17 Forestry Implications of Agricultural Short-rotation Woody Crops in the USA

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Introduction

In considering forestry issues at the national or regional level, it is appropriate to pay attention to major developments that have the potential to change forest resource conditions and shape future options. One recent historical example was the landfill crisis from the early 1980s to the mid-1990s. As recently as 1988, a major study of forest resource conditions in the US South projected real prices for southern pine pulpwood to increase 130–150% by the year 2030 (USDA Forest Service, 1988). The study projected annual use of recycled paper in the USA to rise by only about 20% from the 1980s to 2030. The report barely mentioned emerging solid waste problems and potential implications for pulpwood markets. In reality, from the 1980s to the mid-1990s, government regulation of landfills and declining numbers of operational landfills precipitated unprecedented increases in waste disposal fees in the USA (several hundred per cent or more, according to periodic surveys of the National Solid Waste Management Association). The so-called landfill crisis and higher waste disposal fees prompted thousands of businesses and local communities to massively increase recovery of recyclable materials (Environmental Defense Fund, 1995). The popularity of recycling and a subsequent glut in recovered paper supply in the early 1990s stimulated significant industrial expansion in paper recycling, with annual use of recycled paper increasing in the USA by around 130% since the mid-1980s (AF&PA, 2000). This formerly unexpected development dampened growth in pulpwood demand throughout the 1990s and contributed to the decade ending with flat to declining real pulpwood prices in the US South (University of Georgia, 2001). By the early 1990s, an updated Forest Service timber study had analysed market impacts of paper recycling and projected relatively stable southern pine pulpwood prices (Ince, 1994).

Another potentially significant development that is not closely connected to forest policy in the USA is agricultural short-rotation woody crops (SRWC), which are tree crops that can be grown for wood fibre on cropland more rapidly than trees in a natural forest environment. The purpose of this chapter is to discuss forestry implications of SRWC based on an economic analysis. As with the development of paper recycling, anticipating forestry implications of agricultural SRWC will depend in part on anticipating market conditions and economic impacts of technological

* The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin.

developments. This chapter presents an analytic framework and market outlook for agricultural SRWC as wood fibre crops in the USA and considers some potential implications for forestry.[1]

Methods

We projected long-range market equilibria for agricultural SRWC in this study by linking two large-scale regional market models, the Forest Service North American Pulp and Paper model (NAPAP) and the USDA POLYSYS model of the agricultural sector. The market analysis stems from a base case outlook with alternative scenarios derived by varying base case assumptions. Methods in this study were similar to methods used in a previous analysis of the economic potential of agricultural SRWC for pulp fibre production in the USA (Alig *et al.*, 2000).

In both the current and previous studies, nationwide projections of wood fibre demands were linked to large-scale economic models of the agricultural sector. The previous study used the Forest and Agricultural Sector Optimization Model (FASOM), an intertemporal optimization model. A primary function of FASOM is to derive the economic equilibrium in conversion of agricultural land to wood fibre production and other shifts in land use between forestry and agriculture with time. FASOM solves for a singular spatial land-use equilibrium across decade intervals. FASOM projected a fairly significant conversion of agricultural land to SRWC for pulp production in the next few decades (from 0.6 to 1.0 million ha of SRWC plantations nationwide). In the FASOM results, projected SRWC plantations were concentrated in the Lake States of the upper Midwest and in the Pacific Northwest (unlike the current study, where projected SRWC plantations are concentrated in the South). The FASOM study assumed that SRWC yields would improve with time and technological improvements. FASOM used exogenous projections of pulpwood demands derived earlier from the NAPAP model. However, in this study, NAPAP was linked to POLYSYS to solve for SRWC market equilibria each year (simulating adjustments to annual market equilibria with time rather than deriving a singular equilibrium across the span of decades). In terms of projected agricultural land use, both studies evaluated long-run shifts between conventional cropland use and SRWC, and FASOM also provided an analysis of the long-run potential for converting forestland into agricultural land-use. In POLYSYS, the projection of total agricultural land area remains fixed, but land use may shift within that area from conventional uses to SRWC depending on projected market conditions. The NAPAP–POLYSYS system also simulates evolution of pulp and paper production technology in response to projected market conditions (in FASOM, pulp and paper technology assumptions did not shift in response to market conditions but remained fixed).

The NAPAP model is a partial equilibrium model of the North American pulp and paper sector. The model solves for annual market equilibria by optimizing consumer and producer surplus of the pulp and paper sector each year, subject to evolving constraints of production capacity and technology (Zhang *et al.*, 1996; Ince, 1999). The NAPAP model projects technological changes and market conditions, including markets for wood fibre inputs, given basic assumptions about economic growth and population. The NAPAP model incorporates the timber supply analysis of the 2000 Forest Service draft RPA timber assessment.

POLYSYS is also a partial equilibrium model of the US agricultural sector that solves for annual market equilibria among agricultural crops. POLYSYS is maintained by the Agricultural Policy Analysis Center (APAC) at the University of Tennessee and is used by USDA and other agencies. POLYSYS computes an economically optimal allocation of agricultural land-use among various crops each year. POLYSYS derives equilibrium levels of planting for agricultural crops by optimizing net present values of agricultural crops in relation to costs and projected equilibrium prices (Ray *et al.*, 1998).

POLYSYS simulates the decisions of farmers to plant crops based on their projected prices and relative profitability. It finds the optimal mix of crops to be planted each year among all crop options (including crops such as maize, soybeans, etc.). In POLYSYS, the cropland allocation influences equilibrium crop prices, reflecting the interaction of supply and demand. However, the model starts with a baseline crop price forecast that corresponds to the official USDA 10-year crop price forecast (revised annually by USDA; in this study, we used the 1999 price forecast). Variation in soil productivity and crop productivity by region are also taken into account by POLYSYS.

In recent years, POLYSYS was programmed at APAC to include SRWC as well as other major agricultural food and fibre crops and livestock. POLYSYS includes all US cropland currently in major crop production or that is idled, in pasture, or in the Conservation Reserve Program (CRP). CRP is a Federal programme that pays farmers to take cropland out of crop production for fixed contract periods, promoting the objectives of soil conservation and market stabilization. However, the CRP land was not available for SRWC in this analysis, although it might be considered in future studies.

Iterative solution technique

In this study, we linked NAPAP and POLYSYS solutions by exchanging equilibrium supply quantities and prices for SRWC and running the models toward a convergent equilibrium solution. The POLYSYS solution for SRWC is based on estimates of prices, production costs, rotation lengths and biomass yields, which vary among POLYSYS regions (the 305 agricultural statistical districts (ASD) of the USA). Planting and growth of agricultural SRWC occurs in POLYSYS only if the model has determined that SRWC are competitive compared with other agricultural crops or land uses in terms of net present values. Given a set of price projections for SRWC, POLYSYS derives annual cropland allocation to SRWC and provides projections of annual SRWC supply (projected crop yield and cost by ASD). For the NAPAP model, we adjusted the SRWC yields and costs to include added costs and material losses in debarking, chipping and delivery of clean pulpwood chips. Approximately 71% of SRWC biomass can be converted into debarked or clean pulpwood chips, based on field trials in hybrid poplar plantations using conventional harvesting equipment with mobile chain-flail delimbing and debarking equipment and on-site chipping (B.R. Hartsough *et al.*, unpublished report, Biological and Agricultural Engineering Department, University of California-Davis).

We pooled annual supply and cost estimates from each ASD into larger NAPAP model regions to create annual stepwise supply curves for pulpwood from SRWC in each NAPAP region (the stepwise supply curves are composed of pulpwood supply quantities and costs from all ASD within each NAPAP region). We used the regional supply curves in NAPAP to solve for annual SRWC market equilibria in the pulp and paper sector. The NAPAP model determines supply and demand equilibria for all types of wood pulp fibre, including pulpwood from forests, wood residues and recycled paper, as well as from SRWC. Production capacities of different pulp, paper, and paperboard processes evolve gradually in the model across a multi-decade projection period, with annual changes in capacity favouring the more efficient processes in continuous response to evolving market conditions. In the NAPAP model, clean chips from SRWC are substitutes for hardwood pulpwood, although we also adjusted supply quantities and costs in NAPAP for the weight discrepancy between hybrid poplars and natural hardwoods. Utilization of chips from SRWC occurs in the NAPAP model only if it is competitive in cost compared with other fibre supply options. As part of the equilibrium solution, NAPAP computes equilibrium (shadow) prices for hardwood pulpwood (and SRWC) each year.

We obtained consistent projections of annual market equilibria for SRWC from the models by sequentially solving POLYSYS and NAPAP in an iterative fashion, sharing SRWC supply and price projections between the models until we derived stable projections of market equilibria. We ran POLYSYS first to derive regional supply curves for pulpwood from SRWC based on initial price assumptions. We then ran NAPAP using the supply curves to compute equilibrium prices for SRWC. We then converted pulpwood price projections to equivalent biomass prices and passed them back to POLYSYS, where the projected prices determined SRWC planting in the next iteration. The combined NAPAP–POLYSYS system generally converged upon a stable projection of SRWC supply, demand and prices within a limited number of iterations (for example, five to seven model iterations) with SRWC yields in POLYSYS matching SRWC consumption in NAPAP and with planted cropland area ultimately matching harvested area in POLYSYS.

Additional technical assumptions

The US Department of Energy, Bioenergy Feedstock Development Program provided regional biomass productivity and cost data for short-rotation hybrid poplars and cottonwoods. Professor Daniel G. de la Torre Ugarte at the University of Tennessee (APAC) programmed the SRWC cost and productivity data into POLYSYS. The regions in POLYSYS that can produce SRWC include the majority of the ASDs, including most districts in the eastern USA plus those western districts deemed to have climate and soil conditions suitable for such crops. SRWC productivity and cost data in POLYSYS vary by ASD, with estimated SRWC rotation lengths varying from 6 to 12 years depending on geographical location.

The rate of adoption for SRWC by farmers is also controlled in POLYSYS by a fixed constraint on the percentage of available cropland area that may be planted to SRWC each year within each ASD. This so-called adoption factor was set at 2% in our baseline analysis, reflecting a realistic assumption that just a small fraction of farmers would entertain risks of planting SRWC in any given year. There are no historical data on this factor *per se*, but we believe it is realistic to assume that the adoption of SRWC by farmers will be inhibited to some extent by inherent perceptions of risk (SRWC for example require a much longer time interval between planting and maturity relative to conventional annual crops or livestock). Nevertheless, we varied the adoption factor assumption among different scenarios.

The SRWC productivity and cost data developed by Oak Ridge National Laboratory were based on field experience with short-rotation poplar plantations since the 1970s and on expert opinion. Data represent productivity levels that are known to be achievable based on conventional technology. The productivity and cost data assume that SRWC are fertilized periodically and treated chemically to suppress weed competition early in the rotation. This is common practice in conventional poplar plantations, although chemical applications are much lower than for most other agricultural crops. The productivity and cost data do not assume that the woody crops will be irrigated. Irrigation is used in a few highly productive plantations in the West and South, affording higher productivity and shorter rotations, but higher costs, per hectare. The productivity and cost data provide a basis for developing alternative scenarios – specifically scenarios based on potential gains in production costs or yields with agricultural SRWC – but to do so would require quantitative estimates of future productivity gains for SRWC by ASD. Such scenarios were not developed in this study, but analysis of such scenarios is recommended as a potential topic for further research.

The NAPAP model incorporates an assumption that hardwood chips from SRWC such as hybrid poplars or cottonwoods (*Populus* spp.) can be substituted on an equal weight basis for hardwood from natural forests (after adjusting for the typically lower density of poplars). Thus, the analysis does not assume any cost advantages for pulping associated with use of hybrid poplars. This assumption may be regarded as conservative, given that recent biotechnology research indicates that genetically modified strains of poplars with lower or modified lignin content can be developed, and this might substantially reduce costs of chemical pulping or pulp bleaching. Production cost assumptions for pulping in the NAPAP model may be modified to assess market impacts of cost savings associated with the use of modified hybrid poplar crops, provided that such estimates of production cost savings become available or can be developed in the future.

The NAPAP model also operates with assumptions about future US population and economic growth that drive economic projections of trends in pulp, paper, paperboard, and wood product consumption and production. The population and economic growth assumptions were derived from US Census Bureau and Economics Research Service projections. In general, although demand projections vary substantially among individual products (and projections are derived through equilibrium analysis rather than trend extrapolation), the projections indicate a continuation of aggregate historical trends in paper and paperboard consumption. Thus, the NAPAP model projects a gradually decelerating trend in US *per capita* consumption of paper and paperboard products and a gradually declining trend in consumption per unit of real gross domestic product (GDP) (Fig. 17.1). In addition, the NAPAP model incorporates projected roundwood demands for composite wood panel products such as oriented strandboard (OSB), the production of which is projected to grow

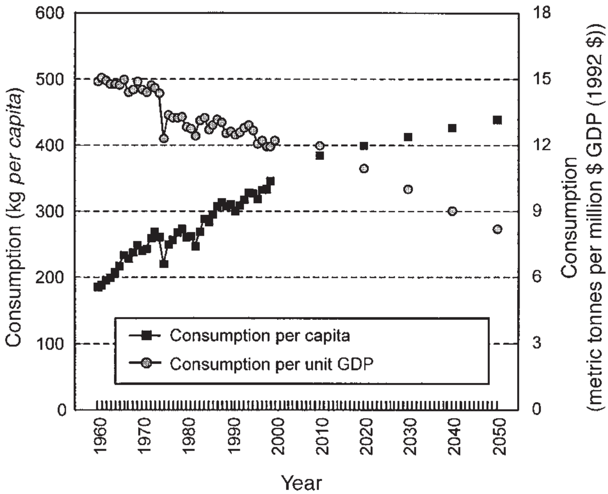

Fig. 17.1. Historical and projected trends in equilibrium annual US paper and paperboard consumption *per capita* and per unit of real GDP (1992 US$).

substantially in the future. Thus, projected pulpwood demands in this analysis include pulpwood demands for wood pulp production and roundwood demand for composite wood panel products. Roundwood demands for composite wood panel products (such as OSB) are projected to more than double in the next 50 years but nevertheless remain less than 20% of total projected pulpwood demand (roundwood and residues).

On a total tonnage basis, US paper and paperboard consumption is projected to increase from 93 million t in 1999 to 114 million t in 2010 and upwards of 168 million t in 2050. The projected annual rate of growth in paper and paperboard decelerates during the next 50 years and averages just 1.1%, which is less than half the average rate of the past 50 years. Population, economic growth, and end-use assumptions primarily drive the projected demands. Projected shifts in fibre supply exert only a modest influence on equilibrium demand levels, as indicated by a relatively flat projected trajectory for long-run product prices despite increased consumption.

Conventional sources of pulpwood supply in the USA include harvest from forestland and wood residues (chips, slabs, and other wood residues from sawmills and plywood mills). In the early 1950s, softwoods (coniferous tree species) accounted for nearly 90% of pulpwood supply. Today, hardwoods (broad-leaved deciduous tree species) account for nearly 40%. Although hardwood pulpwood consumption has increased, softwoods such as the southern pines still remain dominant in total US pulpwood supply. Softwoods have been intensively managed in the USA, with pulpwood supplied increasingly from pine plantations in the South. Pine plantations in the South typically have productivity that ranges several times higher than natural forest stands (in average volume growth per hectare). Hardwoods are generally not managed as intensively as softwoods in plantations and, therefore, hardwoods on forestland have generally lower productivity than do softwoods. Hardwood pulpwood supply has been relatively abundant mainly because of large natural hardwood inventories on forestland. Hardwood plantations, such as hybrid poplars on agricultural land, offer much higher productivity than natural hardwoods in forest stands, up to five or six times higher, but such gains in productivity come at the expense of higher costs.

An important ongoing shift in US timber supply and demand is a projected increase in pulpwood supply from softwood plantations (coniferous tree species) particularly loblolly pine in the South, with a shift toward higher management intensity for softwoods. Between 1952 and 1997, pine plantations on private lands in the South increased by approximately 10 million ha, more than a tenfold increase, displacing hardwoods in some cases. The area of pine plantations in the South is projected to increase by more than 5 million additional hectares in the decades ahead. Southern pine pulpwood supply is projected to become more abundant after 2010 as a result of the ongoing expansion in southern pine forest plantations and shifts to higher intensity timber management regimes.

After continuing to increase during the next decade, hardwood pulpwood supply from private forestland in the South is projected to level out after the year 2010. This assumption may be varied in the NAPAP model, with an alternative scenario reflecting the possibility that hardwood pulpwood supply from forestland may gradually recede after reaching projected peak levels in the South around 2010. In general, demand for pulpwood from agricultural SRWC will tend to increase if more restrictive constraints are placed on hardwood supply from forestland.

Projected trends in paper recycling also have an influence on projected pulpwood markets. The tonnage of paper and paperboard recovered for recycling has doubled since the mid-1980s, but growth in recycling is slowing down and is projected by the NAPAP model to follow a decelerating trend in the future. The rate of paper recovery for recycling rose dramatically from around 25% in the late 1970s to around 45% in the late 1990s, but the recovery rate appears to be reaching a plateau. The recovery rate in the base outlook is projected to climb gradually to 50% by 2010 and to around 55% toward the end of the projection period. By adjusting maximum feasible recovery rate assumptions in the NAPAP model, it is possible to construct an alternative future scenario for paper recycling, with lower projected recycling rates. In general, lower projected recycling rates tend to increase projected demand for fibre from agricultural SRWC.

Alternative scenarios

We explored two types of alternative market scenarios in this study within the context of the assumptions outlined above. One alternative scenario reflects a possibility that hardwood pulpwood supply from private forestland in the South may recede after 2010 (instead of levelling out, as in the base scenario). This alternative scenario was called the low hardwood (LHW) scenario, referring to lower or reduced hardwood pulpwood supply relative to the base case. The base scenario was called the hardwood medium supply (HWM) scenario, in which hardwood supply reaches a plateau after 2010 but does not decline. The LHW scenario reflects a possibility that urbanization, changing forest management practices, and shifting forest landowner preferences (voluntary or otherwise) might result in declining Southern hardwood pulpwood harvest after 2010. The LHW scenario was obtained by simply imposing more restrictive constraints in the NAPAP model on projected harvest of hardwood pulpwood from the forest industry and non-industrial private forestlands in the South. In the LHW scenario, hardwood pulpwood harvest on private forestland in the South increases up to the year 2010, as in the base case, but then recedes to levels just below current harvest levels by 2030.

The second alternative scenario was based on an assumption that future paper recycling rates may be lower than projected in the base case outlook. In this alternative scenario, the rate of paper recovery for recycling gradually increases, but it does not reach 50% by 2010 as projected in the base case outlook. Instead, the recovery rate climbs more slowly and remains just below 50% during the projection period. This alternative scenario was called the low recycling (LR) scenario, referring to a lower projected trend in recycling relative to the base outlook (the recovery rate is still projected to increase but much more modestly in the decades ahead). The LR scenario was obtained by imposing more restrictive constraints on maximum feasible recovery rates for various commodity categories of recovered paper supply in the NAPAP model.

We also identified other types of alternative scenarios but did not explore those because of insufficient technical data. We recommend, however, that other scenarios be explored in future research. One alternative scenario is based on the idea that genetic engineering could provide more highly productive or useful commercial clones of certain tree species suitable for agricultural SRWC, including trees such as short-rotation loblolly pine as well as hybrid poplars.

In addition to analysing the two alternative scenarios, we also adjusted real discount rate and adoption factor assumptions for SRWC in POLYSYS to create variations of the base case outlook and alternative scenarios. In the base case, the real discount rate for SRWC was set at 6% per year (the same as for other agricultural crops), while the adoption factor was set at 2% (not more than 2% of cropland area available for crop transfer in any ASD would be planted to SRWC). In general, lowering the discount rate or raising the adoption factor tended to increase projected supply of SRWC, as expected. However, raising the adoption factor above 5% or so also tended to introduce market volatility by making the SRWC planting and harvest levels more highly variable with time. The base case and the LHW and LR scenarios, coupled with variations in discount rate and adoption factor assumptions, illustrate a spectrum of results and a range of future market possibilities for SRWC.

Results – Market Outlook for SRWC

The base case market outlook derived from the NAPAP and POLYSYS models indicates that hardwood pulpwood supply from agricultural SRWC such as hybrid poplars and cottonwoods will become marginally economical in the decades ahead, particularly in the South, as hardwood pulpwood prices gradually increase. The analysis projects that hardwood pulpwood supply from forestland in the South will reach a peak by around 2010 and then plateau, as hardwood pulpwood harvest on forest industry land recedes during the next decade. However, sustained real price increases for hardwood pulpwood are not projected to occur until approximately 2015, when hardwood pulpwood harvest on non-industrial forestland is expected to decline in the South. After 2020, projected real prices for hardwood pulpwood reach levels sufficient to induce commercial expansion in planting and supply of SRWC in the agricultural sector, although the projected quantity of supply remains modest in the base scenario during the decade after 2020. This outlook is similar to the outlook developed recently for the draft Forest Service RPA timber assessment (based on a more simplified analysis of SRWC supply than the POLYSYS model).

Figure 17.2 illustrates the projected cumulative sum of agricultural SRWC harvests for pulpwood under different scenarios during the projection period (from the year 2000 to 2036). The projected sum of SRWC harvest for the base scenario at 6% discount rate (HWM_DR6) is only about 15 million m^3 during the entire projection period, a quantity equivalent to less than 0.5% of cumulative pulpwood consumption in the USA during the projection period. However, when the discount rate assumption for SRWC in POLYSYS was reduced to 3% (leaving the discount rate at 6% for all other agricultural crops), the projected sum of SRWC harvest exceeded 50 million m^3 during the projection period (HWM_DR3). This observed effect of lowering the discount rate may be viewed as a rough approximation of the effect of providing farmers with investment incentives to plant SRWC, through low-interest loans for example. Significantly greater supply and harvest of SRWC for pulpwood occurs under the LHW scenarios, with a cumulative SRWC harvest during the projection period

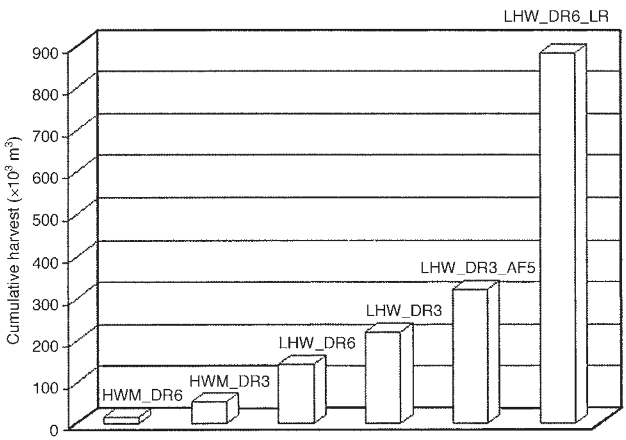

Fig. 17.2. Cumulative projected harvest of agricultural short-rotation woody crops (SRWC) from 2000 to 2036 (HWM, hardwood medium supply; LHW, hardwood low supply; LR, low recycling scenario; DR6 and DR3, 6 and 3% discount rates, respectively; AF5, adoption factor raised from 2 to 5%).

of around 100 million m^3 under the conventional 6% discount rate assumption (LHW_DR6). A cumulative SRWC harvest of around 200 million m^3 occurred with low hardwood supply and a 3% discount rate for farmers growing SRWC (LHW_DR3). A cumulative SRWC harvest of 300 million m^3 occurred with a 3% discount rate and the adoption factor raised from 2 to 5% (LHW_DR3_AF5). This observed effect of raising the adoption factor simulates a reduced perception of risk associated with SRWC, enabling more farmers to accept risks of investment in SRWC each year. Finally, with a combination of low hardwood supply and low paper recycling at the standard 6% discount rate (LHW_DR6_LR), the projected cumulative harvest of SRWC exceeded 800 million m^3 during the projection period.

Projected annual equilibrium harvest levels for SRWC fluctuated from year to year but generally increased with time under all scenarios. Figure 17.3 illustrates projected annual harvest levels for various scenarios, ranging from the base scenario (HWM_DR6) to the scenario with low hardwood supply and low recycling (LHW_DR6_LR). At the highest extreme, the projected annual harvest of SRWC for pulpwood approaches 50–60 million m^3 per year beyond the year 2020, or upwards of 15% of projected annual US pulpwood consumption, a fairly significant market share.

In addition to projected nationwide trends for agricultural SRWC, the NAPAP–POLYSYS system also projected SRWC planting and harvest area by ASD. For example, Figs 17.4 and 17.5 illustrate projected SRWC harvest areas for pulpwood by ASD in the year 2025 for the low hardwood scenario (LHW_DR6) and the low hardwood scenario with low recycling (LHW_DR6_LR), respectively. In general, in all scenarios, projected SRWC planting and harvest volumes were the greatest in the South, particularly in the south-central region (where there is the largest concentration of pulp and paper industry capacity in the USA). In those scenarios where higher levels of SRWC supply and harvest were projected (for example, the LHW_DR6_LR scenario), a considerable volume was also projected in the North (particularly in the north-central region). In some years, there was also some projected supply in the West (exclusively in Oregon and Washington), but projected supply in the West was not as large or consistent as in the eastern regions. The projected maximum nationwide SRWC plantation area varied from less than 0.1 million ha to around 1.8 million ha, depending on the scenario, a range that brackets results obtained in the earlier FASOM-based analysis of 0.6–1.0 million ha (Alig *et al.*, 2000). However, this study projected significantly greater potential for development of agricultural SRWC in the South than projected in the earlier FASOM study.

Some Forestry Implications

Results suggest that hardwood pulpwood supply from fast-growing hybrid poplars and

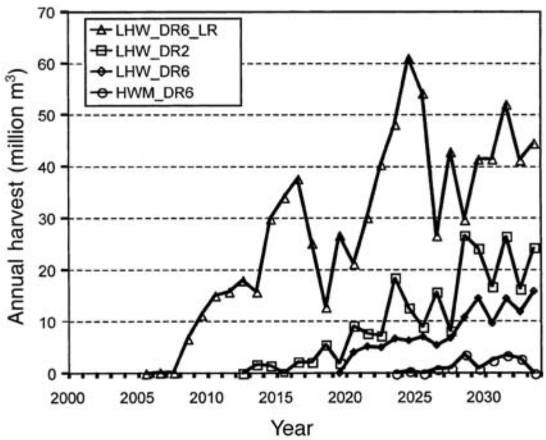

Fig. 17.3. Projected annual harvest of agricultural short-rotation woody crops (SRWC) under four different scenarios (HWM, hardwood medium supply; LHW, hardwood low supply; LR, low recycling scenario; DR6 and DR2, 6 and 2% discount rates, respectively).

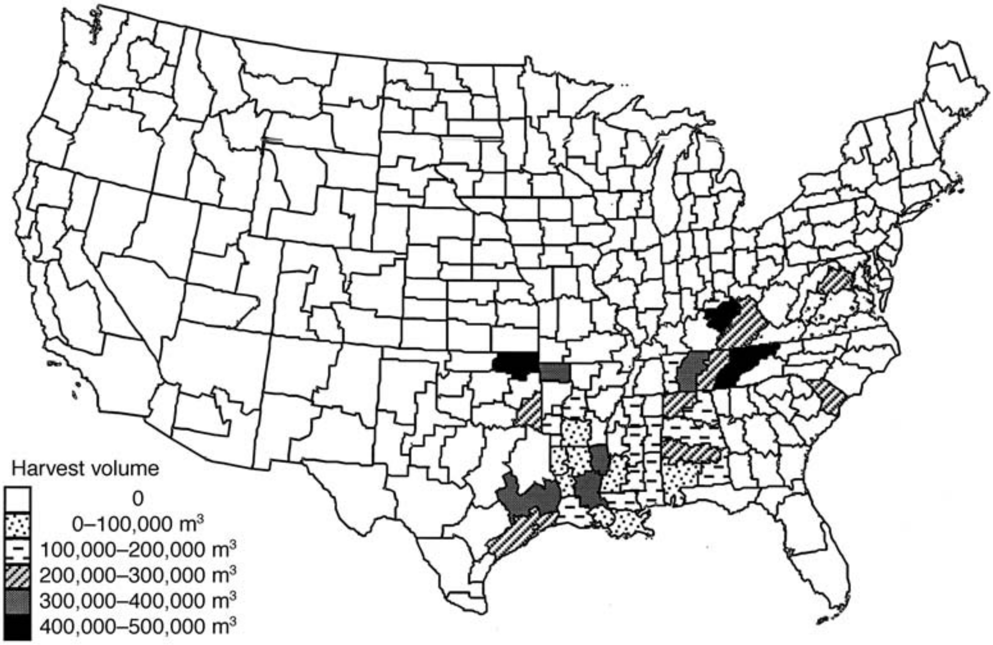

Fig. 17.4. Projected short-rotation woody crop (SRWC) harvest by agricultural statistical district in 2025 for low hardwood 6% discount rate scenario (LHW_DR6).

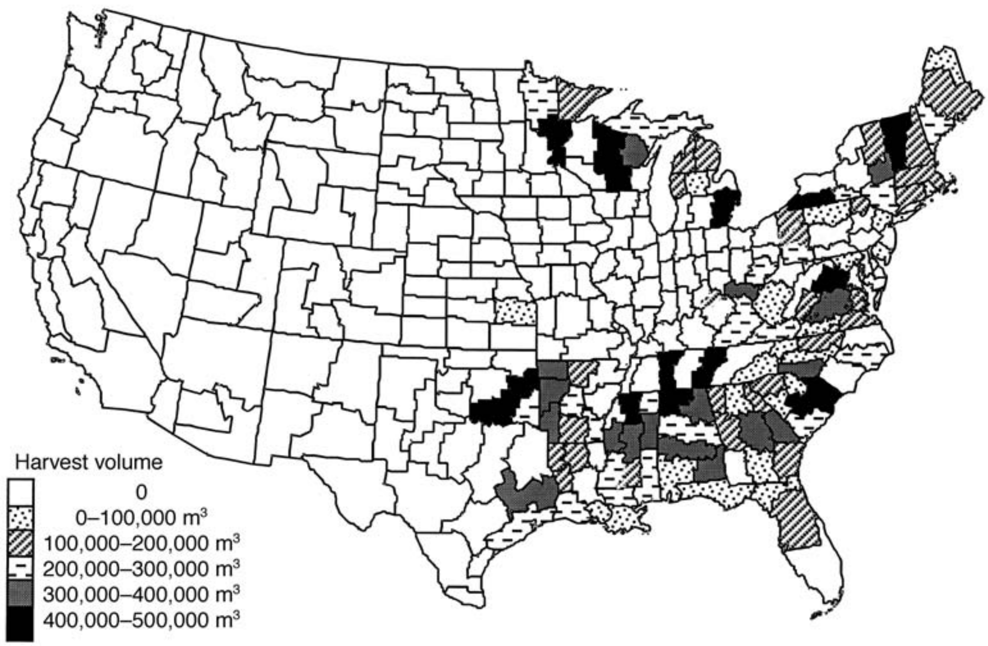

Fig. 17.5. Projected short-rotation woody crop (SRWC) harvest by agricultural statistical district in 2025 for low hardwood 6% discount rate scenario with low recycling (LHW_DR6_LR).

cottonwoods on agricultural land could become marginally economical in the decades ahead, although supply is projected to remain fairly limited in the base scenario. However, the market potential expands significantly under alternative scenarios, such as reduced hardwood pulpwood supply from natural forests or limited future expansion in paper recycling. The market outlook is also enhanced by reducing discount rates for SRWC in agriculture (such as by providing farmers with low-interest loans for SRWC) or by offsetting perceptions of risk in SRWC investments (increasing the maximum rate of adoption).

National attention has focused lately on the development of woody crops as biomass fuels or chemical feedstock to offset dependence on fossil fuels and non-renewable resources. In fact, APAC originally programmed the SRWC option into POLYSYS for the purpose of projecting the supply potential for biomass fuel or chemical feedstock. Currently, however, the value of whole-tree wood chip fuel in the USA is only about half the market value of pulpwood chips (University of Georgia, 2001). Based on POLYSYS cost data, the economic development of hybrid poplars as dedicated fuel or chemical feedstock crops would require biomass prices two to three times higher than current prices for wood biomass fuel, an outcome that seems unlikely unless there was a big increase in demand for biomass. In this study, it was tacitly assumed that a fraction of the SRWC biomass would be used for fuel as wood and bark residues, since only about 71% of the biomass can be recovered as clean pulp chips. Also, in conventional pulp mills, energy is recovered from combustion of wood residues and spent pulping liquors. Thus, the use of wood and bark residues and pulp by-products for fuel is a common practice in the US pulp and paper sector, and this practice was assumed to apply likewise to SRWC. However, growing hybrid poplars on agricultural land strictly for fuel is not very economical at present.

In a previous study using POLYSYS to analyse the biomass market potential for switch-grass, willows and poplars, Walsh *et al.* (1998) found that future biomass prices had to be considerably higher than current whole-tree chip prices before POLYSYS projected significant planting of poplar crops for biomass markets. Also, other biomass crops such as switch-grass or coppice willow appear to be recognized as more economical alternatives than hybrid poplars for chemical feedstock or biomass energy crops. Therefore, it appears somewhat unlikely that hybrid poplars or cottonwoods will be developed competitively in the near future as dedicated chemical feedstock or biomass energy crops, unless there is a significant upturn in demand or prices for biomass or if subsidies were provided to switch from fossil to renewable resources. Such subsidies might be justified economically if the use of biomass resources were to reduce the environmental costs associated with use of fossil fuels, but an assessment of such costs or benefits is beyond the scope of this study. This study does suggest, however, that there is potential for development of hybrid poplars or cottonwoods as agricultural wood fibre crops in the near future (with use of wood and bark residues for fuel), and the potential expands significantly under some fairly plausible alternative scenarios (more restricted hardwood pulpwood harvest on forestland or slower growth in paper recycling).

Given the historical background of shifting forest management concerns, some potential forestry implications might exist for development of agricultural SRWC. Perhaps the most obvious implication for forestry is that the advent of agricultural SRWC will make it even less plausible to base priorities in forestry on a premise of future timber scarcity or ‘timber famine’ (at least in terms of pulpwood resources in the USA). Results of this study indicate that agricultural SRWC exists as a plausible wood resource alternative in the event that forest resources become somewhat scarcer in the future. However, the extent to which agricultural SRWC may be developed as an alternative resource supply will depend also on whether intensive cultivation and genetic improvement of SRWC will be supported by public policy. In that regard, there are likely to be at least two major hurdles for agricultural SRWC, one being its association with the legacy of intensive forest management and the other being a possible future association with genetic engineering.

At first sight, development of SRWC might appear to be just another stage in the historical progression of intensification in forest management. As such, it may appear that agricultural SRWC will engender the same harsh mistrust of intensive industrial forestry that has been voiced by some segments of the public in the past. However, according to this study, agricultural SRWC can be grown on available agricultural cropland and would not necessarily displace native forest stands.

Indeed, SRWC may displace other agricultural crops or land-uses that have more intensive application of tillage, fertilizers, or pesticides. SRWC will typically require some chemicals for fertilizer or weed suppression early in the rotation, but generally, applications are much lower than applications for many other leading agricultural crops. Also, SRWC generally involve no land tillage during the length of the rotation (typically 6–10 years), reducing the potential for soil erosion (Shepard and Tolbert, 1996). Poplar plantations are also starting to receive attention as a method to absorb and store carbon, in both the woody biomass and in the soil (Johnson, 2001). Poplar plantations interspersed with conventional cropland can also help maintain water quality by providing vegetative buffers between cultivated farm fields and nearby lakes or streams. In other words, future expansion of agricultural SRWC could possibly contribute to a de-intensification of land-use in agriculture, helping promote soil conservation and helping achieve an array of other environmental benefits.

Furthermore, expansion of highly productive agricultural SRWC would also tend to offset demand pressures on native forest resources. Each hectare of intensively managed agricultural SRWC can potentially supply the pulpwood output equivalent of roughly 5–6 ha of natural hardwood forests in the USA, and agricultural SRWC may offer other benefits such as better fibre uniformity or modified lignin content. Thus, similar to the establishment of pine plantations on agricultural land in recent decades, development of agricultural SRWC may actually contribute to less-intensive management of native forests than would occur otherwise (offsetting demand pressures on native forest resources). Thus, there may be at least a logical argument that development of agricultural SRWC would be a departure from the pattern of increasing pressure on native forest ecosystems that has often been associated with more intensive forest management.

A somewhat more intractable issue is presented by public perceptions of genetic engineering. Although new research on genetic modification of tree crops may offer potential for significant cost savings in pulping or papermaking, exploitation of that potential may be limited by caution or concern about biological risks of genetically modified trees in the forest environment. However, techniques developed in this study show that it is possible to at least assess the future market potential and future economic benefits to weigh those benefits against possible biological risks. Also relevant in conservation policy are potential environmental benefits of less intensive land-use in agriculture and potential for conservation of forest resources, issues beyond the scope of this analysis but which should be explored in future research.

Summary

In summary, economic development of agricultural SRWC for pulpwood supply in the USA appears likely in the decades ahead based on economic analysis of the forest and agriculture sectors, and this development could have some interesting implications for forestry (as well as agriculture). The market outlook improves if future growth in paper recycling slows or if hardwood forest harvests are diminished. Although cultivation of SRWC is generally more intensive than conventional forestry practices, development of agricultural SRWC may be viewed potentially as a means to de-intensify land management in agriculture and reduce pressures for intensification of management and timber harvest in natural forests. As with developments such as paper recycling, this study suggests that foresters need to carefully consider implications of developments in other sectors remotely connected to forest policy, such as the agriculture sector, for example.

This study has provided an analytic tool (linkage of NAPAP and POLYSYS models) that could be extended in future research to examine potential market impacts of developments such as genetic modification of lignin structure or higher yield through bioengineering of SRWC. Some members of the public will probably view agricultural SRWC with suspicion, because it may be associated with the image of intensive industrial forestry and also with genetic engineering. At the margin of technological possibilities, however, with the advent of genetic engineering, it is possible to envision a future in which agricultural SRWC could potentially make significant inroads upon future timber markets. Results of this study suggest that foresters should consider these and other economic implications of SRWC in forestry and agriculture.

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Endnote

[1] This study focuses on hybrids of cottonwoods and other poplars (so-called hybrid poplars). We use the term 'hybrid poplars' to include cottonwoods in general regardless of intra- or inter-specific genetic origin.

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