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SHORT ROTATION WOODY CROPS: USING AGROFORESTRY TECHNOLOGY FOR ENERGY IN THE UNITED STATES

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INTRODUCTION

Agroforestry in the United States is being primarily defined as the process of using trees in agricultural systems for conservation purposes and multiple products. The conservation definition is being adopted by the new Center for Semiarid Agroforestry recently established in the United States in Lincoln, Nebraska, by the United States Department of Agriculture Forest Service. They suggest that a key concept in agroforestry is that of "working trees"—conservation trees planted in the right place and configuration for a specific purpose (Rietveld and Schaefer 1991). This definition includes practices such as growing tree crops in combination with agricultural crops or pasture, windbreaks, fuelwood plantations, living snow fences, streamside buffer strips, high-value tree crops, tree enclosures for livestock, feedlot filter strips, and wildlife habitat. Often an agroforestry planting would combine two or more of these functions.

The type of agroforestry most commonly practiced in many parts of the world, that is the planting of tree crops in combination with food crops or pasture, is the type least commonly practiced in the United States. The closest approximation is the establishment of annual food crops or perennial crops between rows of high-value black walnut trees planted for both nut and timber production. This is occurring on irrigated croplands in California and the Southwest, where annual crops are being planted between rows of nut or fruit trees during the first few years before canopy closure is complete. Such plantings offer early income as well as maintenance of the tree crops before they reach fruit or nut bearing age.

One type of agroforestry technique, which is beginning now and anticipated to expand to several million acres in the United States, is the planting of short-rotation woody crops (SRWCs) primarily to provide fiber and fuel. SRWC technology can be characterized as the production of trees for harvest in 10 years or less under conditions of closely monitored weed control, nutrient additions, pest management, close spacing of trees, and use of genetically superior plant material. Under SRWC conditions, trees are essentially managed as an agricultural crop, though SRWC differs from standard agricultural practices in that there is less use of chemicals and much less labor involved after successful establishment. It is anticipated that in addition to providing new fiber and fuel sources, SRWC plantings will serve several environmentally beneficial functions such as providing new wildlife habitat, acting as filtering agents for feedlots or other

This paper will discuss the status of short-rotation woody crop research in the United States and briefly summarize the environmental benefits and challenges perceived to be associated with utilization of short-rotation woody crop (SRWC) technology on a large scale.

SRWC RESEARCH STATUS: GENERAL OVERVIEW

Much progress has been made over the past 10–15 years in developing viable energy SRWC production and handling techniques. However, the technology is still in an experimental rather than commercial phase for most parts of the United States. Currently the costs of producing SRWC feedstocks preclude their use commercially. Relatively small reductions in the cost of producing and harvesting SRWCs together with higher fossil fuel energy prices could make biomass energy competitive with coal, gas, and oil. At this time the SRWCs and herbaceous energy crops (HECs) which have been selected as good models for energy crops in the United States are shown in Fig. 1.

Observed experimental yields of SRWC are 2 to 5 times yields currently obtained in natural forest stands and pulpwood plantations. Advances in SRWC technology have occurred primarily as a result of research funded by the Department of Energy's Short Rotation Woody Crops Program (SRWCP) from 1978 to the present. Successes in recent commercial plantings have resulted from good species/site matching, careful establishment techniques, use of improved clones or carefully selected seedlings, and recognition of the importance of weed control. Production rates in the range of 9 to 17 dry Mg/ha/year have been frequently achieved in production research trials (Table 1), and higher yields have been obtained under optimum conditions. Genetics and physiology studies have demonstrated the large potential for yield increases in the SRWC species now being developed. Evaluations of available harvesting equipment and prototypes have shown the need for improving harvesting and handling strategies that will be critical in lowering delivered product costs. SRWC systems are very different from most forestry practices and require establishment techniques similar to agricultural row crops.

High Potential SRWC Species

Desirable SRWC species combine the traits of rapid juvenile growth, wide site adaptability, pest resistance, and disease resistance. Good coppice regrowth is desirable, though perhaps not an essential characteristic. The best-known species exhibiting these characteristics include silver maple (*Acer saccharinum*), sweetgum (*Liquidambar styraciflua*), sycamore (*Platanus occidentalis*), black locust (*Robinia pseudoacacia*), *Eucalyptus* species or hybrid and poplars (*Populus*) species or hybrids. There are other less well-known genera that are considered to be potentially important for limited regions of the United States, such as willows (*Salix* spp.), alders (*Alnus* spp.), mesquite (*Prosopis* spp.), and the Chinese Tallow tree (*Sapium sebiferum*).

Fig. 1. Woody and herbaceous species which appear to be good models for energy feedstock production.

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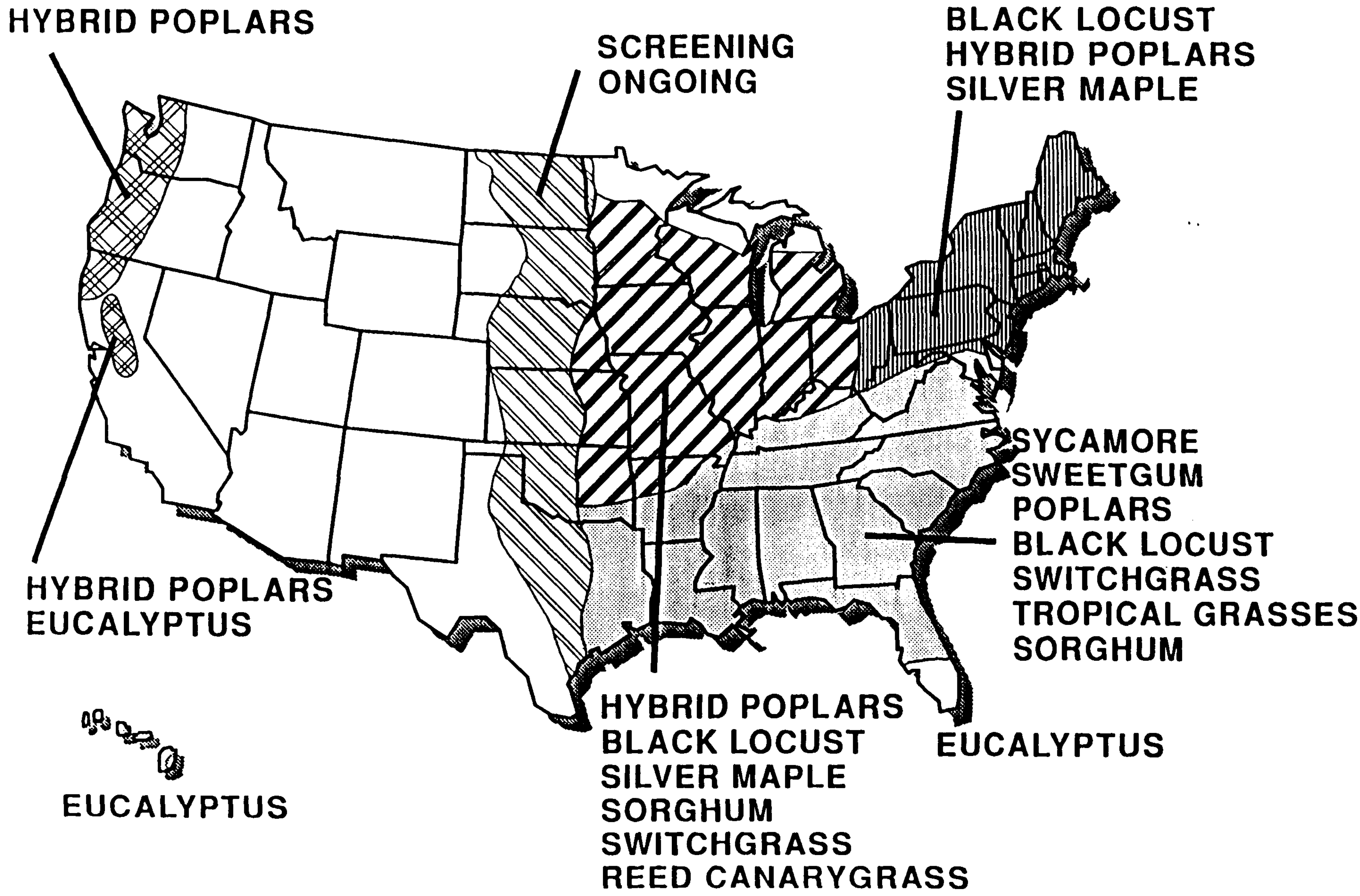

Table 1. Short-rotation woody crop yields by U.S. region—current expected yields for operational conditions and research goals

Region	Yields dry Mg/ha/year		
	Current[a]	Current[b] maximum	Research goals
Northeast	9	15.7	15
South/Southeast	9	15.7	18
Midwest/Lake	11	15.7	20
Northwest	17	43.3	30
Subtropics	17	27.6	30

[a] Estimate based on larger research production plots.
[b] Maximum yields observed in small plot research trials.

Hybrid poplar and eucalyptus have shown the greatest potential thus far for attaining exceptionally fast growth rates in the United States. Both have achieved yields in the range of 20 to 43 Mg/ha//year in experimental trials with selected clones. Hybrid poplars currently have the added advantage of ease of propagation by both stem cuttings and tissue culture. Most eucalyptus are planted as seedlings. Poplars and their hybrids can theoretically grow in many parts of the United States; however, *Eucalyptus* is limited to Hawaii, southern Florida, and parts of California. The most important limitation to widespread use of hybrid poplars for energy is the susceptibility of many clones to fungal diseases. As few as 6–8 poplar hybrid clones are currently suitable for widespread commercial use in the north central region. There are no hybrid poplars currently suitable for the South/Southeast, although a few eastern cottonwood clones are suitable.

The most promising SRWC species for biomass production in the major crop-growing regions of the United States are summarized in Table 3-2. Studies on the stage of development of the various species for biomass suggest that much development needs to be done to implement SRWC as optimized systems. For instance, research shows that clonal plantings can provide major increases in yield due to uniformity of stock and consistency in genetic potential, yet only poplars are now commercially available as clones. The first selected seed sources or provenances of silver maple will not be identified for another 3 to 5

Table 2. Status of development of SRWC species as high-yield energy crops

Species	Genetic improvement status, availability, and clonal techniques
Populus spp.	PNW: Numerous high-yield hybrids now commercially available. Breeding program continues. Industry is involved. NC: Six to eight hybrids have suitable disease resistance, adequate yields. DOE breeding program may have new hybrids within 5 years. NE: NC hybrids may be suitable, no regional breeding ongoing. GP: Some NC hybrids may be suitable, some breeding ongoing. S/SE: Few selected *P. deltoides* clones in industry plantings. Industry involved in some breeding/hybridization work, but clones not commercially available. Well developed: stem cuttings common, micropropagation easy.
Eucalyptus spp.	Eucalyptus is only suitable for Hawaii, Florida, southern Texas, and part of California. Distribution is limited by susceptibility to frost damage. Selection programs in Florida have made only modest gains in finding frost-tolerant species. Hybridization potential is high. Few species have been commercially micropropagated.
Black locust	Black locust seed sources are being tested in Michigan, Kansas, and Georgia. Techniques for genetic improvement through gene insertion are being developed. Improved seed sources and clones are not commercially available. Micropropagation has been done, stem cutting technology is under development.
Sycamore	Modest improvement over wild type has been made through industry-university cooperative programs. Quality of commercially available seed sources is highly variable. Clones are not commercially available. Industry is continuing genetic improvement programs. Stem cutting and micropropagation techniques under development.
Sweetgum	Modest improvement over wild type has been made through industry-university cooperative programs. Feasibility of gene transfer has been proven. Industry is developing clonal propagation techniques for commercial use, but clones are not yet commercially available. Stem cutting and micropropagation techniques proven.
Silver maple	Genetic improvement programs recently begun. Provenance testing with tissue-cultured clones initiated in 1990 and 1991. Improved seed sources or clones are not commercially available now. Micropropagation techniques recently developed through research.

years since the first provenance trials were established in 1989 and 1990. Availability of additional poplar clones for the rest of the United States is being held up while research programs work on breeding new clones specifically for resistance to several diseases.

In all regions, clonal material or seedlings may need to be ordered from local suppliers a year or two in advance, particularly if large numbers are required. Commercial operations have had problems obtaining satisfactory numbers and qualities of seedlings. Sorting of seedlings by root collar diameter and root quality can have a very positive effect on survival and productivity. High-quality cuttings or seedlings are essential to obtaining acceptable establishment survival. It will take several years before the high-yielding clones or seed sources developed in research programs are available to the public in large quantities.

Site Requirements

The best growth conditions for most SRWCs are found on deep, well-drained fertile soils with adequate moisture. In regions such as the South/Southeast where summer drought can be a problem, these type soils would most commonly be found in bottomlands. Light textured soils such as sandy loams and silt loams are generally best, but heavier textured soils containing more clay can produce excellent growth if the soil is relatively well drained. Upland sites can also successfully support SRWC if soil depth and moisture are adequate. SRWC sites should not have slopes of over 8% to prevent erosion and allow ease of access for harvesting equipment. All sites suitable for SRWC trees fall within the SCS classification of cropland or potential cropland. High quality SRWC land includes good cropland as well as land marginal for crop production due to wetness or erodibility potential.

Establishment of SRWC species on cut-over upland forested sites has been tested. Results indicate relatively poor growth compared with establishment on cropland. This may be a function of the greater difficulty in controlling competing vegetation on such sites or may reflect the poorer quality of the soil compared to most cropland. The lower nitrogen levels often associated with upland forested or cropland sites can limit growth. A variety of site limitations can be partially overcome by selecting appropriate species/clones for a given site.

Where deep, fertile soils with adequate moisture are available and disease incidence is low, hybrid poplars are likely to be the species of choice. However, different SRWC species allow the potential for exploiting wetter, dryer, and more nutrient-poor areas unsuitable for many poplar clones. For example, silver maple is probably better adapted to bottomland sites in the north central states that experience frequent flooding; black locust, a nitrogen-fixing species, effectively utilizes sites with poor nutrient status almost anywhere in the United States; sycamore has similar nutrient and drainage requirements to that of poplar species but is better adapted to the southeastern United States, where respiration demands are higher and drought stress a more common occurrence; and sweetgum is better adapted to southeastern sites with lower fertility, poorer drainage, and more droughty conditions.

Woody Crop Agronomics/Cropping Strategies

Site Preparation and Planting

One key to successful SRWC plantations is effective site preparation. SRWC trees need to be established under the same conditions as almost any other agricultural crop. Most experts agree that site preparation should begin as much as 1 year prior to establishment. However, because of demands on staff time or lack of experience, many of the operational plantations being established today only begin site preparation in the fall prior to establishment of the trees in the spring. Initial site preparation for SRWC will vary depending on previous ground cover. Abandoned cropland or pasture may require an initial brush removal or mowing operation, plowing and subsoiling application of a broad spectrum herbicide, and further cultivation and/or herbicides to remove problem weeds (Kroll 1990, Anonymous 1987, Heilman 1991). Conversion of a row-crop field to SRWC may require only a single spring plowing and row-marking operation. No-till establishment techniques have not been effective (Hansen et al. 1986).

Weed Control After Planting

Good survival and growth of SRWC can be achieved with less effort than row crop production if the site is thoroughly prepared and planted with fast-growing clonal material. Various weed control methods are used to eliminate competition for light, water, and nutrients. Cultivation down and across rows can be used to control weeds after planting if enough space is available to move equipment among the trees. However, herbicide applications before and after planting have been effective in reducing labor and avoiding pruning of the developing roots near the surface. The cost-effective operational techniques demonstrated in experiments involve a combination of tillage and herbicide applications. An additional approach being used in industrial SRWC production is to institute frequent monitoring and quick spot treatment of problem areas.

During the extreme drought conditions of 1987 and 1988, survival success of hybrid poplar clones at several sites in Minnesota and Wisconsin was believed to have a high positive correlation to effectiveness of the weed control (Hansen, Ed, North Central Forest Experiment Station, personal communication, 1989). This suggests that under drought stress conditions, hybrid poplars can obtain sufficient moisture for growth if weed competition is eliminated.

To address public concern about herbicide use, several strategies are being pursued to minimize its use. For example, alternative cultivation methods being evaluated include application of herbicide to only a narrow band within the row of trees with between-row treatments of either cultivation, mowing, or seeding of an easily shaded herbaceous cover. Discussion is beginning on the use of traditional agroforestry techniques as a means of improving weed control while reducing herbicide use. One experiment has been established which alternates rows of trees and switchgrass, a perennial grass also being grown as an energy crop. The interest in perennial leguminous crops for planting between the rows is increasing, though relatively little experimental work has been initiated to date. It is anticipated that such research will begin in the near future.

Selection of Spacing/Rotation Length

Spacing alone does not have a large effect on yield if the stands are managed such that they grow long enough to achieve their maximum current annual growth rate and are cut before competition-related mortality begins to occur. However, different spacings will result in different establishment costs, optimal rotation ages, and tree sizes at harvest age. Spacing guidelines have to be tailored to the specific trees or clones, the site quality, the desired size at harvest, and/or the desired cutting cycle.

In the Pacific Northwest, Heilman et al. (1991) indicate that on good sites the spacing between hybrid poplars, in feet, would be the desired harvest cycle in years plus 2 [e.g., 8 ft x 8 ft (2.4 m x 2.4 m) for a 6-year rotation]. In the South, sycamore is expected to be ready for harvest at age 5 at a spacing of about 1.5 m x 3 m (5 ft x 10 ft). Insufficient data have been developed to generate economically optimized production curves for all SRWC species and regions.

An important aspect of the production of short-rotation woody crops is that the rapid juvenile growth and high carbon sequestration rates can be sustained only if the stands are harvested on a regular basis. With short-rotation trees established for an 8- to 10-year rotation, the incremental growth rate will likely peak at years 4 to 6 and then be quickly slowed by competitive interactions among the trees. Although the mean annual growth pattern can be expected to continue to increase 2 to 4 more years, the carbon sequestration rate slows along with the incremental growth rate. Weaker trees die and begin releasing carbon. At this point it is uncertain whether carbon sequestration will be less than, equal to, or slightly greater than carbon releases. It will undoubtedly vary from stand to stand. Very few over-aged short-rotation stands currently exist from which to draw conclusions. However, it is certain that the carbon sequestration rate would be much higher if the trees were harvested allowing rapid regrowth to occur.

Fertilization

It is anticipated that fertilization will be needed for most SRWC species at some point to maintain rapid growth and sustain the fertility of the land. For fertile bottomland sites this may not occur until later in the first rotation or even in the second rotation. For upland sites with low organic matter, some fertilization may be required several times during each rotation (Hansen 1987). Application of organic sludge might be an alternate low-cost method of improving long-term nutrient levels on nutrient-limited sites. If weed control is effective, fertilizer application in the first year is generally not needed. Conversely, in the absence of effective weed control, fertilization during the first year can result in severe weed competition problems. To limit production costs and possibility of nutrient runoff, fertilization should be added only when it is needed and can be quickly used by the trees. Development of fertilization protocols based on soil and tissue indicators is currently a goal of the SRWC research program. Research currently suggests that the optimum fertilization strategy may require additions of phosphorus, potassium, and lime prior to planting for site amelioration (Tolstead 1988). However nitrogen should be withheld initially, then added in larger amounts as the trees increase in size and/or as nitrogen deficiency is detected in the leaves. Additional phosphorus and potassium and micronutrients will be added when deficiencies are detected.

Pest Control

Pest control measures will be very specific to regions and even to individual fields depending on surrounding conditions. There are a large number of insect and microbial pests that can pose problems for SRWC (Ostry 1988). From both an environmental and economical perspective, the best control is to select species and clones that show resistance to some of the more common problems and to use establishment and maintenance techniques that assure vigorous growth. Only a few hybrid poplar clones can currently be recommended for SRWC plantations in the eastern United States because of pest problems, but over reliance on a few clones should be avoided in case new problems emerge. Integrated pest management techniques should serve to identify pests early and determine appropriate control mechanisms (Ostry and McNabb 1990). Often in vigorously growing stands, no control for insect or fungal pests will be needed. Animals such as deer, elk, domestic livestock, beavers, voles, and gophers can cause serious problems during the first year or two of growth. Local county extension agents should be able to offer advice on control of animal pests.

Harvesting Approaches

Timing of the harvest of SRWC will depend on soil and climatic conditions of a given site unless feedstock demands by the conversion facility demand otherwise. When considering stand survival and nutrient conservation, most SRWC trees should be harvested during their dormant season. Coppice regrowth will be much more vigorous. Significant amounts of nutrients will have been either translocated to the roots or returned to the soil by leaf fall. However, during the winter, wet soils may prohibit equipment use. Crops would be harvested during the summer or a drier season. Even in stands managed for coppice regrowth, some harvesting during the summer will be appropriate as a management tool to prepare sites for planting of new material. Economic analysis suggests that coppice stands should only be harvested three times before replanting. This could be a period of 15 to 30 years depending on average rotation length. The decision to coppice or replant after a harvest should take into account the progress made in the selection of faster growing, hardier clones.

Analysts disagree about assumptions on how SRWC might be harvested, handled, and transported (Table 3-3). The differences result from different assumptions about the conversion process and different assumptions on handling and processing. These disagreements demonstrate the need to optimize harvesting and handling techniques for specific wood uses.

Table 3. Short-rotation woody crop harvesting and handling assumptions

Harvesting	Field handling	Transportation	Plant handling	Reference
Severance head on tractor	Baler/ loader-unloader	Tractor-trailer with bales for 40 km	Plant chipper	Strauss et al. (1988)
Harvester/ chipper combine	Forwarder transfer utility	Tractor-trailer with chips for 40 km	Unloader	Strauss et al. (1988)
Continuous feller buncher	Large skidder, large chipper	Not considered	Not considered	Stokes et al. (1986)
Continuous feller buncher	Small skidder, small chipper	Not considered	Not considered	Stokes et al. (1986)
Continuous feller buncher with attached loader	None	Whole-tree transport for 40 km at $0.055 Mg/km	Not considered	Lothner et al. (1988)

Several pulp and paper companies with large plantations are deciding how to efficiently harvest and handle their SRWC plantations now. Considerable innovation is expected to occur. Analysts believe that within 5 years more information will be available on appropriate harvesting techniques for a range of tree sizes and site conditions. However, companies harvesting trees for paper are less likely to be interested in coppice management strategies. They generally prefer to harvest large single stems that can easily be delimbed and debarked. Thus additional research and development will be required to define the optimum equipment for wood energy crops managed as coppice stands.

ENVIRONMENTAL BENEFITS AND CHALLENGES

The potential exists for short-rotation wood and herbaceous grasses and legumes to provide a significant and environmental benign source of renewable energy resources in the future in the United States. Futhermore these crops can help resolve multiple problems in the agricultural sector of the U.S. economy and significantly contribute toward reducing CO_2 buildup and its associated global warming dangers.

The future biomass resource potential for energy crop production in the United States is somewhere between 5 and 20 GJ of primary energy depending on research advances and public policy decisions (Fig. 2). The biggest issue determining the resource potential is the amount and type of land available. Analysis has shown that about 160 million hectares of land in the U.S. are capable of producing energy crops (Graham, in press). Much of this land is currently in use for production of agricultural crops or is serving as pasture and range. However, about 25 million hectares of cropland are currently being idled as a result of government efforts to reduce surplus crop production, particularly on land sensitive to erosion. Much greater amounts of cropland may be idled between 2010 and 2030. Much of the surplus and sensitive cropland could be used for the production of energy crops using environmentally sound production techniques. This would not only supply energy but revitalize the rural economy of the United States.

The carbon mitigation benefits of SRWC will depend not only on the amount of land actually converted to energy crop production, but also on the type of fuels that SRWC displaces, the efficiency of conversion processes and the amount of fossil inputs into the fuel production process. Estimates of carbon mitigation potential based on assumptions of 28 million hectares of land, yields of 22 dry Mg/ha/year, use of SRWC to displace coal to produce electricity at a conversion efficiency of 42% (Wright et. al, 1992) show that nearly 5% of the current annual U.S.carbon emissions could be avoided each year in the
future. No credit was taken for the additional carbon which will be tied up in the soil and in the average standing wood. Those considerations, improve the near-term carbon benefit considerably, but only contribute to the annual carbon emission reduction for a period of 50 to 100 years (Ranney et. al. 1991). The assumed yields are very optimistic for woody crops in the United States but such yields might be achievable in 20 to 30 years on large amounts of land in the U.S. if high yielding herbaceous crops are used where feasible and if research in genetic improvement of woody crops is pursued aggressively as it has been in Brazil.

The perceived positive benefits of using SRWC technology for producing energy is being recognized by several environmental and conservation groups in the U.S. but any technology that has the potential for making such large changes in land use patterns raises a lot of concerns as well. Many questions about environmental effects are being asked: (1) will SRWC plantings affect biodiversity and wildlife habitats, (2) will air and water quality be degraded or enhanced, (3) will soil erosion increase or decrease, (4) is high productivity sustainable over the long term and (5) is there the potential for genetic pollution or the facilitation of widespread insect and disease dissemination?. Clearly it is impossible to answer these questions definitively since very few operational plantings of SRWCs exist today and because we do not know precisely which land will be converted to SRWC production. However, considerable effort is now being put into collecting data where available and/or evaluating current agriculture and forestry techniques to hypothesize the probable effects.

Effects on biodiversity and wildlife habitats are anticipated to be generally positive. The addition of perennial energy crops, especially woody crops will add diversity to regions consisting of extensive monoculture of annual food and fiber crops. However, energy crops will not likely add to biodiversity on a global level. At the local level, energy crop plantings can be managed to increase the potential for wildlife habitat within plantings. For instance, SRWC plantations can purposely include patches of ground cover, and some percentage of natural woodland area containing dead trees, mast producing trees and winter cover. The placement of SRWC plantings next to existing woodlands can create corridors for wildlife movement. The potential for SRWC planting to serve as at least temporary habitat for a wide variety of birds including rare species has been confirmed by an Audubon Society study on hybrid poplar plantings in Canada (Jim Cook, Audubon Society, personal communication, 1992).

Air quality changes resulting from increased use of SRWC are mainly indirect and are dependent on it's end use, whether or not fossil fuel use is being displaced, and the land use changes caused by increased production of energy crops. The potential for very beneficial effects on atmospheric carbon dioxide were discussed above. There are minor local effects on air quality to be considered, however. For instance there are diesel emissions from equipment used to plant, maintain and harvest the wood. There could be some methane emission from soils, and N2O emissions from enriched sites but these have never been measured and are expected to be less than those associated with agricultural crops. Occasional dust and pollen emissions could present problems at a local level. With some species such as poplars and eucalyptus, the emissions of volatile organic compounds (VOC) from tree leaves may be somewhat to considerably higher than background levels. The potential negative impacts of these natural VOC emissions is anticipated to be small compared to the overall air quality benefits resulting from using biomass resources to produce energy.

Water quality impacts from fertilizer and herbicide use are most likely to occur at the time of initial crop establishment. However the establishment period only accounts for 10% of production cycle. Other chemicals for pest control, however, may need to be applied at any time during the production cycle. In comparisons with row crops, SRWC systems clearly cause less potential insult to the environment. However comparisons with pasture land or forested land is a different issue. The challenge for SRWC systems is to find economically viable methods of reducing chemical use even further. Agroforestry techniques clearly need to be investigated for their potential in reducing the need for chemical applications.

Erosion and long-term sustainability are linked issues. Much of the reduction of productive capacity in the soils in the United States is due to erosion. Currently the widespread application of fertilizers compensates for that loss. That means, however, that water quality is being reduced not only by soil runoff but also by nutrient runoff and leaching. Both of these issues can be addressed by the increased use of woody crops or perennial grasses for energy on land currently used for row crops. Strategic placement of perennial woody or herbaceous crops on gently sloping hillsides, as buffers between agricultural fields or animal feedlots and streams and as windbreaks in dry areas presents the opportunity to use energy crops in environmentally beneficial ways. There is a challenge, however, to assure that the establishment phase of woody crops does not result in excessive short-term erosion. The use of leguminous cover crops, food crops or even weed strips between the tree rows are all alternatives that need further investigation.

Nutrient additions, especially nitrogen, is assumed to be necessary to maintain high yields in SRWC systems. Micronutrient additions will also likely be needed over long periods of time. The challenge will be to develop systems that are highly efficient in use of nutrients and that allow as much recycling of nutrients as possible. For instance, it is recommended that woody crops be harvested only during the dormant season to avoid removing green leafy material. Supplying a facility year-round may require using alternative feedstocks during periods of the year or year-round storage of materials. If year-round harvesting of SRWC is required, it may be necessary to leave tops and branches in the field to maintain site quality.

One concern that often arises is that genetically improved selections of energy crops will interbreed with native strains of the same species in the surrounding landscape, thereby eventually changing the genetic makeup of native populations. This is generally not perceived to be a problem with SRWC trees since they are usually harvested well before flowering occurring. However, some species flower earlier than other, and under good growth conditions, flowering may be induced earlier than expected. One solution is to use only sterile strains.

It is currently anticipated that the environmental benefits of SRWC crops will be much greater than the risks. Yet many challenges remain for developing establishment, maintenance and harvesting protocols which add minimum insult to the environment without greatly increasing cost of production. The United States will likely find it necessary to document environment effects and resolve environmental questions before commercialization will proceed on any major scale.

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