorus runoff varied with each site. There were large peaks of groundwater nitrate losses following spring fertilization and was greatest under agricultural crops.

The hypothesis for the future is that trees will make more efficient use of the fertilizer than agricultural crops, which take longer to get established. Also, trees will require smaller third and fourth year fertilizer additions. These conditions will result in less runoff and less groundwater contamination for trees as compared to agricultural crops. A buildup of the litter layer with some minimal weedy ground cover will further reduce erosion under short rotation woody crops in later years.

Harvesting Systems for Short Rotation Woody Crops

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Bryce Stokes, USDA Forest Service, Auburn, AL

Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

Acknowledgment

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Abstract

We conducted a state-of-the-art survey of equipment and systems that are or might be used to harvest short-rotation woody crops. Most equipment currently in use in the US has been developed for conventional forest operations and is probably suboptimal for short-rotation conditions. The notable exception is the agricultural equipment-based harvesters recently developed in Scandinavia for small SRWC harvested as fuel. We reviewed potential means of improving harvesting systems for larger SRWC in the US.

Introduction

Various harvesting systems have been suggested for SRWC plantations for pulp production and biomass energy production. A system may include five functions:

1. felling,
2. in-stand transport (primary transport: skidding or forwarding),
3. separation of pulpable wood from residues (only for pulp production),
4. chipping or other comminution,
5. and stand-to-facility (secondary) transport.

Two or more of these may be combined together in one operation, making the system more compact, and utilizing less equipment. They may be reordered.

Separation is not necessary in the production of fuel for direct-combustion, and chipping would not be included if the trees were to be burned in whole tree form.

Conventional Equipment

Systems Currently Used in the US for Harvesting SRWC

SRWC harvesting in the US has been geared towards the paper/pulp industry with by products targeted, in some cases, for biomass energy production. Essentially all harvesting is carried out with conventional forestry equipment (Stokes and McDonald 1994). The two common systems and equipment used to produce clean pulp chips are described below.

1. Feller/Buncher - Grapple Skidder- Chain Flail Delimber/Debarker - Mobile Chipper - Chip Van (Delimber/debarker residues are comminuted by tub grinder, then transported in chip vans.)
2. Feller-Buncher - Grapple Skidder - Irongate Delimber - Log Truck - Drum Debarker - Fixed Chipper (Residues from the delimber are left on site. Those from the drum debarker are hogged at the mill for fuel.)

Tricycle or articulated rubber-tired drive-to-tree feller/bunchers are by far the cheapest commercially available machines for felling and bunching trees in the 5" to 10" DBH range, to be followed by skidding, whole-tree forwarding or woods-mobile chipping. They cause more soil disturbance than other felling methods. Rubber-tired or tracked limited-area (excavator-style) feller-bunchers are more expensive than drive-to-tree machines, but they can travel in a single track, causing very little surface disturbance.

Rubber-tired grapple skidders are well-proven machines. They are obviously overbuilt for most SRWC plantations; the heavy guarding for machine protection, extreme axle or frame oscillation capabilities for rough terrain, low gearing for handling slopes, and decking blade may have little or no utility.

For pulpwood, separation of wood and residues is essential since bark, small branches and foliage are undesirable in the pulping process. (Whole-tree chips are being used by some pulp mills, but only as very minor fractions of their total furnish.) Delimbing of small trees is carried out by irongates within the stand, or chain flails at the landing. Currently, the two main types of debarkers used in the pulp industry are drum debarkers, typically used in short-wood harvesting operations and located at the pulp mill or a central processing yard, and chain flail delimber/debarkers, used at landings to which skidders deliver whole trees.

Chain flail delimber-debarkers are capable of handling small trees effectively, because multiple stems can be processed simultaneously. They are mobile and do not require much space, so they are used at landings adjacent to the harvesting units. They may (or may not, depending on tree characteristics) recover more pulpable fiber from branches and tops than some other methods. The main disadvantage is the inherently inefficient separation concept, i.e. using a blunt instrument to beat off the bark and limbs, which results in high chain costs and damage to the surface of the bole. Poplar is more easily broken than conifers, so smaller diameter chain must be used to prevent excessive breakage of tops. Debarked trees from the delimber/debarker are fed directly into the chipper. In recent years, manufacturers have produced machines known as delimber/debarker/chippers, which combine a chain flail and a disk chipper into a single machine. This eliminates the need for a second operator. Some new delimber/debarkers incorporate a third drum to increase chain-stem contact. Many operators are using multiple chains on each opening on the flail drum to improve debarking (Watson and Twaddle 1990).

Irongate delimbers, consisting of steel grids resembling stout fence gates, are commonly used in the southeast US. Grapple skidders back the tops of bunches of trees through the openings in the grate, stripping off the limbs. The gates are effective for small stems because many trees can be delimbed simultaneously.

Drum debarkers are used primarily for debarking, but several Scandinavian companies, and Proctor and Gamble in Florida, have us I drums to delimb and debark conifer tree sections or whole trees. Drums are massive, so are installed permanently at central processing yards or at mills. A few mobile models are available.

Essentially any chipper will produce chips that are acceptable for the direct combustion energy market. The ideal pulp chip, however, has relatively tight size tolerances, and larger disk chippers produce the highest quality chips. The blade and anvil on a disk chipper can be set to control chip thickness, and bigger chippers with higher inertia travel at more uniform speeds. Large chippers at fixed installations are powered by synchronous motors and turn at essentially constant speed. Knives on chippers at fixed installations are probably less susceptible to damage from rocks and can be replaced at more uniform intervals. All these factors result, in theory, in better chips from large fixed chippers than from small mobile chippers.

Drum chippers can process larger and less-uniform material than an equivalent-sized disk chipper. Knives on drum chippers are less susceptible to damage by rocks and dirt, and can be sharpened many times without removing the knives, therefore drum chippers are commonly used to produce biomass fuel.

Other Conventional Harvesting and Processing Equipment, not Currently Used for SRWC

Cut-to-Length Systems (Harvesters and Forwarders): Harvesters are much more expensive than feller/bunchers, but are used in many countries or regions where it is desirable to leave residues on site rather than accumulating them at roadside or using them for fuel. They also cause almost no site disturbance, and can create a mat of slash that is traveled on by the forwarders which transport the log lengths to roadside. They have been used to simultaneously delimb and debark eucalyptus. Disadvantages include the extra cost of processing trees into shorter lengths, and the extra downstream costs of handling the multiple smaller pieces. The use of a log-length forwarders has been shown to cause less soil compaction and disturbance than a skidder. Forwarders may cause less damage to stumps, but this is not a consideration for SRWC plantations that are replanted.

Boom/Stroke Processors and Single-Grip Processors typically handle only one stem at a time, although two or three stems can be roughly delimbed by some processors. They can be used at the stump or landing, but any of these machines is relatively expensive for very small trees.

Ring debarkers are used mostly with sawlogs and are located at the sawmills, but rings for smaller trees have recently been developed and may have potential for pulp material. They are the most energy efficient of existing debarking methods, because they use knives rather than impact to remove bark, and are likely to cause the least bole damage. They are usually located in a permanent yard because of their size and the auxiliary conveyers coupled with the debarker. Although combination ring delimber/debarkers have been developed, they were considerably more expensive and are not currently used. The main disadvantage of a ring is the single-stem processing and fixed lineal throughput rate for a given debarker. New designs for smaller stems have higher feed rates.

Golob (1986) proposed the use of front-end loaders for transporting bunches of small whole trees to roadside. This would eliminate the soil disturbance caused by dragging of trees, however it is probably not feasible for trees of 60 feet or longer, because of potential breakage.

Cable systems have been considered for use when soils are too wet to support tractive equipment, but tests at James River (with a Koller 300) showed their costs to be prohibitively high, as expected (Hartsough et al 1992). Productivity is low, and labor costs are high because members of the crew are idle during some parts of the cycle. Intermediate supports, which are time consuming and costly to rig, are needed at close spacing on flat ground.

Disadvantages/Limitations of Conventional Equipment

Conventional forestry machines are designed for rough terrain and a wide range of tree sizes and are therefore usually oversized and more rugged than required for most SRWC applications. While conventional machines could be redesigned for the easier operating conditions, major reductions in cost require non-conventional approaches because of the small size of SRWC trees.

Some conventional harvesting machines, such as feller/bunchers, process about the same number of trees or pieces per hour over their full range of size capability; others handle approximately fixed volumes, independent of tree size. Feller/bunchers are examples of the former, chip vans of the latter. Equipment such as grapple skidders or loaders handle fixed cross-sectional areas, and other, e.g. ring debarkers, have fixed linear throughput rates. For the fixed tree number handlers, cost per volume increases exponentially with decreasing tree size; for fixed area or length devices, costs increase but less dramatically.

Essentially every harvesting system includes some equipment that can be classified as either piece or area or length handling, so harvesting costs must be higher for smaller trees. This is strictly true only for equipment of the same concept and size. Smaller equipment of the same concept is cheaper to purchase and can be designed to process at faster rates; e.g. small ring debarkers have faster linear speeds than those of larger diameter. Labor costs per hour don't decrease, and the smaller tree volume more than offsets the faster piece or area or length handling rate, so, for the same concept, costs per volume still increase with decreasing tree size, even with optimally sized equipment. Since SRWC trees are smaller than the average trees being harvested in conventional forestry, costs per volume will be relatively high, if conventional harvesting equipment is used.

Special-purpose Harvesters for Small SRWC (dbh < 3")

Trees with DBH values less than 3 inches are generally not suitable for pulp production; hence, this harvested woody material is usually used for biomass fuel. Two categories of harvesters are currently employed in Scandinavia: cut-and-chip and cut-only machines. A third, cut and forward harvester, has been tested but has significantly lower productivity than the other two categories. Recent tests have shown that harvesting costs are minimized with the cut-and-chip approach (Culshaw 1993). Machines based on agricultural harvesters have been most successful because the base machines were already proven, and the developments needed were relatively minor. Most efforts with purpose-built equipment have been abandoned, or are less successful.

Cut-and-Chip Harvesters

A. Purpose-Built Machines

The Bord na Mona consisted of a trailed unit pulled by a farm tractor and was designed to harvest willow up to about 3 inches in diameter (Curtin and Barnett, 1986). The project did not proceed beyond the initial stages.

The Gandini Bioharvester 93 consisted of a farm tractor with a felling and comminuting head fitted to the three-point hitch and a chip bin mounted on a steel frame on top of the tractor nose. Several problems were identified during testing (Culshaw 1993), and the project was terminated in 1994, in favor of more promising machines such as the Claas and Austoft (Spinelli, 1996).

The Salix Maskiner Harvester ('The Bender',) was designed to harvest twin rows of willow coppice, while attached to the three-point hitch of a reverse-drive Ford Versatile tractor. Stems are folded and compressed into a 'sausage-shaped' mass which may be handled, stored, and processed as though it were a log. After compression, stems are chipped; chips are blown into hitched trailers or tractor trailer units. Test runs in the UK indicated a productivity of about 4.0 ODT/standard hr, assuming a yield of 8 ODT/acre (Anon., 1995; a standard (std) hour includes allowances for servicing and personal breaks, but does not include downtime for unscheduled repairs).

The Texas A&M Harvester, primarily designed for harvesting mesquite, consists of a flail cutter head mounted on a John Deere forage harvester, and an auger and blower to convey the comminuted material to a towed van. 1994 tests in coppice regrowth stands indicated the harvester was capable of traveling about 2 mph and collecting most of the comminuted material. Another trial in a three-year-old sycamore plantation, where the trees averaged 15 feet tall and 4" diameter, was less successful. The cutter head severed stems, but it could not capture and comminute the material. Culshaw and Stokes (1995) believe that redesign of the cutter head may resolve this problem, but it is not likely that a flail cutter/comminuter can compete with more efficient approaches (saws and knives and blades). This harvester is still under development.

B. Agricultural Harvester-Based Machines

The Austoft sugar cane harvester cuts and billets stems, then conveys the billets to a trailer. As an alternative, 35 cubic feet of billets may be stored on the conveyer until a trailer arrives. Tests in the UK showed that the Austoft could average 0.9 acres/std hr or 9 ODT/std hr (Anon., 1994). Average travel speeds while cutting ranged from 1.3 to 2.4 miles/hr.

The Claas Jaguar was initially run with a slightly modified forage corn header, but the header frequently broke down and the feed control was not reliable (Culshaw and Stokes, 1995). Claas then developed a purpose-built header, which is now fully supported through their dealer network. The Claas blows chips into a chip forwarder which travels behind the harvester. During tests in the UK, travel speeds while cutting twin rows averaged 2.5 to 4.3 miles/hr, calculations indicated chat dhe Claas could produce 8.6 ODT/std hr, assuming a yield of 7.7 ODT/acre (Anon., 1995). Much higher production rates have been indicated for the Claas under Swedish conditions: 7000 cubic feet (on dhe order of 50 ODT) of chips per hour (Culshaw, 1993), and 2.5 acres per hour while cutting (Wiltsee and Hughes, 1995). These higher rates, which must be adjusted downwards to reflect expected delays, could reflect better terrain conditions and higher crop yields.

The John Deere 6910 Harvester is similar in design and method of harvesting to the Claas. Equipped with a Kemper corn header, it produced 6.8 ODT/std hr width stand densities of 13.1 ODT/acre (Anon., 1995), but dhe Kemper header was considered unsatisfactory for SRWC.

The New Holland 719 is a single-axle, single-wheeled trailed device with a header, powered by a towing tractor. The header may be detached and replaced by other units for different operations (Anon., 1994). The 719 with a corn header was tested for SRIC harvesting in the UK; it performed reasonably well in willow stands, but productivities were not measured.

Cut-Only Harvesters

Several continuous-travel cut-only harvester prototypes were developed or proposed in the 1980s and then abandoned because of the downturn in energy prices. These machines included the Virginia Polytechnical Institute/Department of Energy (VPI/DOE) Harvester (Curtin and Barnett 1986), which cut and crushed small stems to promote drying, the University of Hawaii Biomass Harvester (proposed but never built; Paquin et al 1989), the National Research Council of Canada (NRCC) FB2 and the NRCC Coppice Harvester (Curtin and Barnett, 1986).

Other continuous-travel cut-only harvesters are still under development. The

Loughry Coppice Willow Harvester is mounted on the 3-point hitch of a 55 hp farm tractor. It cuts and bundles stems, then ejects tied bundles weighing about 70 lb behind the harvester (Curtin and Barnett, 1986). Tests in 2- to 4-year old stands of willow and poplar showed a range of productivities from 1.7 to 4.4 green tons/pmh (Ledin and Alriksson 1992). More recent tests of the latest version of the harvester, the Mk IV, had to be abandoned due to blockages in the feeding system. An average output of 0.04 acres/std hr (0.3 ODT/std hr) was calculated (Anon., 1994). After further tests, researchers concluded that the Loughry was unsatisfactory for SRWC (Anon., 1995).

The Frobbesta Harvester is a Swedish machine which severs stems, tilts them with an inclined auger, then releases them to fall horizontally onto a rear trailer platform. When the platform is full, the bunch of stems is pushed off. During trials in the UK, the harvester was found to have a productivity of 2.0 ODT/std hr (Anon., 1994).

Another self-propelled "cut-only" machine is the Empire 2000 which was built and demonstrated in Sweden. Stems are cut, conveyed and held horizontally in a collection chamber. Bunches may be transferred to a tractor and trailer or discharged at the end of the row. In tests in the UK, the machine achieved an overall average productivity of 6.7 ODT/std hr (Anon., 1995). The tests identified several inherent problems, which prevented the Empire 2000 from being classified as a functional machine at that time.

The Nicholson Harvester, designed in Great Britain, is intended for 1 to 2-year-old willow, (Anon., 1994). Stems are gathered between two gates, severed by two circular saws and transferred to a bundle chamber by pinch-belts. A stem counter automatically triggers a bundle tying and discharge sequence. In January 1994, a test run was carried out in the UK (Anon., 1994), indicating a productivity of 0.1 acres/std hr. Blockages were a significant problem.

Like the Probbesta, the Energiskogsmaskiner AB (ESM) Harvester carries bundles of sticks on a platform which may be tipped to form a stack.

None of the current"cut-only" machines (Empire 2000, ESM, Frobbesta, Loughry Coppice Harvester, and Nicholson) are supported by major manufacturers, but developers are willing to produce machines to order (Culshaw and Stokes, 1995).

Cut-and-Forward Harvester

The Brunn AIB SRICB Harvester was a large machine, which accumulated loads of stems up to 15,000 pounds. It cut stems and conveyed them to a bunk on the carrier, a Brunnett forwarder (Curtin and Barnett, 1986). It had low, productivity and was relatively expensive.

Special-purpose Harvester Larger Trees (dbh > 3")

Non-conventional harvesters for larger trees, including large SRWC, can be categorized as continuous-travel cut-and-chip, cut-only, cut/chip-and-forward, or cut/delimb/debark/chip-and forward. Conventional single-grip harvesters have been modified to cut-and-delimb/debark eucalyptus. In contrast to the current situation for smaller trees, none of this equipment is under active development, and only the Pallari Harvester and cut-and-delimb/debark harvesters are currency being manufactured.

Cut-and-Chip Harvesters

The Nicholson-Koch Mobile Harvester was primarily developed to recover biomass residues left by conventional timber harvesting systems in natural stands (Curtin and Barnett, 1986). Chips were blown into a trailing forwarder. The Harvester was quite large: 33 feet long, 9 feet wide, and 15 feet high. Tests in 1980, in a stand containing mostly residual pines averaging 6 inches DBH, indicated a production rate of approximately 1 acre/hr (20 tons/hr) (Sirois, 1981).

The Pallari Harvester cuts trees up to 4 inches in diameter with a set of rotating sickles and stationary anvils. Two vertical drums with triangular rotating inserts then direct the severed stems into a drum chipper (Curtin and Barnett, 1986). The Pallari Harvester provided the basic design for the Canadian Crab Combine; the latter, however, could harvest trees up to 8 inches in diameter. Both machines operated in a continuous motion. The Pallari is still being manufactured in limited quantities in Finland (Hakkila, 1996).

Continuous-Travel Cut-Only Harvesters (Continuous-Travel Feller/Bunchers)

The US Forest Service Harvester was a continuous-motion header for a forestry skidder. Trees were cut with a two-fluted milling cutter that could retract if the cutting rate was less than the forward speed of the harvester. After cutting the stem, the cutter sprung forward to sever the next stem. Cut stems were stored vertically in an accumulating area and then discharged as a loose bunch (Christopherson et al, 1989). No further development is planned (Thompson 1996).

The A-Line Swather was designed to harvest trees ranging from 4 to 8 inches DBH, in natural stands. Towed by a skidder, this machine consisted of a trailer with a side-mounted circular saw. When a tree was severed, a rotating "bat" struck the tree about 11 feet above the stump, directing the tree backwards into a collection bed. Simultaneously, the butt of the tree was knocked forward by a trip chain mounted behind the saw. Bunches (1 to 2 cords) were side-dumped away from the stand. In tests conducted in 1980, the A-line Swather achieved a production rate of approximately 300 trees/pmh (Curtin and Barnett,1986), considerably higher than a conventional feller-buncher working in similar stands. Production potentials, however, were not fully realized, primarily because the machine was very sensitive to stand conditions, especially stand density. The A-Line is currently in Canada but is not being used (Karsky 1996).

The Missoula Technology and Development Center (MTDC) Harvester was based on the A-Line Swather but had the collecting bunk and saw assembly mounted directly on a TimberJack 520A prime mover (Karsky, 1992). In one trial in natural stands averaging 6,000 stems/acre with most trees ranging from 3 to 8 inch DBH, the harvester's production rate was about 500 to 600 trees per hour. In September of

1990, the Harvester was tested at James River Corporation's Fiber Farm in Clatskanie, Oregon. It left stumps 3 to 4 inches high; James River desired to have trees cut at ground level to recover as much fiber as possible. During dumping, trees would occasionally remain in the bunk, decreasing the Harvester's productivity. Also, felled trees would bounce forward when they landed in the tree bunk, since the "trip chain" and "rotating bat" mechanisms did not guide the larger trees adequately. Consequently, after 3 or 4 trees were felled, the butts of the trees would begin to hang over the front edge of the bed. After several more trees were cut, the felled trees would hit the butts of the trees on the bed and fall forward rather than into the bunk (Kaiser, 1996). After this test, a "power roller" was added to the Harvester to force the felled trees past the cutting blade and back into the bunk. This addition was not field tested, and the machine is not currently being developed or used (Karsky, 1996).

The National Research Council of Canada NRCC FB7 was a continuous-travel harvester consisting of a 60 hp tractor with a cuffing/collecting/off loading header. All functions except driving and off loading were automatically sequenced by an on-board microprocessor. Also, once off loading was initiated by the operator, the remaining off loading process was automatic. As the Harvester reached a tree, sensors located in the cutting opening initiated the accumulation operation simultaneously with cutting by two 24 inch diameter, counter-rotating, inserted-tooth saws. An accumulator arm held the tree, then pushed it into a holding area After the holding area was filled with 8 to 10 trees (held vertically), the operator activated the of loading process: a grapple closed around the trees, swung them to the side, and placed them on the ground parallel to the direction of travel. The FB7 had two holding areas and off loading mechanisms, one on each side, so the operator could cut back and forth on the face of a plantation. In a three-year-old sycamore plantation (2.5 inch average dbh and 6-foot spacing), the FB7 produced 850 stems/hour (19 tons/hr) (Stokes, et al., 1986). Operational problems with hydraulic components, sensor switches, leaves and vines building up in the head, and some of the computer components, were expected to be overcome with only minor changes. Despite the very encouraging results, development of the FB7 was abandoned due to the drop in energy costs. The prototype is now at Massey University in New Zealand.

The concept for the National Research Council of Canada FB12 was similar to that of the NRCC FB7. The FB12, however, used a larger tractor as a prime mover and was a substantially larger machine, at approximately 30,000 lb. It was expected to have a productivity of about 800 trees/hr when cutting tree sizes of 10 inches to 12 inches DBH and 60 feet in height. Initial field tests on a ten-year-old hybrid poplar plantation near Kempville, Ontario and on a ten-year-old cottonwood stand near Vicksburg, Mississippi indicated that the FB12 might be a reliable and highly productive harvester. However, the FB12 was unable to efficiently hold large trees upright, because the grip on the stems was not firm enough. The prototype is currently in storage at HydMech Ltd. (the company that developed both the FB7 and FB 12 under contract to the NRCC) in Woodstock, Ontario.

Cut/Chip-and-Forward Harvester

The Georgia Pacific Biomass Harvester felled, chipped, and forwarded material while moving in a continuous motion through residual trees in natural stands. Woody material was severed by two counter-rotating cutters, and chipped material was fed into a bin towed by the harvester. This machine could comminute standing stems up to 5 inches DBH, randomly distributed across the harvester's front, at rates in excess of 13 tons/pmh (Curtin and Barnett 1986).It was never tested in SRWC plantations and is not being developed any further.

Cut/Delimb/Debark/Chip-and Forward Harvesters

Examples include the MB-Trac and the Bruks IF 300 Chipmaster Harvester. The latter, built on a forwarder chassis, was intended to cut and chip small trees from thinnings, and included delimbing knives and a flail debarker to produce clean chips for pulp. Trees up to 12 inches in diameter could be felled using a head on a long crane (Froding, 1989). A disk chipper blew chips into a 530 ft 3 chip bin, which could be unloaded by dumping sideways (Anon., 1989). The multiple functions resulted in a costly machine whose production rate was too low to be economical.

Cut-and-Delimb/Debark Harvesters

Examples of conventional single-grip harvesters that have been modified to debark eucalyptus as well at to fell, delimb and buck include the Bell SP35 Harvester, the Lako/Kato Harvester and the Waratah HTH. According to Bell, productivity of approximately 18 to 20 tons/hr has been achieved with the SP35 (Anon., 1991). In Australian tests, the Lako/Kato processed 30 to 70 trees/PMH (200 to 950 cubic feet/PMH) while removing 70-100% of the bark (Kerruish and Rawlins 1991). The Waratah design, based on the Lako/Kato, has proven to be more robust, reliable, and efficient in removing bark. In thinning of stringy-barked eucalyptus in Tasmania, the mean bark removal was 91 percent, and debarking, delimbing, and topping time averaged 0.71 minutes per tree (Kerruish and Rawlins (1991). In a June 1994 study on eucalyptus in New Zealand, the Waratah produced 31 tree-lengths/PMH (880 cubic feet; Gadd and Sowerby, 1995) with trees averaging 11 inches DBH. These machines leave all of the biomass at the felling site, which effectively eliminates the opportunity to utilize the residues for fuel.

Potential Improvements

Many studies indicate that harvesting and handling constitute one of the largest components of SRWC costs, and therefore one of the largest opportunities for improvement (e.g.Wiltsee and Hughes, 1995). Hartsough and Richter (1994) pointed out that conventional harvesting equipment has been primarily developed for forest conditions, where conditions such as rough and broken terrain with rocks, large stumps, and down logs exist. Additionally, these harvesting machines were generally developed for harvesting coniferous trees that are larger and less uniform in size than trees produced on SRWC plantations. These machines are currently being used on SRWC plantations intended for pulp production, because the SRWC market has been too small to allow for development of systems that are ideally suited to short rotation conditions.

Improvements over the conventional systems may come in a variety of areas, some incremental and some dramatic. In the former category, delimbing and debarking improvements and reduction in truck/trailer tare weights hold some potential. More radical improvements are possible by developing effective continuous-travel felling equipment, by combining functions to eliminate multiple handling, and by the development of an effective and economic process to upgrade whole-tree chips to pulp quality.

Continuous-Travel Felling

In felling, costs might be reduced by developing continuous-travel machines, similar to those proposed by Golob (1986) and prototyped by Hyd-Mech for the Bioenergy Program of the National Research Council of Canada. Effective derivatives of the Hyd-Mech FB7 or FB12 would eliminate the stop-and-go, forward-and-back travel pattern inherent to conventional feller/bunchers. Although limited studies show that feller/bunchers can be highly productive in short rotation plantations (McDonald and Stokes 1993), it is difficult to imagine a conventional machine competing with a continuous-travel machine over the long term. Impressive productivity results demonstrated by continuous-travel machines such as the Claas Jaguar for harvesting willow in Sweden support this view. Based on the FB7 results (Stones, et al., 1986) and Stokes' unpublished data on the FB12 performance, Hartsough and Richter (1994) estimated that current felling and bunching costs could possibly be reduced by 40 percent. Condnuoustravel machines would also eliminate the repetitive aspects of the operator's job; with current feller/bunchers, operators cut and bunch 150+ trees per productive hour.

The FB7 cut at a rate of 1000 trees per hour while traveling down the row (Stokes et al, 1986) but the FB12 prototype had trouble with bigger stems because of stability problems when trying to hold the large stems loosely and keep them upright; positive control of upright stems is a necessity. The Claas and similar machines are successful in part because they do not have to resist large overturning moments from the crop trees. For larger stems, it would probably be better to immediately lower the trees as soon as possible to lower the center of gravity; the trees could be held horizontally while more were accumulated, rather than holding them upright. This would reduce the size, weight and boom strength requirements for the felling equipment. An analogous situation is the comparison between feller/bunchers and feller/directors; the latter are much lighter for the same-sized tree because they do not attempt to keep the trees vertical.

Accumulated bunches could be dropped on the ground or off loaded onto trailers in the field. In the long run, continuous-travel machines of some type will be the best option, but they will involve development costs, which may be substantial.

Combining Multiple Functions

To be effective, all functions on a multifunction machine must be well-utilized. Two concepts -feller/loaders and feller/chippers -- have the most potential, because each is relatively simple and could be applied in both the pulp and biomass fuel areas. (The size of the equipment would probably be smaller for the biomass market.)

A. Feller/Loaders

Many agricultural crops such as tomatoes and sugar beets are loaded directly onto on-highway transport trailers in the field by the harvester. A similar concept for tree harvesting and transport has been proposed by several individuals, including the proponents of whole tree burners (e.g. Schaller, et al, 1993). Existing excavator-style feller/bunchers could be used as feller/loaders initially, and a continuous-travel machine eventually developed.

B. Feller/Chippers

For short-rotation (three-year) willow energy crops in Sweden, continuous-travel feller/chippers such as the Claas Jaguar are the best alternatives tested to date; they are superior to continuous travel feller/bunchers or feller/forwarders because all processing is done by one machine, and the material is handled downstream as a bulk commodity rather than individual pieces. Production rates of these machines have been very impressive in some cases, on the order of those for conventional forestry equipment with large trees, even though the willow is less than 3" DBH. Chips are blown into separate chip bins, towed by agricultural tractors. The advantages are a minimum amount of equipment and minimum handling. An effective chip/residue separation method is needed to make this concept feasible for the pulp industry.

C. Feller/Forwarders

If on-highway transport vehicles cannot be towed through the field, then continuous-travel feller./forwarders may provide reasonable alternatives. Examples include the commercial Koehring KFF and the continuous-swathing A-Line and its descendent, the MTDC Swather. (The latter two are really feller/bunchers, but with an automated cut-and-deliver-to-bunk cycle would be useful in SRWC.)

D. Less-Attractive Combinations

A few feller/delimber/debarker/chippers such as the MB-Trac and Braks IF 300 have been developed (Froding, 1989), but they did not produce at economic rates. As with delimber/debarker/chippers at the landing, the delimbing/debarking function is limiting.

Feller/chipper/chip forwarders are similar to feller/chippers, but have their own integral chip bin. They may be reasonable options for small-tract, low-production operations where move-in costs are major considerations. In large tracts or dense stands they are more expensive per ton than the two-machine combination (feller/chipper and separate chip forwarder) because the felling and chipping equipment is idle while the machine is traveling with a full bin. Examples include the modified Brunnett, L1)GSET (Hall, 1995), HAFO, Bruks and Silvatec/Hedelskebet machines developed in Scandinavia

Separation of Pulpwood from Residues

A. Delimbing/Debarking

Chain costs represent the single largest operating cost component for chain flail delimber/debarkers. Stokes and Watson (1989) estimated that chain costs represent approximately 20 to 28 percent of the total flailing costs ($0.8 to $1.6 per BDT) assuming a life of 25 PMH per set of chains. But empirical tests on hardwoods in 1989, 1991, and 1994 have shown these early estimates to be low (Hartsough and Richter, 1994); chain costs may be as much as $5/BDT of chips. This discrepancy may be due to the differences between the strength properties of bark on conifers and hardwoods. These differences might be exploited to design a more efficient debarking method for hardwoods.

Chain flail delimbing/debarking is considered the bottleneck in converting trees to wood chips at the landing. A more efficient concept such as a fast ring debarker (probably located at a central yard or mill) may be preferable in the long run.

B. Upgrading Whole-Tree Chips

The new Massahake process separates whole tree chips into clean chips and residues. It has been under development in Finland for several years, and is promising because it allows whole-tree chipping at the stump or landing, and also allows landing-to-processing facility transport of highway-legal, full-capacity chip vans. Other methods for upgrading chips have been tried over the last twenty years or so, but the Massahake process is substantially different from earlier concepts: screens remove oversized chips and fines, grinders physically separate bark from the wood, a screen and pneumatic device remove more fines, then a Simco/Ramic optical sorter separates the larger pieces of bark from the clean chips, resulting in two output streams: clean chips and hog fuel. According to Gingras (1995), an industrial plant based on this process was nearing completion and start-up in Kankaanpea, Finland, and was to provide birch chips to neighboring pulp mills and hog fuel to a district heating plant. The capital cost of this plant was estimated at 14.5 million FIM (about $US 3 million) and had a rated capacity of about 1800 ft3 / hr of loose chips .

Transportation

A. Tare Weight Reductions

Recent reductions in log trailer weights (Stuart 1993) indicate a potential for similar reductions in chip van weights, but these reductions would not be unique to SRWC transport.

B. Combined Primary and Secondary Transport

Given that highway trucks and/or trailers are loaded in-field for transporting agricultural crops, it appears feasible and highly desirable to do the same with SRWC, assuming that the trees or chips will be processed at a site other than the landing. This concept could be applied with log trailers or chip vans, used in combination with feller/loaders or feller/chippers. The trailers or vans could be towed in the field by standard on-highway tractors or by agricultural tractors. The Fast Trac in-field/on-road tractors from the U.K. (Hall, 1995) may be a higher-traction alternative to standard highway tractors.

A major concern is the feasibility of moving on-highway vehicles through the field while soils are wet. Compaction will certainly result; it can be alleviated with tillage. But it is unlikely that an unmodified on-highway vehicle can travel on wet soils. Options include central tire inflation (CTI), larger, lower-pressure tires, or load platforms that can be transferred from an in-field transporter to an on-highway vehicle. Storage buffers to supply the mills or plants during the wet season are alternatives to wet season harvesting, but debarking of stored trees is difficult, and chip quality decreases with storage time.

C. Whole tree transport

With delimbed tree lengths or shortwood from slower-growing natural stands, weight limits are almost always reached before volume limits. Log trucks have been modified to haul whole trees, tree sections with limbs, or baled material (Axelsson and Bjorheden,l991). Changes are required to prevent limbs and tops from extending beyond the legal load dimensions, to prevent small broken material from falling from the load, and to compact the load. For whole trees or tree sections, considerable experience with conifers indicates that packing efficiency decreases, so payload weights are less than for chips or delimbed logs, resulting in higher transportation costs. Similar results might be expected with SRWC, and such was the case in limited tests with tree length short rotation poplar in western Oregon (Kaiser, 1994), although weight limits are reached with delimbed poplar in Mississippi. Limited trials with transporting hardwoods from natural stands on conventional trucks in the upper Midwest resulted in payloads of 21 to 26 green tons; few problems were encountered with crowns and limbs or material falling from the whole tree loads (Schaller, et al, 1993).

Most-promising Systems

Continuous-Travel Feller/Chipper - (Chip Forwarder) - Chip Truck - Permanent Chip/Residue Separation Facility: This is potentially one of the simplest and possibly cheapest systems, certainly for the stump-to-facility equipment. Separation equipment is the biggest question mark. If it were possible to move chip vans through the field, no chip forwarder would be needed. This is less of an issue than for whole trees because chip forwarders can rapidly transfer their loads to on highway trucks.

Continuous-Travel Feller/Loader - Log Trailer - Permanent Separation/Comminution Facility: Load weights and on-highway permitting are the main issues with this system, unless off-public road hauling is used. Existing feller/bunchers could be used at present, and an optimal continuous travel machine eventually developed. Choice of an optimal separation/comminution method is a question for the pulp industry. By eliminating the separation/comminution functions, the system could deliver whole trees to an energy plant.

Summary

To date, conventional forestry equipment and methods have been employed for all operational harvesting, processing and transportation of SRWC in the U.S. for pulp production. These operations are highly mechanized, the most common utilizes feller/bunchers, grapple skidders, a chain flail delimber/debarker/chipper and chip vans. Another replaces the flail/chipper and vans with irongate delimbers, log trucks and a drum debarker. All deliver clean chips to pulp mills. Residues from the flail/chipper or drum debarker may be comminuted with a tub grinder or hammer hog and transferred to an energy production facility by van or conveyer.

Conventional forestry equipment is probably not optimal for SRWC plantations; it is used by default because it is productive and reliable. The amount of SRWC harvested has not justified the full-cycle development of specialized equipment for larger trees, i.e., grater than 3" DBH. But the conditions in SRWC plantations -- flat, obstacle-free ground, small trees of uniform size growing in straight rows, uniform road spacing (in many cases), short transportation distances to the mill (in some cases), small branches and bark characteristics which differ from those of conifers -- all suggest that SRWC harvesting, processing and transportation can be carried out in different and cheaper ways.

Equipment manufacturers and researchers have pursued numerous alternatives for harvesting smaller trees less than 3" DBH) for energy production. Some of the most recent efforts in Scandinavia have been highly successful and have nearly reached the end of the development cycle. The best machines are based on well-developed harvesters for traditional crops such as corn or sugar cane, and involve relatively minor developments, such as headers specifically designed for harvesting small diameter hardwoods. Small, closely-spaced trees are not tremendously different than sugar cane or corn, which accounts for the relatively rapid success of the development efforts with the modified agricultural harvesters. In contrast, projects involving purpose-built machines designed from the ground up for small SRWC have mostly been terminated.

For small trees, harvesting concepts may be classified as cut-and-chip by one machine, cut-only, or cut-and-forward. Cut-and-chip appears to be the best option, because the bulk chips are cheaper to handle than whole trees, and because the harvester is smaller and has less idle time than a combination harvester-forwarder. (With cut-and-chip machines, separate machines usually carry and transport the chips.)

One apparent improvement for harvesting large SRWC involves continuous-travel harvesting, to replace the stop-and-go, back-and-forth (or swing-and-return) motion of conventional feller/bunchers. The readily negotiable terrain and straight rows are amenable to continuous straight line travel, which in theory should be faster (for the same machine power) than any other alternative. (Note that essentially all agricultural harvesters and the successful machines for small SRWC all travel continuously.) Many continuous travel prototypes have been built for larger trees, most of them for natural stands. None of these has met with much success, for a variety of reasons. The most promising machines, the National Research Council of Canada FB7 and FB 12, were intended for SRWC for energy, but funding for their development was terminated in the mid-1980s due to the drop in energy prices. Renewal of efforts with these or similar concepts would benefit all producers of large SRWC, but the task is not as easy as with smaller SRWC because of the larger mass and higher center of gravity of the bigger trees.

Several machines with multiple functions are available or have been tested for larger trees in conventional forest harvesting Examples include feller/chippers, feller/chipper/forwarders, feller/delimber/barkers (called harvesters in conventional forest terminology), feller/delimber/debarkers, and feller/delimber/debarker/chipper/forwarders. Some of these are successful, many are not. Multi-function machines tend to require fewer operators, be less reliable and may not utilize the components as fully as single function equipment, but this depends on the combination. For SRWC, combinations with potential benefits include feller/loaders, feller/chippers and feller/forwarders. In addition, equipment capable of both primary (i.e. within the plantation) and secondary (on-road) transportation would eliminate unloading and reloading at roadside.

Improvements in separation of pulp and residues might include a better alternative to the inherently inefficient chain flail, and an economical means of upgrading whole-tree chips for use by pulp mills. The Massahake process being developed in Finland may prove to be the latter.

A list of "ideal" harvesting/processing/transportation systems for large SSRC might include the following two examples (and others):

1. Continuous-travel feller/chipper, combined primary/secondary chip transport, and separation of clean chips from residues
2. Continuous-travel feller/loader, combined primary/secondary transport of whole trees, delimbing/debarking, and chipping.

Both systems could be used to produce either pulp chips or, by eliminating the separation step (and chipping in the second tree system), whole-tree chips or trees for energy.

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A Review of Short-Rotation Forestry Harvesting in Europe

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Introduction

In Europe, the interest in energy forestry dates back to the '70s. The sudden shock of the energy crisis pushed national governments to investigate all the alternatives to fossil fuels - including energy forestry.

Since then the scenario has changed a lot, and new needs have been incorporated into the energy forestry concept. In many Countries, the major reason for using biofuels is the obligation put on utilities to reduce the emission of carbon dioxide. This coincides with a wish of the European Union to reduce the agricultural surplus.

Another important change - and a necessary implication of development - has been the subdivision of energy forestry in a number of specialized sectors. Short rotation forestry is one of such sectors, and it ranks among "recovery of forest residues", "thinning to energy" or "upgrading traditional energy forestry". This paper deals with the harvesting of short rotation energy forests, describing how Europe copes with the specific problems it poses.

Short Rotation Energy Coppice

As a definition "short rotation forestry" is rather ambiguous. For a forester it may describe a common poplar plantation: its 12 years rotation certainly proves short when compared to that of a "normal forest", cut after 70-140 years. Adding the attribute "energy" gives a marginal help only. Nobody can prevent us to tag 12 year old poplar for the energy market. Indeed, something similar already happens in some Countries. Similarly, the term "energy coppice" might indicate any conventional coppice grown for fuelwood.

The crop we are dealing with is just another thing. This paper concerns the harvesting of a certain type of short rotation energy forest, which happens to be the most common in Europe - and the one with the largest potential for expansion. We are talking about specialized energy forests, grown according to the "grassland" concept. Extremely dense stands, harvested at 3-4 years intervals and regenerated from the stools, which are expected to survive 5 rotations at least (fig.1).

Figure 1 - View of a typical short rotation coppice

Figure 2 shows a synthetic description of the most important such crops growing in Europe.

Figure 2 - Short rotation coppice in Europe

Species	Willow	Poplar	Robinia
Crop density stools/ha	18-25,000	10-15,000	8-12,000
Rotation years	3-4	1-3	2-4
Av. butt diameter at harvest (mm)	15-30	20-50	20-40
Av height at harvest (m)	3.5-5.0	2.5-7.5	2.0-5.0
Growing stock at harvest (fresh tons/ha)	30-60	20-45	15-40
Moisture content (% weight)	50-55	50-55	40-45
Part of Europe	Scandinavia British Islands	Central Europe	Mediterranean Europe

At present, short rotation forestry is still at the experimental stage. In Sweden, however, the experiment is carried out at full-scale proportions, with 11,000 hectares of short rotation willow planted and managed on a commercial basis. More willow is available in

Denmark and in Britain. Austria claims several thousands of hectares of energy poplar, and many experimental plantations have been established in Germany. Robinia is being planted in Italy by Regional Management Agencies, who are keeping an eye on poplar and eucalyptus as well.

All these crops are very similar to each other in terms of rotation, density and yield. One may even say that they are regional versions of the same concept, each version being adapted to the local climate and terrain. Southern SRF - for example - resorts to species needing less water, which are grown at lower densities, yield less and produce drier biomass. Geography and climate, however, do not account for all differences. Some of them can simply be explained by the growers' preferences. This is especially true for the planting system. Willow growers generally adopt the twin-row system, with a spacing of 0.75 m in the twin-row and 1.50 m between the twin rows. On the contrary, people growing Poplar and Robinia seem to prefer single rows 1 m apart. The distance along the row is subject to large variation, and it is generally between 0.5 and 1.0 m. Of course, these "details" have a strong impact on harvesting technology and performance.

Systematics of SRF Harvesting Equipment

SRF compares neither to conventional forestry nor to common agriculture. The crop is a completely new one, posing completely new problems. The question of how to harvest these new crops was raised already 10 years ago. Manual system, conventional forestry equipment and unmodified agricultural machinery were all tried, but the experiments generally met with little success. Fortunately, much progress has been made since then, thanks to the efforts of many European scientists and to the confidence put by the National Governments and the European Union in the potential of SRF. Many projects have been carried out, investigating a number of alternative solutions. More projects and networks are still going on, and we expect substantial progress in the near future. So far, the most impressive result of these efforts is the production of a number of SRF harvesters, able to cope with a variety of different conditions. In the following pages we propose a systematization of SRF harvesting equipment, based on the harvester's functions, on its derivation and on its locomotion. This system provides vital, synthetic information that allows framing the operational scenarios connected to any given harvester.

Functions

SRF harvesting consists of four main operations: cutting, collection, extraction and comminution. The main functional difference between harvester types is the number and the type of operations that they can perform. In order of growing integration, we find the following functional types (figure 3):

Cut-only harvester. The harvester cuts the stems, laying them in windrows or heaps. Cut stems are then collected by a separate unit, which delivers them to a chipper. As an alternative one can use a chip/forwarder to collect, chip and extract in one pass.

Cut-and-bundle harvester. The harvester cuts the stems and collects them in bundles. Bundles are dropped on the field, like hay bales. They are later collected by a separate unit, most often a conventional forwarder or a farm tractor with forestry trailer.

Cut-and-extract harvester. The harvester cuts the stems, collecting and loading them over a deck of some sort. It then takes its load to the field edge or to any suitable landing. Chipping is the only operation delegated to a separate unit.

Cut-and-chip harvester. The harvester cuts, collects and comminutes the crop, delivering the chip at the field edge. In alternative, the extraction can be delegated to chip shuttles, to keep the harvester going. Chip shuttling is used preferably when the extraction distance is large.

All these four functional types are actually represented by some existing machines. However, cut-and- extract and cut-and-chip are by far the most common types.

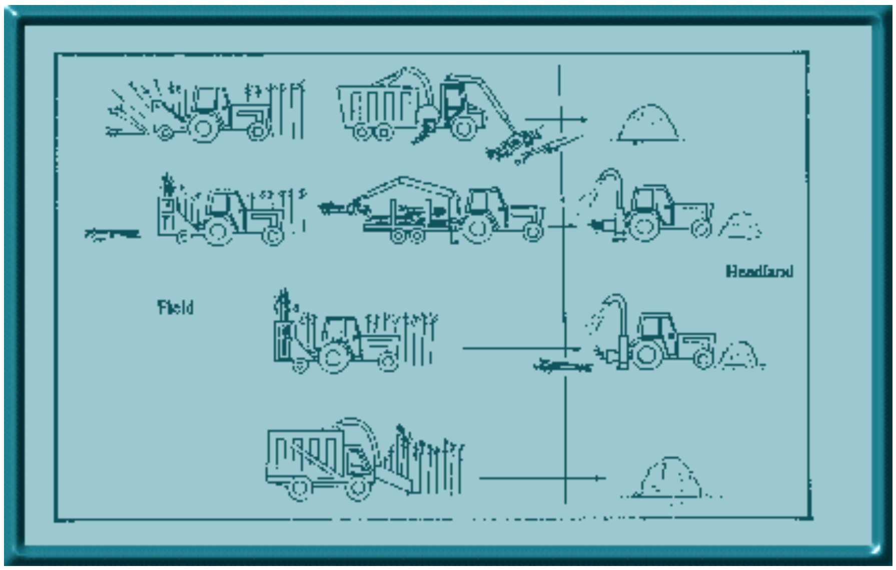

Figure 3 - Alternative SRF harvesting systems

Origin

SRF harvester can be classified according to their origin - i.e. the machine they derive from. Up to now, SRF harvesters have been derived from one of the following machines:

Cuttings harvesters. Some SRF harvesters are the blown-up version of cuttings harvesters, which are normally used in poplar and willow nurseries. This origin is especially common for cut-only and cut-and- extract harvesters. Of course, no cut-and-chip harvester sprouted from this source.

Forage harvesters. In the early days of SRF harvesting, unmodified forage harvesters where tried, with encouraging results. It is then logical that a whole generation of cut-and-chip harvesters has been obtained by modifying mass-produced combine harvesters. In fact, two of the best SRF harvesters now available - the Austoft and the Claas - derive respectively from a sugar cane and a forage harvester.

Prototype. In this case the SRF harvester is built from scratch. The majority of SRF harvester models have this origin. Of course, designers have often used mass-produce prime movers for their machine, so that building from scratch only applies to the harvesting device proper.

An harvester's origin involves certain consequences. The modification of a mass-produced unit - for example - is generally more reliable in its base components than a machine built from scratch. Besides, using mass-produced modules allows reducing production costs. On the other hand, modifying existing equipment requires a certain amount of compromise, which may involve renouncing the perfect match between crop and harvester characteristics.

Locomotion

Finally, one can class SRF harvesting according to the way they are connected to their prime mover. Again, there are three options:

Towed harvesters. The harvester comes in the form of a trailer, which can be towed by any conventional prime mover - most often a farm tractor. Towed harvesters are generally light and simple. They are designed for the part-time user, who wants a cheap device, easy to connect and disconnect to his multi- purpose prime mover. Limited mobility and low productivity are the most frequent constraints of towed harvesters.

Carried harvesters. The harvester comes as a module, which can be mounted on a wide range of prime movers. These machines are often heavier and more expensive than towed models, but they also offer better mobility and higher productivity. Connecting the harvesting module to the prime mover may require some time.

Self-propelled harvesters. They offer the best in terms of both mobility and productivity. On the other hand, they prove the most expensive due to the immobilization of the prime mover, often very expensive itself. Self propelled harvesters are thought and designed for the full-time contractor, who can provide his harvester with a sustained volume of work.

As we can see, locomotion provides a good deal of information on harvester capabilities and on its potential user. More can be inferred from the power of the prime mover and the overall weight of the whole harvesting unit.

An Overall Picture

Figure 4 gives information about a number of SRF harvesters that have been built and tested in Europe in the last 5 years. Most of these harvesters are still in use and many are undergoing further development. Some of them are used in commercial operations: this is the case with the Austoft, the Claas, the Dansalix, the Hvidsted and the Fröbbesta. Other ones did not work well and were dropped,

Figure 4 - SRF harvesters used in Europe

Model	Functions	Origin	Locomotion	Power (kW)	Weight* (kg)	Country
Fröbbesta	cut-only	cuttings harvester	towed	70	3,000	Sweden
Loughry	cut-and-bundle	prototype	towed	70	3,000	N. Ireland

Nicholson	cut-and-bundle	cuttings harvester	towed	65	3,000	Britain
Dansalix	cut-and-extract	cuttings harvester	towed	65	2,000	Denmark
Berni	cut-and-extract	cuttings harvester	towed	80	2,000	Italy
Hvidsted	cut-and-extract	cuttings harvester	self-propelled	80	6,000	Denmark
Sagerslätt	cut-and-extract	prototype	self-propelled	130	12,000	Sweden
ESM 901	cut-and-extract	prototype	self-propelled	74	7,000	Sweden
Gandini	cut-and-chip	prototype	carried	50	850	Italy
Diemelstadt	cut-and-chip	prototype	carried	90	800	Germany
MBB Biber	cut-and-chip	prototype	self-propelled	52	4,300	Germany
Bender I	cut-and-chip	prototype	carried	85	950	Sweden
Bender II	cut-and-chip	prototype	carried	120	1,250	Sweden
Austoft 7700	cut-and-chip	forage harvester	self-propelled	179	12,500	Sweden
Claas Jaguar	cut-and-chip	forage harvester	self-propelled	230	9,400	Germany
JD/Kemper	cut-and-chip	forage harvester	self-propelled	301	11,700	Britain

* Note: in the case of towed and carried harvesters, the figure applies to the harvesting trailer only, excluding the prime mover since no money was available for their improvement. They are the Biber, the Gandini, the ESM 901 and the Bender I, this one replaced by the better Bender II.

Of course, more harvesters are being developed in these days, to cover a larger range of harvesting conditions. At present, however, there are models to satisfy most needs. Specific harvesters are available for the part-time user and for the full-time contractor.

There are models for farm tractors, so that individual farmers can harvest their plantations on their own. Some models can cope with difficult terrain, even during the wet season. This is the case of tracked harvesters, such as the Austoft, the Hvidsted or the ESM 901. Concerning high-mobility harvesters one point must be stressed, however: their special capabilities are no use, if biomass extraction is delegated to conventional units. In this case, the harvester will cope with the soft or sloping terrain, but the chip-shuttle will get stuck. Some attention should be paid to the auxiliary units as well. So far, studies have concentrated on harvesting and extraction has been neglected. Things are changing, however. In Britain, for example, a Caterpillar Challenger tractor has recently been tested along the Austoft harvester, operating on soft terrain.

This paper analyses in detail the Austoft and the Claas harvesters. These two machines have attracted considerable attention in Europe, and have been studied extensively by several teams. The Authors themselves have carried out a series of trials aimed at evaluating them in both Danish and Italian conditions. Most of the work was done in the scope of the European Project EU-AIR2-CT94-1102, “Harvesting and Storage Technologies Essential for the Establishment of Short Rotation Coppice as an Economic Source of Fuel in Europe.” However, similar trials have concerned most harvesters, and data are available for the majority of the models listed in figure 4. Yet, there are several reasons for giving a special place to the Austoft and the Claas in this paper.

The first one is that they are cut-and-chip harvesters. Cutting and chipping in one single pass is still the most effective option, as far as harvesting logistics are concerned. Harvesting and chipping in two separate stages may be more sensible in a storage perspective, but it is still disproportionately expensive and therefore totally impractical.

Secondly, the Austoft and Claas harvesters are some of the most mature products now available. They result from the modification of mass-produced machines and are much more reliable than those models that have been built from scratch. These ones can be more innovative and have bigger potential - at least in some cases - but their development is longer and requires much effort and money. As a consequence, the majority of harvesters built from scratch are not mature yet, and often require considerable improvement.

Finally, both the Austoft and the Claas are the only SRF harvesters used in large commercial operations. They are owned by actual entrepreneurs who harvest several hundreds hectares each year. This can be of special interest to the US reader, who generally regards agriculture as a large-scale, industrial activity.

The Austoft 7700

The Austoft 7700 is a self-propelled sugar cane harvester, adapted to SRF harvesting. The machine consists of a 179 kW tracked prime-mover with a cutting-conveying header in the front, a comminuting device in the middle and a belt conveyor in the rear (figure 5). All functions are hydraulic. Mobility benefits from the long steel tracks and the hydrostatic transmission.

Figure 5 - The Austoft 7700 cut-and-chip harvester

The cutting head consists of two disc saws placed side by side, which can harvest two rows at a time: stems are pushed forward by an adjustable pushing bar and are directed to the saws by two vertical feeding augers. An horizontal feeding roller mounted on the tip of a pushing bar also contributes to correct feeding. Once they are cut, stem butts jump upwards and horizontally into the infeed mechanism and are taken to the comminuting device. This is a two-blade propeller, which cuts 5-10 cm chips and let them fall down to the bottom end of a ladder conveyor. The ladder conveyor is attached to the rear of the chassis and can be rotated 170·, so that it can direct chip flow to shuttle units approaching the harvester both to the left and to the right side.

Figure 6 shows the average productivity recorded in 5 trial programmes.

Figure 6 - Comparison among the productivities recorded for the Austoft harvester in Sweden, Britain, Italy and Denmark (from Kofman & Spinelli, 1996)

Place	**Sweden**	**Sweden**	**Britain**	**Italy**	**Denmark**
Year	1994	1995	1994	1996	1996
Species	Willow	Willow	Willow Poplar	Poplar	Willow
Age (years)	N.A.	N.A.	3	1-2	4-5
Row system (row)	twin	twin	single	single	twin
Butt diameter (mm)	16-25	18-25	N.A.	23-61	14-22
Stocking (Ton/ha)	37-42	29-63	37-80	11-34	28-50
Harvesting speed (km/hr)	3.3-4.5	2.6-5.1	2.1-3.8	5.1-8.8	3.3-6.0

Productivity (Tons/Wphr)	19-26	21-32	9-25	18-22	14-23
(Danfors & Nordén, 1995; Deboys, 1994; Kofman & Spinelli, 1996; Spinelli 1996.)					

All studies agree in describing the Austoft harvester as a sturdy, reliable machine. Some blockages of the infeed mechanism have been recorded in Britain, and attributed to the thick weed layer. In any case, the Austoft showed the lowest downtime rate of all machines tested in the British trials.

General agreement is also on the high mobility of the tracked harvester. The machine can negotiate both steep and soft terrain. In Denmark it harvested the wettest spots without any trouble. In Britain and Italy, it harvested wet slopes of over 20% gradient, uphill, downhill and sideways. Such a good performance on slopes is due to the low center of gravity, which falls in the center of the harvester. In turn, this explains the backwards and forwards pitching recorded when traveling at speed.

Harvesting speed is largely variable. It was lower where the crop was thicker, such as in some Danish, British and Swedish stands. In Italy, where the crop was thinnest, harvesting speed exceeded 8 km/hr. This confirms the assumption that the Austoft may benefit from a more powerful engine.

Excessive stool height was recorded everywhere. The Danish and British reports indicate a large variability in stump height: from 0 to 38 cm. This can be explained by the backwards and forwards pitching of the harvester at speed, mentioned in the same report. Besides, cutting height adjustment is generally inaccurate: the system should either changed or coupled to a precision gauge, acting automatically.

Stool damage was frequent and severe in all trials. Bush blades are held responsible for it. Both the British and the Swedish studies compared bush blades with conventional circular saws, concluding that the use of circular saws substantially reduces damage severity. Circular saws were tested in Italy with the large-size poplar, but they proved too flexible and were soon replaced. The Italian study identifies a further cause of stool damage in the peculiar cutting height adjustment system. Cutting height adjustment is obtained by tilting the whole chassis upwards or downwards, so that any variation of the cutting height will also result in a change of the cutting angle. If the cut is too high, the saws will work on a horizontal plane and the stools will be hit by the lower of the two fixing plates that sandwich the blade.

All studies indicate that the Austoft creates a very limited soil disturbance. Rutting was absent in most cases, and whenever recorded it was blamed on the chip shuttle fleet. Harvesting losses are limited, seldom exceeding 4% of the standing crop. Chip quality was found mediocre in most studies. All reports mention the presence of numerous oversize particles in the Austoft chip.

On-road transportation can be a problem. The Austoft 7700 is a tracked vehicle and cannot travel on roads. Moving between different harvesting sites requires a deep loader and involves a certain amount of delays. Small, scattered stands are unsuitable for the Austoft system.

In general, the Austoft system requires a number of support units, whose movements must be carefully planned and supervised. The logistics of such system can be rather complicated, and are made more difficult by the excellent machine performance. This does not mean that the system cannot be managed, on the contrary. But its management requires skilled professionals and careful planning. In fact, the Austoft system is designed for full-time contractors, who should be skilled enough to use it effectively.

The Claas Jaguar 695

The Claas SRF harvester consists of a conventional forage harvester, equipped with a new header for harvesting short rotation coppice. The header is fitted to the standard faceplate of the Claas Jaguar, so that all owners of this Claas model can expand their job range to SRF harvesting (figure 7). The prime mover is powered by a 230 kW engine and has hydrostatic transmission on all four wheels.

Figure 7 - The Claas Jaguar cut- and-chip harvester

The special header consists of two counter-rotating disc saws, placed side by side and separated by a crop divider. Horizontal feeding rolls are also provided, both before and after the saws. A pushing bar is mounted on top of the assembly cover and can be adjusted hydraulically.

The base machine is fitted with its standard processing drum, with 12 knives instead of the usual 24. The 12-blades configuration produces 28 mm long chip, which is accepted by heating plants, but it is still rather short for optimum conversion.

The many hydraulic functions of the SRF header exceed the capacity of the standard hydraulics of the Jaguar Mega. For this reason, the SRF version is fitted with auxiliary oil pump and tank.

Figure 8 shows the average productivity recorded in 5 trial programmes. The Claas harvester is a very productive piece of equipment, given the right site conditions. Productivity largely varies from Country to Country. The Danish and Swedish figures are the highest. In Italy and in Britain, Claas productivity was comparably lower. This can be explained by the lower stand stocking, and especially by the different row system.

Both in Italy and in Britain, the Claas harvested one row only, and harvesting speed did not substantially increase if compared with double-row harvesting.

Figure 8 - Comparison among the productivities recorded for the Claas harvester in Sweden, Britain, Italy and Denmark (Kofman & Spinelli, 1996).

Place	**Sweden**	**Sweden**	**Britain**	**Italy**	**Denmark**
Year	1994	1995	1995	1995	1996
Species	Willow	Willow	Willow	Poplar	Willow
Age (years)	N.A.	N.A.	3	1-2	4-5
Row system (row)	twin	twin	single	single	twin
Butt diameter (mm)	16-34	16-22	N.A.	17-56	N.A.
Stocking (Ton/ha)	21-53	27-54	12-32	14-48	31-60
Harvesting speed (km/hr)	4.7-9.1	5.5-9.2	3.5-6.9	5.2-7.3	5.1-7.1
Productivity (Tons/Wphr)	22-35	26-42	7-13	8-21	12-31

The Claas harvester is generally described as a reliable machine. However, both the British and the Italian report mention a large incidence of infeed jams. Blockages exceed respectively 40% and 55% of the net cycle time. The problem is certainly related to the row system. The Claas is designed for harvesting double-rows and dealing with single rows may result in attacking the crop at wrong angle. As a consequence, stems tend to jam between the blades and the crop divider, the central height skid or the vertical spacer.

Mobility is a problem. The Claas must be operated on flat, firm ground. In Middle Sweden this is not a problem, since the soil is frozen during the harvesting season. However, the climate of Southern Sweden, of Denmark and of Britain is considerably milder and frozen soil conditions are not assured every year. In this case, the Claas will prove too heavy to negotiate the wet sites where willow is grown. Both the Danish and the British reports highlight this problem. In Italy, the problem is slope.

Everything goes well when harvesting poplar, which is grown on flat, sandy soils. On the other hand, nobody even tried to take the Claas on the slopes where Robinia grows.

Limited cross-country capabilities are somewhat compensated by high road mobility. The Claas harvester is not dependent on a deep-loader for its transportation, especially if the fields are grouped within a few kilometers radius.

Another asset of the Claas machine is the possibility of converting any conventional Jaguar forage combine into an effective SRF harvester. This will allow better depreciation for the base machine. However, this advantage should not be overestimated. The SRF conversion kit is rather expensive, since it includes not only the header, but also the additional oil pump and tank.

Most studies report stool heights above the 10 cm limit. However, the Claas can cut lower and more regularly than the Austoft. The cutting height adjustment device is more effective.

British studies mention minimal stool damage, the lowest recorded with the range of machinery tested. On the contrary, heavy stool damage was observed in Italy. The fact can be explained by the different tree species. Poplar is less flexible than willow, and the bending stress applied by the Claas to the stems to be cut is more likely to result in deep stool splits, such as those observed in Italy. Besides, the Italian poplar was planted on small ridges, resulting from inter-row tillage. The Claas had to raise the cutting height to avoid grazing the soil, but the combined height of the stool and the ridge was enough for scratching the harvester's belly in many occasions. This might have resulted into further stool damage.

Only the Italian report mentions extensive soil damage, which is blamed on the chip shuttle units rather than on the Claas itself. Very little soil disturbance was recorded in Denmark and Britain. In Sweden, concrete-like frozen soil prevented all problems. Harvesting losses are slightly higher than those recorded for the Austoft. All studies agree that Claas chip is regular, yet too small.

A limit of the Claas harvester is its dependency on a precise row spacing. This means that Claas harvesting must be planned at the establishment. Even if everyone agrees that harvesting must be planned since the establishment stage, reality often differs from optimum theoretical rules and the fact is that many stands are established giving little consideration to all following stages. In this case, the limited flexibility of the Claas system offers a little edge to bad planning.

Conclusions

Harvesting short rotation energy coppice requires special equipment. In Europe, large efforts have been done to design, build and tests suitable machinery. A number of harvesters have been produced, and some are already employed in large-scale commercial operations.

The Austoft and the Claas are such harvesters. Both work fine and achieve high harvesting productivity. The Austoft is sturdier and enjoys better off-road mobility, whereas the Claas can travel on-road and inflicts less damage to the stools.

However, a number of problems still have to be solved. Some concern machine design only, and can be tackled by mechanical engineers. Others involve the crop/machine interaction and must be faced by growers and engineers together. The most important among them are off-road mobility and crop spacing.

Most SRF harvesters have limited cross-country mobility. As a consequence, soil bearing capacity becomes crucial to SRF harvesting. If the soil is too soft, most machines will bog down. The Austoft is the only harvester that can negotiate soft soil, but its capability has no use if the support fleet will eventually get stuck. Then the point is the careful selection of the sites where one will plant short rotation crops. Either one refrains from planting in the wettest spots or new machinery will have to be designed.

Irrational spacing is detrimental to work efficiency. It will slow down most machines and stop some of them. More thought must be given to correct field design. The double-row system works fine for most harvesters, even if it is not the best for all of them. The Claas cannot harvest effectively single rows, if the inter-row is smaller than 1.5 m. Even so, the productivity will be greatly reduced. In fact, the 75/125 cm twin-row system was designed especially for the Claas. However, this spacing will result to narrow for the same Claas harvester, when fitted with wide tires. For the time being it is advisable to conform with the internationally agreed 75/150 cm twin-row system.

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Proceedings

Short Rotation Woody Crops Operations in the Industrial South

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Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

Abstract

Short Rotation is a relative term. Natural hardwood stands represent a significant resource of southern lands. Industry needs to identify treatments that will shorten rotation lengths in natural hardwood lands. Fertilization and stocking control hold the most promise. We hope to shorten the rotations for natural from 40 years to 20 years and to double the growth rate.

In hardwood plantations, we need species site trials to determine what to grow where. The best silvicultural treatments need to refined and developed -- weed control treatments; fertilization rates, timing, and delivery mechanisms; insect monitoring and control treatments; and irrigation methods and monitoring systems.

Along with the silviculture, we need to develop the genetic resource. Breeding and testing of current sources, identification of new sources of genetic material, and hybridization of sources all hold promise for developing trees to plant under SRWC regimes. Humankind will realize the full potential of our genetic resources when we learn to clone the best genetic material. Industry needs to develop operational scale vegetative propagation techniques for trees that do not readily regenerate through vegetative means.

Overshadowing this entire discussion, industry has to pay its own way. To determine if SRWC will pay, industry needs information on wood quality characteristics, and growth and yield information. We feel that SRWC will pay its own way, we need good numbers to convince the people minding the purse.

Introduction

To start off, I will limit my comments primarily to hardwood stands. Short rotation is a relative term. In hardwood plantations, short rotations may be as few as 3 and as long as 10 to 12 years. The rest of this meeting and our field trip demonstrate the potential of plantations. One other area in the South that needs to be mentioned is natural stands.

Natural Hardwood Stands

Natural hardwood stands compromise approximately 20% of Champion’s landholdings in the South. I fully expect other industrial landholdings to approximate this number. Champion’s land managers consider hardwood growth rates of 30 to 50 cubic feet per acre per year and rotation lengths of 40 years to be realistic.

If we could identify treatments that would allow us to grow 100 cubic feet of wood per acre per year, 20 year rotations for natural hardwood stands would become feasible -- short rotations.

Mother Nature provides us a bounty of regeneration whenever we disturb sites. On most sites, plant life emerges with such force and vigor, that you may not want to stand still for fear of being overwhelmed. The problem is too much regeneration. As wise land stewards, our challenge is to manage this regeneration to grow wood in a form we may utilize for mankind’s benefit. These stands may take twenty or more years to sort out which stems will survive to become large enough to become useful to humankind. Treatments to hasten stand development hold the most promise in managing natural hardwood stands. To put words around this, our goal as industrial foresters, is to grow 100 cubic feet of wood per acre per year. Research in stocking control methods and in fertilization holds the most promise for producing Short Rotation Woody Crops from natural hardwood stands.

Plantations

We have seen exceptional examples SRWC during this meeting. Some of my following points may cover areas mentioned by some of the previous speakers. Here are what some in industry feel we need in the South.

1. Identify species well adapted to grow on sites under plantation culture.
2. Identify the best methods to achieve acceptable weed control in plantations such as:
    1. Cover crops;
    2. Herbicides and application methods;
    3. Mechanical methods.
3. Identify the appropriate fertilization regimes for each site. Research issues include:
    1. Sources of nutrients;
    2. Fertilization rates;
    3. Application methods;
    4. Interaction of fertilization and stocking levels.
4. Identify the appropriate methods to monitor and control damaging insects.
5. Develop irrigation methods and water management regimes such as:
    1. Methods to monitor the moisture stress in the irrigated area;
    2. Scheduling the water applications;
    3. Methods to monitor water demands over time and their impact on tree growth.

Tree Improvement

The Hardwood Tree Improvement Program will identify and develop the best sources of hardwood species, hybrids and genotypes to plant. Genetic gains in hardwood tree improvement are difficult to predict due to the little amount of tree improvement work to date. The exception is the Populus genus. Hybridization and cloning within selected sub-genus sections of cottonwoods and aspens are projected to produce volume gains of 30 to over 50% compared to the parental species. Selecting and cloning of the currently available hardwood genetic material will provide good short-term gains. Traditional tree improvement methods will develop genetic materials for further improvement, hybridization and clonal selection for the long-term.

The major steps to accomplish the tree improvement goals are:

1. Identify the hardwoods species that will grow well in the South.
2. Identify and obtain sources of hardwood genetic material. Possible sources:
    1. USFS,
    2. Pacific Northwest,
    3. Midwest/Lakes States,
    4. Europe/Middle East,
    5. DOE/MSU Cottonwood Project,
    6. NCSU.
3. Screen hardwood phenotypes for performance and adaptability. Screening trials serve to weed out obvious poor performers. Clonal and open-pollinated tests, using relatively small samples of each genotype, are used to determine which genotypes warrant further development.
4. Test seed origin or clones for productivity and quality traits that will provide information for field deployment. These tests include the materials that pass the screening stage and are used to develop information for further breeding and hybridization and information for field deployment.
5. Long term tree improvement will use breeding, testing and selection to improve the parental species for inclusion in seed orchards and to produce hybrids and clones. Species that currently cannot be cloned will need improved seed to produce planting stock. Species that can be cloned will require the development of better parents for the production of hybrids and/or selection of clones.

Propagation

Propagation methods are not well developed for many of the hardwood species. Even in cottonwoods and aspens, some of the hybrids are difficult to root. The hardwood propagation research will develop the methods to propagate, on an operational scale, the best material identified in the Hardwood Tree Improvement Program.

Vegetative propagation (cloning) allows for the entire genetic make-up of a single plant to be utilized on an operational scale. Cloning makes possible the reproduction of the rare genotypes that contain the genes for high productivity and other desirable characteristics. Because the entire genetic make-up can be exploited, much higher genetic gains are possible than with sexual reproduction. Cloning alone could result in over 20% volume increase in genetic gain compared to sexual reproduction methods.

The major steps to accomplish the propagation goals are:

1. Assess the suitability of various propagation methods for the desired species or genotypes. Available methods include:
    1. Rooted cuttings,
    2. Air-layering,
    3. Root cuttings,
    4. Micropropagation,
    5. Somatic embryogenesis,
    6. Others as they become available.
2. Determine the factors that limit or promote successful propagation of the desired trees. Many factors affect vegetative reproduction of trees. The genetic effects, environmental effects and physiologic processes require better understanding to make vegetative propagation operational. Areas of research include:
    1. Stock plant and media nutrition,
    2. Rooting and/or tissue culture media type,
    3. Photoperiod effects,
    4. Cold storage effects,
    5. Genetic control of rooting/embryogenesis,
    6. Others as they become available.
3. Develop cost effective operational methods to propagate desired trees. Once methods are developed to clone specific species and genotypes, they must be assessed to determine if they are conducive to the scale and speed of operational systems and are within acceptable financial bounds.

Wood Quality

The goal of the pulp and paper industry's wood quality efforts is to grow wood with excellent pulp yield and quality. The steps needed to achieve this goal:

1. Identify the range of pulp yields and fiber characteristics for each intensively managed species;
2. Quantify the relationships between intensive cultural activities, genetics, and the environment and their impacts on fiber yield and pulping characteristics;
3. Develop techniques to measure fiber characteristics for clones;
4. Develop reliable Growth and Yield models for hardwood stands;
5. Integrate wood quality research into Hardwood Tree Improvement Program for selecting specific species, families and clones;
6. Incorporate the wood quality results and the Growth and Yield models into decision support models and information systems for analysis of forest to mill system benefits.

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Short Rotation Woody Crops in the Industrial West

Chuck Kaiser, Don Rice, and Bill Schuette, James River Clatskanie, OR

Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

Since the conception of Short Rotation Woody Crops operations, many varied strategies have been attempted to maximize tree survival and yields per acre while reducing costs associated with crop management. The complexity of determining what to do, when, and with what has been compounded greatly with the entrance of four major wood producers widely located in the Pacific Northwest -- i.e. MacMillan Bloedel in northern Washington, Georgia Pacific in southern Oregon, Potlatch Corporation and Boise Cascade Corporation in central Oregon/Washington. Each area of operation is unique in itself and will require field and harvesting operations tailored to meet the demands of crop production.

Attempts have been made to bring these interested parties together to focus on operations that might be common to all in order to collectively determine a procedure for overcoming deficiencies in the production of hybrid cottonwood. The uniqueness of everyone's program has prevented any progress to date. Although not a conclusive list, the following areas have been identified in the past as needing further investigation.

1. The industry must begin to promote multiple product markets. Presently, all large growers have targeted their operations for providing raw material for the production of pulp and paper. This market, to say the least, is always fluctuating and unsteady and may not be the best practice for everyone. Markets for saw logs, plywood and oriented strand board should be developed. This would provide security for all growers especially the small, local farmer who is attempting to find a supplemental crop that would lead to a diversified income.
2. A continuing genetic research strategy should be developed regionally. Presently, major companies are expending large sums of money in their individual genetic research and development programs. This includes participating in joint, cooperative programs with university groups including all other companies within the region. Much duplication of time and energy are being expended in this endeavor. This could be reduced if a joint research program was initiated so breeding material and efforts were available for all to use.
3. Animal damage mitigation will become a necessity in the near future. This

problem is only growing as more and more plantations are planted throughout the Northwest into areas normally inhabited with deer, elk, moose, etc. Federal and state fish and wildlife agencies must become aware of this fact with existing laws and regulations modified to meet this new occurrence.

4. Much work remains in attempting to reduce harvest cost. This cost represents up to one-half of the total expenditures in providing material for a pulp mill. All facets of harvesting from felling/bunching, skidding/forwarding, delimbing/debarking, chipping, and transportation must become more efficient and less costly if the industry is to survive.
5. New methods must be developed for post harvest site preparation and ensuing cultivation that will fulfill the many situations existing among major growers in the region. Although a method has been somewhat successful for one company, it may not come close to fulfilling the requirements of other major producers.
6. Genetic engineering must become a top priority for all wood producers. This program is in its infancy in the Northwest with the Tree Genetic Engineering Research Cooperative. Nationally, this will become important for all wood producers as a united voice must be raised to work through stringent federal and state regulations regarding "bio-tech" plants and trees. Setting priorities and following through will eventually enable SRWC growers to have material that will enable them to be good environmental stewards at the same time easing the ever-present paranoia of "another monster weed."
7. The next area tying closely with genetics is alternatives to herbicides/insecticides through IPM (integrated pest management) programs. Some work is now in progress to work with universities to study natural pests and their predators in order to combat these detrimental pests. Much work needs to be done including developing manufacturing of beneficial insects locally in the region. Although this goal is obtainable, some herbicide/insecticide use will continue. The process required to have chemicals labeled for use on hybrid cottonwood needs to be revamped in order to have them for use on a more timely basis as well as reducing the cost. Further development and/or selection of new or old chemicals not labeled for SRWC needs to continue.
8. Companion crop development is the next area that needs considerable effort in answering questions such as:
    1. Are there any?
    2. What are they?
    3. What techniques need to be used so that yields and/or survival is not hampered?
    4. Will it be part of a total IPM plan or can it stand alone?
9. Finally, alternatives for harvest residue must be developed. Presently, few options are available to most producers. Hog fuel markets, composting, and in-field use as a soil additive or top-dressing mulch are those now being pursued.

In summary, the western industry has many challenges facing it today. A discussion of this list with all producers in the west would have identified more areas than are presently listed. The opportunities are there; we just need to capitalize on them!

Manufacturer's Perspective

**Larry Burkholder and Milan "Lucky"Robinson,
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Paper presented at the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, KY, September 23-25, 1996

Brief history of Morbark

Founded in 1957 in Winn, Michigan by Norval Morey, a local sawmill owner/operator. First product was a portable pulpwood debarker. Success of debarker led to the development of other products for the forest products industry, including log debarkers, pole peelers, chippers, etc. In early 1970s invented the first portable whole tree chipper, the Total Chipharvestor. Morbark has been the number one manufacturer of in-woods chipping systems for nearly 25 years. Today, Morbark has diversified into several distinct markets, including flail debarkers and in-woods chipping systems, timber harvesting equipment, sawmill equipment, solid waste and recycling equipment, land clearing equipment and tree care equipment. Morbark manufactures more than 60 different equipment models. (Refer to your Morbark Product Guide for more details.) Our plant in Winn, Michigan has been steadily expanded to 1.5 million square feet, and our workforce now includes nearly 700 employees.

Morbark involvement in SRWC

Because a healthy fiber supply is important to our success as an equipment designer/manufacturer. Although we do not see SRWC as replacing current fiber sources, we do see it as one potential alternative for supplementing the existing supply of hardwood fiber. Because we currently manufacture equipment systems, which are capable of economically harvesting and processing the type of small diameter, multiple stems generated by SRWC. Because SRWC can help in creating a more positive public image for the forest products industry and counter negative publicity generated by the "green" movement.

Equipment development

Morbark Flail Chipharvestors. In-woods flail/chipping systems are becoming a larger part of the pulp & paper industry. As flail technology advances, the role of in-woods chipping continues to grow in size and significance. Many design improvements have been made in Morbark flails since 1990. High production, low bark content and excellent chip quality are documented in dozens of Morbark equipped chipping operations across North America. Morbark Total Fiber Utilization System. We have designed a specially equipped Forestry Tub Grinder to process the waste from the flail's debris conveyor. As much as 30 percent of a tree's mass is removed during the flailing process in the form of bark, small limbs and foliage. This material can be processed into hog fuel where there is a market. The tub is positioned to receive debris directly and a hydraulic blower fills 40 foot vans. One operator controls all flail, chipper and tub functions.

Morbark Wolverine Tractors. Morbark has been a leader in the development of quick, agile three-wheel feller buncher tractors. Our new Wolverine 6300ET has many innovative features such as an extended boom, tilt cab, 360 degree visibility and more. It is ideal for the type of harvesting required by SRWC applications. Please refer to our video for more detailed information on all the above mentioned equipment.

Research and development

Morbark's style is to conduct R&D in the field. We have built a long standing reputation for listening to customer feedback in developing new equipment technology. Morbark has always been known for rapid response in designing and manufacturing to meet the challenges of industry. To best meet the needs of the SRWC industry, it would be best to install a field chipping system, collect data and, if necessary, make adjustments in the equipment Something to consider in terms of flail debris: if there is no market for boiler fuel, the ground up waste can be spread back over the land as a fertilizer and soil amendment.

Conclusion

As a manufacturer, we see SRWC as an opportunity to continue developing equipment designs for use in meeting the fiber demands of industry. In order for this type of harvesting to be economically feasible, we believe plantation fiber will probably need to be supplemented with natural thinnings of hardwood and pine stands. We welcome two way communication with principles in the SRWC field, and as always, we invite interested parties to visit our manufacturing facility and demonstration site in Michigan for a close look at Morbark operations.

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FIELD TOUR - First Conference of the Short-Rotation Woody Crops Operations Working Group

Tuesday, September 24, 1996

Hosted by Westvaco, Timberlands Division, Central Division, Wickliffe, KY

Hosts

Name	Title	Organization
Jim Baer	North Area Superintendent	Westvaco
David Garrett	District Supervisor	Westvaco
Dr. Victor Ford	Research Scientist	Westvaco
Pat Hahs	Sr. Wildlife Biologist	KY Dept. of Fish & Wildlife
Andy Malmquist	District Forester	Westvaco
Jamie Quinn	Forest Ranger	Westvaco
Dwight Rainwater	Forest Technician	Westvaco
Kenny Robertson	Forest Specialist	Westvaco
Dr. Gail Simonds	Research Scientist	Westvaco

Safety Briefing

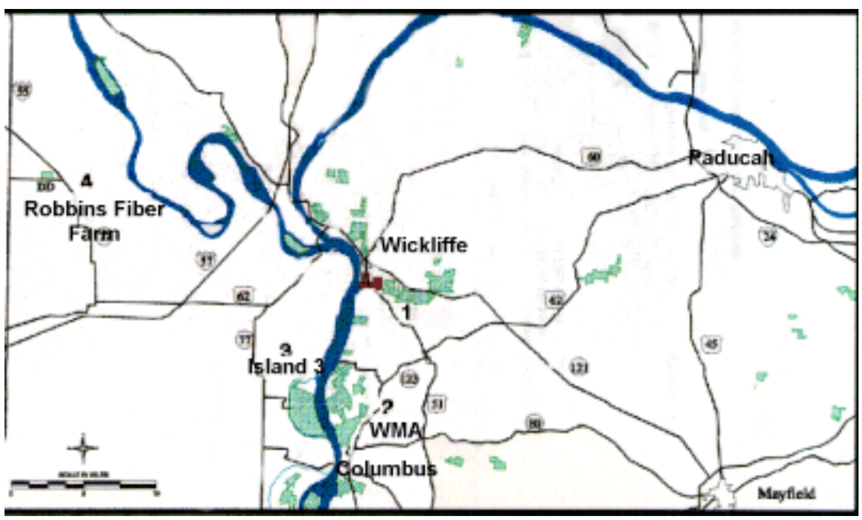
SAFETY FIRST is our major concern. To ensure your safety and the safety of others, please remember to:

1. Wear your hard hats at our field stops. Struck by falling objects is the leading cause of injuries in the woods.
2. Stay with your group and on the designated tour routes. Equipment operators don't have eyes in the back of their heads.
3. Stay a safe distance from all operating equipment.
4. Do not climb on machines. Watch your footing boarding and exiting the buses and in the woods.
5. Be cautious and alert for safety hazards. If you see any safety concerns please inform your tour hosts.

Tour Schedule

7:30 AM Leave J.R. 's Executive Inn - Paducah
8:30 AM STOP 1 - Wickliffe Cottonwood Nursery

Stop 1 Nursery Management - Dave Garrett
Oak Species Tests - Vic Ford
9:00 AM Leave Nursery
9:45 AM STOP 2 - Westvaco Wildlife Management Area
Stop 1 Moist-Soil Unit Waterfowl Management - Jamie Quinn & Pat Hahs
Stop 2 Cottonwood and Sycamore Agroforestry - Jim Baer
11:30 AM Noon Lunch at Columbus-Belmont Battlefield State Park overlooking the Mississippi River (Courtesy of Westvaco)
12:30 PMLeave Columbus-Belmont Battlefield State Park
2:00 PM STOP 3 - Island No. 3
Stop 1 Cottonwood and Sycamore Plantation Harvesting and Site Preparation - Andy Malmquist & Dave Garrett
Stop 2 Herbicide Applications in Cottonwood and Sycamore Plantations - Vic Ford & Kenny Robertson
Cottonwood Coppice and Machine Planting
3:00 PM Leave Island No. 3
4:00 PM STOP 4 - Robbins Fiber Farm
Stop 1 Background and Design - Jim Baer
Demonstration of Fertigation System - Dwight Rainwater
5:00 PM Leave Fiber Farm
6:30 PM Arrive J.R. 's Executive Inn - Paducah



SRWCP Operations Working Group Tour
Westvaco, October 24, 1996

TOUR STOP SUMMARIES

STOP 1 - COTTONWOOD NURSERY

Nursery Management - Dave Garrett

- Nursery has approximately 8 acres of cottonwood stool beds in production, established from unrooted cuttings and are kept for three years.
- Nursery is sprayed with a pre-emergence herbicide and usually mechanically cultivated at least once.

- The stool beds are irrigated with the Ag-Rain traveling irrigation gun, normally starting by June 1st to provide 1 inch of water per week.
- Fertilization is started in May and granular 18-18-18 is applied with a farm tractor. When whips exceed a height of 4 feet, liquid fertilizer is applied through the irrigation system.
- Insecticides are sprayed as needed to control the cottonwood leaf beetle and adult cottonwood borer.
- The whips reach a height of 15 feet by October. They are harvested in December, delimbed, lopped down processed into cuttings.

Sweetgum and Oak Growth on Acid Clay Soils - Vic Ford

- Reforestation of old agriculture fields and cut-over ground can be accomplished using these species; Nuttail and pin oaks are the preferred species of the oaks.
- Productivity of these species on these sites comparable to loblolly pine growing in the Highland Fim. Site index at 25 years for these species is between 65 and 80 feet.
- These species can be managed at a low intensity with chemical site preparation. Mechanical site preparation can also be used.
- Fertilization is an option depending on soil levels.

STOP 2 - WESTVACO WILDLIFE MANAGEMENT AREA

WMA Moist Soil Unit Management - Jamie J. Quinn & Pat Hahs

- 1991 Westvaco signed a 20 year MOU with Kentucky Department of Fish & Wildlife Resources (KDFWR). KDFWR agreed to assist in managing the area for wildlife (the primary target species being waterfowl, esp. ducks), help set regulations and patrol the area for law enforcement.
- The WMA is a unique venture in that it is the first public/private wildlife conservation partnership in support of the North American Waterfowl Management Plan in the Lower Mississippi Valley Project Area.
- Westvaco WMA integrates forestry, agriculture and moist soil management to create habitat diversity for waterfowl and other game & non-game species.
- The WMA is comprised of 3,402 acres and is closed to the public from November 1 to March 15th of each year. There is 644 acres open to public hunting year round with the purchase of a permit.
- Westvaco has installed 3 wells capable of pumping over 10 million gallons of water per day, 6.5 miles of levees have been constructed with 24 water control structures to impound water including a large sheet pile structure in Town Creek, and developed a self guided walking trail and drive-through tour.
- Westvaco has also completed two Ducks Unlimited MARSH Projects in which DU contributed $50,000 to restoring and developing over 675 acres of waterfowl habitat on Westvaco WMA.

Agroforestry Cottonwood Plantation - WMA - Jim Baer

-This cottonwood plantation was planted in 1983. Today the trees are 90-100 feet tall and 14-16 inches in diameter. This forest was thinned (removed 30 percent of the trees) during the winter of 1993. Agroforestry was practiced. In this cottonwood tree plantation successful crops were grown for three years in the 30-foot zones between the double rows of cottonwood trees. Today, the trees still allow enough light through the canopy to plant wildlife plots of milo, millet, and buckwheat.

STOP 3 - ISLAND NO. 3

Hardwood Site Prep - Dave Garrett

- After harvest, D-6 and D-7 dozers are used to shear the stumps and any unmerchantable understory trees. The debris is raked into a windrow and burned.
- The site is disked with a large offset disk pulled by a 150hp farm tractor. This disking is followed by a smaller offset disk that breaks up the large clods and prepares the site for row marking and slitting.
- Row marking and slitting establishes a 12 ft. by 12 ft. grid pattern on the soil that assures that the cuttings will be planted at the correct spacing and at the correct number of 300 trees per acre. The cuttings are planted at the junction of the row mark and slit. The slitting operation also subsoils the site which aids in planting the cutting at the proper depth and ensures that the trees will grow in a straight line which is necessary for cultivation.

Cottonwood and Sycamore Plantation Harvesting - Andy Malmquist

Overview of North Area

- Geographic regions...uplands vs. bottomlands
- Programs
  - Hardwood plantations
  - Pine plantations
- Will be looking at a Gary Casey logging job in sycamore using Bell felling saw and grapple skidder.

Competition Control in Sycamore and Cottonwood Plantations - Vic Ford

- Site preparation is necessary to control perennials (especially vines) and penetration of herbaceous canopy.
- Herbaceous weed control is completed by pre-emergent and post-emergent, and by mechanical systems.

STOP 4 - ROBBINS FIBER FARM

Background, Design and Future Plans - Jim Baer

- The Robbins Fiber Farm Tract (340 acres) was acquired June of 1995 and was selected because it was reasonably priced, located on a good road with 3-phase power, and abundant high quality ground water. While the soils are sandy, excessively drained, and low in nutrients, they do permit excellent year round equipment access and offer uninterrupted drip fertigation free from the interference of natural rainfall events.
- With minimal additional construction, the centralized drip irrigation system will eventually serve 180 acres of production plantings (4 zones), 14 acres of research (12 plots),and a 5-acre nursery. The most unique feature of this design is that all three systems can be fertigated independently from the same wells and filters located in the irrigation center.
- Fifty acres of cottonwood cuttings and once acre of sycamore seedlings were planted last March in the Research and Production areas at 11' x 8' (495 trees per acre). The balance of the fiber farm will be regenerated during the next two planting seasons placing approximately 200 acres under drip irrigation.

Fiber Farm Research Activities - Gail Simonds

Demonstration of Fertigation System - Dwight Rainwater

- System Components
    - Motorola “Aeronaut” Controller
    - Variable Frequency Drive Motor
    - Spin Keen Disc Filters
- Management Techniques
    - Daily water and fertilizer rates
    - Tensiometer
    - Pan evaporation

File posted on March 17, 1998; Date Modified: February 21, 1999

short rotation
WOODY CROPS
operations working group

CHARTER

BACKGROUND

Short rotation woody crops (SRWC) are an environmentally acceptable and potentially economically efficient method of producing wood for fiber and fuel. As demand increases for hardwood fiber, new readily available sources are needed to reduce demands on upland and bottomland forests. SRWC plantations can reduce demands on national forests, improve local rural economic development, and ensure future wood supplies. The environmental benefits of woody crops when grown in a renewable fashion are also important. Woody crops can reduce the rate of atmospheric CO_2 buildup by sequestering carbon and by substituting for fossil fuels. The combustion of woody crops can also reduce SO_2 and NOx emissions relative to fossil fuels. At the local environmental level, woody crops can reduce soil erosion, filter soil leachates from water entering streams and ground water, and promote greater wildlife habitat and biodiversity.

With the advent of successfully developed genetically superior clones of woody crops interest has substantially increased in the entire scope of SRWC operations. At a recent mechanization conference hosted by the DOE and the USDA Forest Service, a number of impediments were underscored as deficiencies to the development of commercialized woody crops:

- the stalled development of practices, equipment, and implements to establish, maintain, and utilize large plantations (i.e., commercialization operations);
- the lack of consideration of the diversity of operations and machinery required by different feedstock producers; and
- the necessity of commercializing SRWC for differing end-users.

Successful commercialization of SRWC as either a source of fiber or as an energy feedstock material, depends on a diversity of practices and equipment for these highly specialized crops.

MISSION AND OBJECTIVES

In a mutually beneficial and collaborative fashion, the USDA Forest Service, DOE's Oak Ridge National Laboratory (ORNL), and the Electric Power Research Institute (EPRI) have established a SRWC Operations Working Group to consider the efficient development of practices and equipment to culture, harvest and handle large-scale woody biomass plantations.

The mission of the Working Group is to promote collaborative efforts in developing needed operations for SRWC plantations that comply with the principles of economic viability, ecological soundness, and social acceptance. To fulfill its mission, the Working Group has the following objectives:

- understand and communicate the SRWC operational needs for different end-users and end-products; and
- promote the development of cost-effective and environmentally sound SRWC plantation operations and refinement of existing practices (equipment, systems, and technologies).

SCOPE

The Working Group will serve as a venue for information exchange and for the management, promotion, evaluation, and development of SRWC operations that are low-cost and environmentally acceptable. The Working Group will serve as a liaison among forest industries, equipment manufacturers, electric utilities, DOE, USDA Forest Service, International Energy Agency and researchers. The Working Group will also interface with researchers in plant development and propagation (e.g., nurseries) as well as end-product users and conversion technology developers. The Working Group will primarily be national in scope. It will focus on all operational aspects of growing and harvesting SRWC plantations including site preparation, planting, cultural management, harvesting and extraction, handling and processing, hauling, and plantation design) managed for tree stems 3-10 inches in diameter.

ACTIVITIES

A primary purpose of the Working Group is to foster communication and enhance cooperation, identify issues and concerns (see annex), promote collaborative action and research, and facilitate funding support for equipment and systems development and demonstrations. Specific activities will include:

- Maintaining a mailing list
- Sponsoring a newsletter
- Serving as an information clearinghouse (database, internet home-page, etc.)
- Sponsoring workshops, conferences, and demonstrations
- Promoting and prioritizing collaborative research and development
- Establishing protocols for the evaluation, reporting, testing, and design of equipment and systems
- Assisting in research funding

STRUCTURE

The Working Group will be ad-hoc in structure and be open to all organizations and individuals with an interest in the commercialization of SRWC. The Working Group will be managed by a Steering Committee. The immediate responsibilities of the Steering Committee are to organize the Working Group, plan and execute an organizing conference, assess issues and needs, establish an information clearinghouse and network for exchange, and seek funding for Working Group activities. The Steering Committee members as well as specific functions will be re-assessed at annual meetings of the Working Group.

ANNEX ISSUES AND CONCERNS

- Improving the cost-effectiveness of site preparation, planting, cultural, harvesting, processing, handling, and hauling operations
  - identify high priority R&D needs (e.g., harvest efficiency, improved delimbing/debarking, wet ground operation, stump removal and use, multi- functional machines for combining operations, improved recovery of multiple products)
  - identify appropriate development processes (e.g., incremental improvements to existing technologies; develop smaller-sized equipment; include users in equipment development; develop analytical framework for design; develop systems)
- Understanding the biological and cultural considerations in the design and configuration of harvesting and handling equipment
  - species considerations (stem form, coppice habits)
  - silvicultural and operational considerations (topography, scale of operation, contiguous block size, spacing and age, site accessibility, soil compaction, coppice/non-coppice regeneration, handling stumps and residues)
- Conducting economic, engineering, and environmental characterizations of multiple harvesting and handling systems (felling and bunching, pre-haul, comminution, handling, multi-product processing, in-field vs. mill processing, product contamination and effects on conversion process, etc.)
- Collecting information and developing a data base (operating parameters and costs) on currently available equipment systems; producing a set of design parameters to aid the development of specialized equipment
- Reducing site impacts through the development of equipment, operations, and systems that are environmentally and socially acceptable
  - assess effects of soil compaction on biomass productivity and mitigation measures either through remediation or through equipment design
  - evaluate quantitatively the tradeoffs between soil compaction and biomass productivity

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