Understanding Short-Rotation Woody Crops

The term short-rotation woody crops (SRWCs) has been used synonymously with dedicated energy plantations (DEPs) and woody perennial energy crops (WPECs). However, DEPs and WPECs can include material from a non-forestry system. For the context of this publication, the term SWRCs will be used as a reference to forestry systems.

These are designed to be intensively managed for production of a high-quality feedstock that can easily be placed into a bioenergy or biofuel process or be used to develop various polymers, such as carbon fiber. Intensive management relies primarily on genetic improvement of a variety of traits and various silvicultural techniques to enhance productivity. While fertilization and irrigation have been included in the past, these additions can greatly inflate the cost of production as well as the carbon footprint of this type of system.

Research and development of SRWCs resulted from the oil embargo of the 1970s, but since then, lower costs and an abundant oil supply limited research and development in the area of biomass production for conversion to bioenergy or biofuels. However, the infusion of funding during this early period allowed for the development of short-rotation woody cropping systems (Johnson et al. 2007).

In the United States, fast-growth hardwoods such as poplars (*Populus* spp.) and willows (*Salix* spp.) garnered the most interest for SRWCs. However, a variety of other species such as American sycamore (*Platanus occidentalis* L.), sweetgum (*Liquidambar styraciflua* L.), and yellow poplar (*Liriodendron tulipifera* L.) were also evaluated (Tuskan 1998; Kszos, 2007).

Globally, various species and hybrids of poplars and eucalyptus (*Eucalyptus* spp.) received the majority of research and operational efforts for SRWCs. Unfortunately, the SRWC system found few viable outlets in the United States, except in the pulp and paper market. Even in the pulp and paper market, demand was limited for a variety of reasons, including lack of added value (e.g., sawtimber), lack of fit with specific pulping processes, and insufficient acreage for a significant annual impact to a specific processor.

However, a global debate began in 1992 regarding fossil fuel emissions of greenhouse gasses (GHG) and the resulting climate changes. This debate highlighted the need for renewable sources of energy. In 2005, the Kyoto Protocol resulted in policy changes focused on reduction of GHGs by the ratifying countries, which included the European Union and Great Britain. Inflated transportation fuel costs in 2007 resulted in a more serious focus on using biomass to produce biofuels.

With increased interest in biomass production, there was a renewed interest in SRWC systems. This type of forestry system was not included in the forestry sector of the 2005 U.S. Department of Energy's Billion-Ton Study or future updates; instead, it is included in the energy crop sector of the agricultural sector (Perlack et al. 2005; U.S. Department of Energy 2016). This sector is expected to see a tremendous increase in production through 2030. Best estimates show approximately 132,000 acres of SRWC plantations in the United States, which represents approximately 0.1 percent of privately owned agricultural and forest lands (Zalesny et al. 2008).

Discussion

Short-rotation woody crops seem to be the most appropriate method for producing greater amounts of biomass feedstock. The various advantages to using SRWCs follow:

1. Reduced transportation costs. Typically, movement of wood to a mill site is a large portion of the overall delivered price of feedstock. By establishing dedicated energy plantations very close to the operational mill site, limited transportation costs could greatly lower the overall cost.
2. Self-sufficiency. Although there is no need to be 100 percent self-sufficient, a certain percentage of self-sufficiency may reduce costs and have a positive public relations impact.
3. Rapid incorporation of technology. New feedstock technology could be easily incorporated into this type of system.
4. Insurance of wood flow. These dedicated energy plantations could be used to offset costs of more expensive feedstock during difficult procurement periods. Wood can be stored on the stump, and rotation lengths can be varied depending on availability and cost of outside wood.
5. Reduction of the overall carbon footprint. By establishing high-yielding, fast-growth plantations near the processing facility, carbon emissions from transportation are reduced, and lessen overall impact on the environment.
6. Greatly reduced impact to natural stands. The high productivity level of SRWCs and the proximity of plantations to the production facility reduce or eliminate the need to remove biomass from natural stands.
7. Positive public relations. Dedicated energy plantations demonstrate that the company embraces technology and is willing to lead the way in producing a viable feedstock. In addition, the technology could be shared with growers near the mill site.

Short-rotation woody crop systems could and should play a major role in meeting future needs for woody biomass. Optimal traits for a biomass species include: 1) ease of producing identical growing stock from genetically superior selections of any age (allows a very short period of time from selection to a large-scale planting); 2) rapid juvenile growth rates that reach expected harvest in 2–5 years; 3) ease of coppice (regeneration from stumps of harvested trees), which reduces replanting costs for numerous rotations; 4) adaptability across a wide variety of sites; and 5) ability to spray herbicides directly over the top of plantations to control vegetative competition. These traits can accelerate development of superior genetic material and reduce growing costs substantially.

Typically, only fast-growth hardwood species were initially evaluated as a biomass feedstock source. However, care must be used in matching these species to specific sites in order to maximize potential productivity and minimize problems associated with a variety of diseases. In addition, the number of trees per acre (800 to 12,000) for dedicated hardwood energy plantations will exceed any type of previous planting.

Hardwood species, including a variety of species and hybrids of poplars, willows, and eucalyptus, are currently being thoroughly evaluated through breeding and clonal testing for survival, growth, and disease resistance. These species and hybrids share a number of desirable traits that include more easily produced clones, rapid early growth rates, and ability to stump sprout. However, these species and hybrids also have problems associated with adaptability to various site types, disease susceptibility, and poor resistance to herbicides needed to control vegetative competition. For example, eucalyptus would be grown only on upland soils marginal for agricultural production, whereas black willow would be grown on heavy clay soils that exhibit poor drainage and are considered marginal agricultural sites.

Fast-growth hardwoods can only tolerate a few herbicides applied as pre- or post-emergent treatments. A lack of herbaceous competition control results in significantly reduced tree growth. Herbaceous and vine competition control is a major cost associated with SRWCs. Most sites have a rich weed seedbed that can greatly limit growth and survival during the first year. Mechanical cultivation has been used extensively in the past, but is limited by the cost associated with the number of entries needed to maintain a nearly weed-free environment. Herbicidal weed control is a more desirable alternative, but few chemicals are labeled for hardwoods (Self and Ezell 2020). Continued evaluation of various existing herbicides and development of new products will be needed to provide safe labeled herbicides that will reduce vegetative competition.

Currently, there is little information concerning optimal spacing for bioenergy plantations of various hardwood species. Most bioenergy plantations are planted at various density levels depending on the geographic area and the expected rotation length for the desired product. The grower will also have to consider not only how the material will be used, but how it will be harvested. The ability of the species to effectively coppice following the first rotation would be a strong advantage because it would reduce planting and establishment costs for subsequent rotations. Factors that would lead to economic gains from dedicated bioenergy plantations follow:

- Incorporate chemical site preparation and herbaceous weed control where needed to reduce first-year competition from herbaceous perennial weeds and vines.
- Use genetically superior clonal planting stock selected to increase yields in biomass production.
- Employ optimal spacing for species and type of biomass desired.
- Develop and use herbicides that can be sprayed over the top of actively growing trees to control vegetative competition.
- Develop nutrient amendment prescriptions necessary to ensure rapid growth.
- Development of equipment that can efficiently and effectively harvest small-diameter material at close spacing.

In the past, pine has not been considered a bioenergy crop because of its slower early growth, difficulty in cloning, and lack of coppice regeneration. However, genetically improved pine can be planted over a very wide geographic area, and a number of herbicides can be sprayed to maintain herbaceous competition control. This makes pine one of the cheaper biomass options. In addition, pine plantations have been sustainably grown in the southern U.S. for nearly 90 years and cover more than 30 million acres (McKeand et al. 2006). These plantations will be among the primary biomass feedstock sources needed to meet future productivity of bioenergy and biofuels. Thinnings at various ages in traditional pine plantations can produce a substantial tonnage of high-quality biomass feedstock. These thinnings also reduce stand density for remaining trees that are harvested at a later date for added-value products (e.g., sawtimber, plywood, and poles).

Summary

Short rotation woody crop systems could be a major source of renewable dedicated woody feedstock for bioenergy and biofuel products. This intensive system requires use of technology in areas such as genetics and harvesting. Forest residues, woody urban waste, and weather-related salvage wood can provide quantities of biomass to bioenergy/biofuel systems that do not place limitations on feedstock quality. However, only an intensive system, such as an SRWC, can provide high-quality feedstock to more demanding users. In the future, these types of systems could reduce demand on native forest resources, while providing greater diversity and requiring a less-intensive management strategy.

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Publication 3019 (POD-11-21)

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Produced by Agricultural Communications.