

Future Market Scenarios for Pulpwood Supply from Agricultural Short-Rotation Woody Crops

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ABSTRACT

The North American Pulp And Paper (NAPAP) model and USDA POLYSYS agricultural policy analysis model were linked to project future market scenarios for pulpwood supply from agricultural short-rotation woody crops in the United States. Results suggest that pulpwood supply from fast-growing hybrid poplars and cottonwoods will become marginally economical but fairly limited in the next several decades. This supply could become significant under certain scenarios, such as reduced hardwood pulpwood supply from natural forests or limited future expansion in paper recycling. Woody crops might also be developed as feedstock for fuels or chemicals, but competitive development of hybrid poplars for such markets would require higher biomass feedstock values than current market values.

INTRODUCTION

The NAPAP model is a partial equilibrium model of the entire North American pulp and paper sector. It projects market conditions and technological changes by solving for annual equilibrium levels of supply, demand, and prices, given basic assumptions about long-run economic growth and population. The annual projected market equilibrium is obtained by optimizing total consumer and producer surplus of the pulp and paper sector, subject to constraints of production capacity, technology, and material balance (Ince, 1999, Zhang et al. 1996). Production capacities of different processes evolve gradually over a multi-decade projection period, with annual changes in capacity favoring efficient processes in continuous response to evolving market conditions. POLYSYS is a similar model of the U.S. agricultural sector that solves for annual equilibrium planting levels among agricultural crops by optimizing net present values of agricultural crops (Ray et al. 1998). POLYSYS includes short-rotation woody crops (SRWC) as well as other major agricultural food and fiber crops and livestock. It includes cropland acres currently in major crop production or that are idled, in pasture, or in the Conservation Reserve Program. POLYSYS computes an optimal allocation of agricultural land use among various crops each year.

The NAPAP and POLYSYS solutions were linked by sharing projections of equilibrium supply quantities and prices for SRWC. The NAPAP model projects for each year the equilibrium demand quantities of all types of wood pulp fiber, including pulpwood from forests, wood residues, and recycled paper, as well as pulpwood from SRWC. As part of the equilibrium solution, the NAPAP model computes equilibrium (shadow) prices for hardwood pulpwood each year. The pulpwood price projections are passed to POLYSYS, where pulpwood prices influence SRWC planting and land allocation decisions. POLYSYS in turn computes land area allocation to SRWC and provides the NAPAP model with estimates of SRWC supply (including yields and costs).

The combined NAPAP/POLYSYS system will generally converge upon a stable equilibrium pathway within a limited number of iterations (5 to 7). Technical assumptions in POLYSYS include productivity and cost data, interest rates, and an “adoption factor” for SRWC, all of which can influence results and provide a technical basis for alternative scenarios. The U.S. Department of Energy Bioenergy Feedstock Development Program (<http://bioenergy.gov/>) developed regional productivity and cost data for hybrid poplars and cottonwoods programmed into POLYSYS. POLYSYS regions that can produce SRWC include the majority of USDA Agricultural Statistical Districts (ASDs), including most districts in the eastern United States plus those western districts deemed to have climate and soil conditions suitable for such crops. The rate of SRWC adoption is controlled by a fixed constraint on the percentage of available cropland area that may be planted to SRWC each year within each ASD (the so-called adoption factor). Productivity and cost data in POLYSYS vary by ASD, with estimated woody crop rotation lengths varying from 6 to 12 years depending on geographic location. The productivity and cost data developed by Oak Ridge Laboratory were based on field experience with short-rotation poplar plantations since the 1970s and on expert opinion. The data represent productivity levels considered to be achievable based on conventional technology. The productivity and cost data assume that woody crops 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 acre.

Base Case Assumptions and Alternatives

The market analysis stems from a base case outlook along with some alternative scenarios derived by varying base case assumptions in the economic models. The NAPAP model operates with assumptions about future U.S. population and economic growth that drive projected trends in pulp, paper, paperboard, and wood panel consumption and production. The population and economic growth assumptions were derived from U.S. Census Bureau and Economics Research Service projections (Fig. 1). In general, although demand projections vary substantially among individual products and projections are derived by equilibrium analysis rather than by trend extrapolation, the projections indicate a continuation of historical trends in paper and paperboard consumption. With the conventional trend assumptions about population and real GDP, the NAPAP model projects a gradually decelerating trend in U.S. per capita consumption of paper and paperboard products, and a gradually declining trend in consumption per unit of real gross domestic product (GDP) (Fig. 2).

On a total tonnage basis, U.S. paper and paperboard consumption is projected to increase from 103 million short tons in 1999 to 126 million tons in 2010 and upwards of 185 million tons in 2050. The projected annual rate of growth in tonnage decelerates over the next 50 years and averages just 1.1%, 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 fiber supply exert only modest influences on

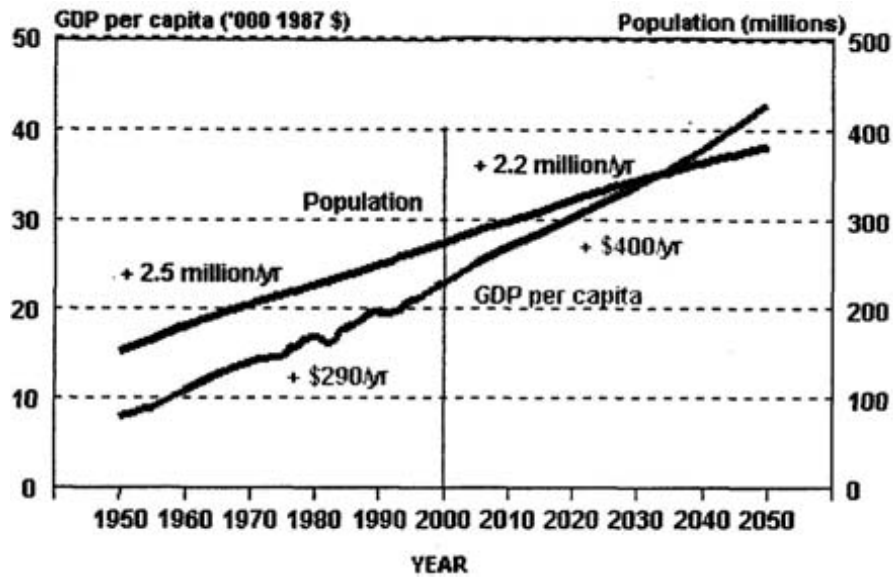


Figure 1. Historical and projected trend assumptions for U.S. population and GDP per capita. Slower population growth and increasing GDP per capita are projected.

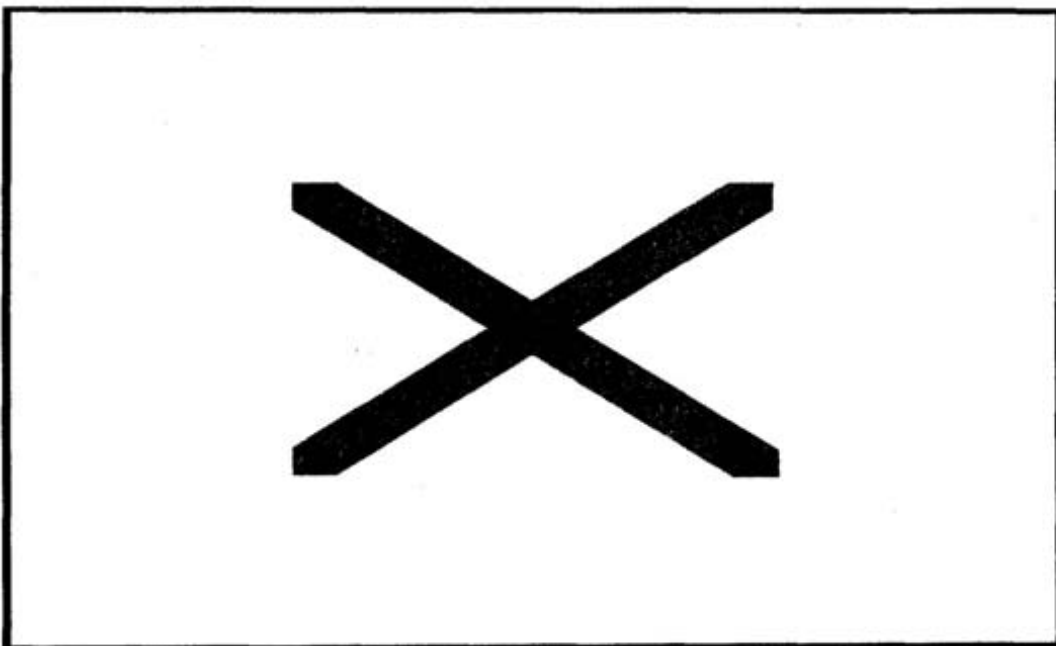


Figure 2. Historical and projected trends in equilibrium annual U.S. per capita paper and paperboard consumption, and consumption per unit of real GDP (1992 US\$).

equilibrium demand levels, as indicated by a flat projected trajectory for long-run product prices despite increased consumption.

The base case outlook assumes increased U.S. imports of pulp, paper, and paperboard over the next decade, with slower than historical growth in exports, consistent with recent trends. However, the analysis indicates that domestic production will account for the bulk of projected increases in domestic demands, as in past decades. U.S. imports of paper and paperboard surged in recent years, attracted by a strong dollar. Exports declined as a result of the Asian economic decline in 1997 and 1998 and more recently because of the high dollar value. Imports are projected to continue increasing over the next decade (from 17 million tons in 1999 to more than 20 million tons by 2010). In the long run, however, with projected expansion in U.S. softwood pulpwood supplies, annual paper and paperboard exports are projected to increase while imports are projected to decline somewhat in the period after 2010. Paper and paperboard exports are projected to recover from 1999 levels (at less than 10 million tons) and climb gradually over the projection period. Projected annual U.S. trade flows remain small in relation to domestic production and consumption (Fig. 3).

A key assumption about SRWC in the base case outlook is that no productivity or cost saving improvements occur over the projection period. This assumption is probably overly conservative, as the productivity and economic potential of agrifiber crops are likely to improve over time with advances in biotechnology and cultivation techniques, but future assumptions about yield gains for woody crops have not yet been programmed into POLYSYS. Thus, in the base analysis, productivity and costs of woody crops remain constant over the next 30 years in the POLYSYS model (projections extend from 2000 to 2030). The fixed productivity and cost assumptions could be varied in POLYSYS to derive alternative supply and demand scenarios, but the base case outlook assumes conservatively that productivity, crop yields, and costs for SRWC will remain constant at current established crop productivity levels.

Similarly, the analysis of timber supply embedded in the NAPAP model also has a set of fixed forest productivity assumptions, although the analysis does project continuing shifts in forestland area from lower to higher management intensity classes, such as from natural forests to plantations. An important projected shift in U.S. fiber supply and demand is an increase in pulpwood supply from softwood (coniferous tree species) plantations. Southern pine pulpwood supply is projected to become more abundant after 2010 as a result of expanded southern pine forest plantations and shifts to higher intensity timber management regimes. On the other hand, pulpwood supplies from natural hardwoods (deciduous broad-leaved tree species) are projected to be constrained by available forest inventories in the long run. Thus, after continuing to increase over the next decade, hardwood pulpwood supply from forestland is projected to level out after the year 2010.

In this analysis, the NAPAP model incorporates an assumption that hardwood fiber from SRWC such as hybrid poplars or cottonwoods (*Populus* sp.) can be substituted on an equal weight basis for hardwood from natural forests (after adjusting for the typical lower density of poplars). However, the analysis does not assume any cost advantages in the pulping process associated with utilization of hybrid poplars. This assumption may also be regarded as rather conservative given that recent biotechnology research indicates that strains of poplars with lower or modified lignin content may be developed in the

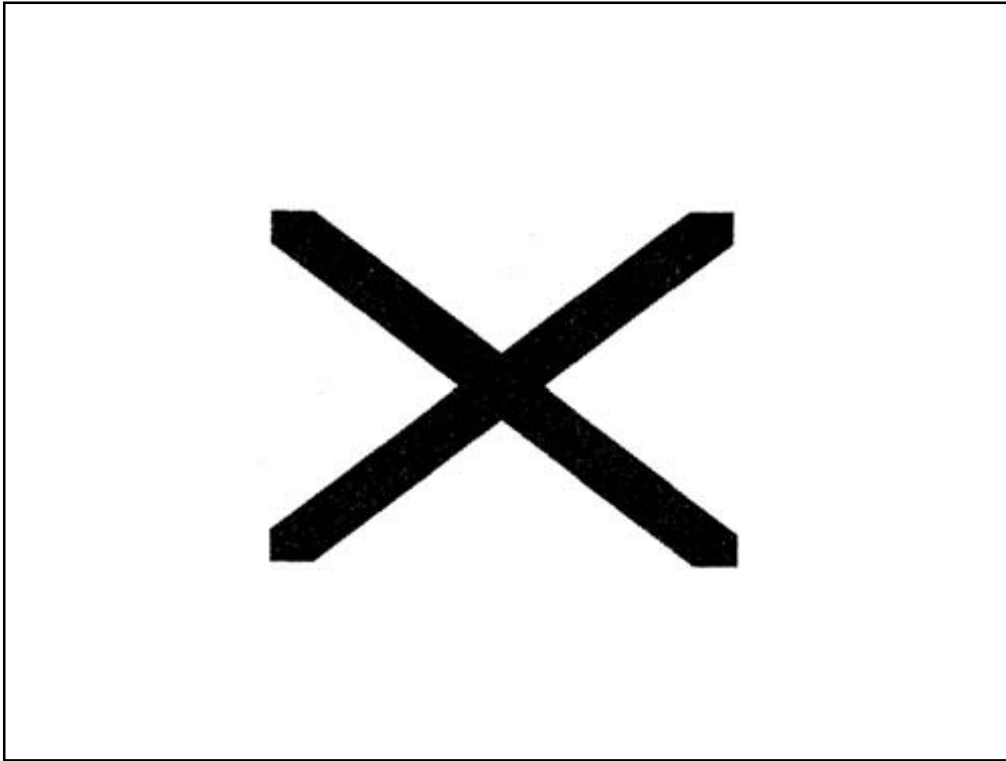


Figure 3. Historical and projected U.S. paper and paperboard production, consumption and trade.

future and could substantially reduce costs of pulping and pulp bleaching. In the future, the NAPAP model could be modified to reflect cost savings associated with the use of modified hybrid poplar crops in alternative scenarios, if such estimates of production cost savings become available.

Conventional sources of hardwood pulpwood supply include pulpwood harvest on forestland and wood residues (chips and slabs primarily from hardwood sawmills). The U.S. hardwood pulpwood market is dominated by hardwood timber supply in the South, the leading region in production and consumption of pulpwood. For example, hardwood pulpwood supply in the eight-state South Central region increased by about six fold over the past 40 years, as the pulp and paper industry expanded in the South and as hardwood pulpwood utilization increased relative to softwoods. In the early 1950s, softwoods accounted for nearly 90% of pulpwood use; today, hardwoods account for nearly 40%. Although hardwood supply and demand have increased, softwoods such as the southern pines still remain dominant in total U.S. pulpwood supply.

Softwoods have been intensively managed in the United States, with pulpwood supplied increasingly from pine plantations in the South. Hardwood forest resources are generally not managed as intensively, and therefore hardwoods on forestland have generally lower productivity than do softwoods. Pine plantations in the South typically have productivity that ranges several times higher than that of natural forest stands (in average volume growth per acre). Hardwood plantations, such as hybrid poplars on agricultural land, also have typically much higher productivity than do natural hardwoods in forest stands, often up to five or six times higher, although higher productivity comes at the expense of higher costs.

Pine plantations on private lands in the South increased by approximately 25 million acres between 1952 and 1997, a more than tenfold increase, displacing hardwoods in many cases. The area of pine plantations in the South is projected to increase by more than 15 million additional acres in the decades ahead. The outlook for pulpwood supply corresponds to the current base case outlook in the Forest Service draft 2000 RPA Timber Assessment, a recently completed Forest Service national study of the overall timber supply and demand situation in the United States (see <http://www.fs.fed.us/pnw/sev/rpa/>). The Forest Service analysis indicates that the historical and ongoing increase in hardwood pulpwood consumption in the U.S. South cannot be maintained for more than another decade or so, without incurring significant depletion of remaining available hardwood timber inventories on industrial and private forestlands. Thus, the timber supply outlook assumes that hardwood pulpwood harvest on forestland in the South will increase modestly over the next decade but then level out at a plateau beyond 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. Potential supply of hardwood fiber from agricultural land will increase if hardwood supply from forestland recedes.

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 recent years, but the recovery rate appears to be reaching a plateau (Fig. 4). 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, such as a scenario with lower projected recycling rates. In general, lower projected recycling rates will tend to increase the projected demand for hardwood fiber from agricultural land.

Market Outlook and Alternative Scenarios

The market outlook derived from the NAPAP and POLYSYS models indicates that hardwood pulpwood supply from agricultural SRWC such as hybrid poplars and cottonwood will become marginally economical in the decades ahead. 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 over the next decade. However, sustained real price increases for hardwood pulpwood are not projected to occur until approximately 2015 to 2020, when hardwood pulpwood harvest on non-industrial forest land is expected to decline in the South. After 2020, projected real prices for hardwood pulpwood will be sustained at levels sufficient to induce limited expansion of pulpwood supply from agricultural SRWC, but with only modest projected quantities of SRWC supply from agricultural fiber during the decade after 2020.

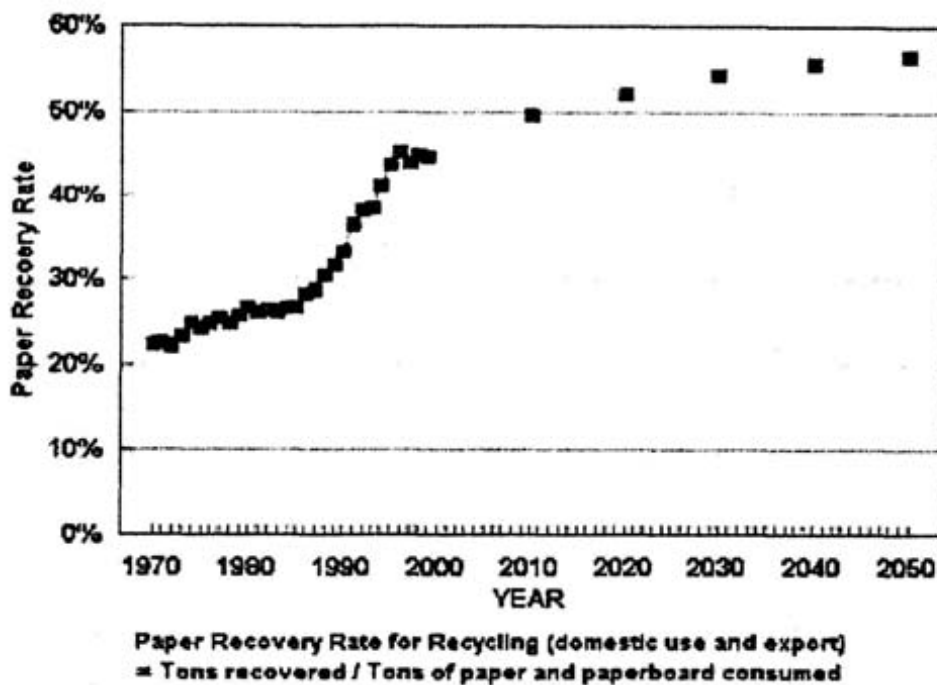


Figure 4. Historical and projected trends in U.S. wastepaper recovery rate.

Two principal alternative market scenarios were explored in this study within the context of assumptions outlined above. One alternative scenario was based on the possibility that hardwood pulpwood supply in the South would not only peak around 2010 but supply may also then recede after 2010. This alternative scenario is called the "lowhardwood" (LHW) scenario, referring to lower or reduced hardwood pulpwood supply relative to the base case (in which hardwood pulpwood supply merely plateaus after 2010). The LHW scenario reflects a possibility that increased urbanization coupled with changing forest management practices and shifting forest landowner preferences (voluntary or otherwise) could result in declining Southern hardwood pulpwood harvest after 2010, even though a reduction may appear unlikely or unnecessary to sustain hardwood forest resources in the future. The LHW scenario is obtained by simply imposing more restrictive constraints in the NAPAP model on the projected harvest of hardwood pulpwood from forest industry and non-industrial private forestlands in the South. In the LHW scenario, hardwood pulpwood harvest on 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.

A 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 remains below 50% over the projection period (the recovery rate is still projected to increase, but only very modestly in the decades ahead). This alternative scenario is called the "lowrecycling" (LR) scenario, referring to a lower projected trend in recycling relative to the base outlook. The LR scenario is obtained by imposing more restrictive

constraints on maximum feasible recovery rates for various commodity categories of recovered paper supply in the NAPAP model.

In addition, variations of the base case outlook and the alternative scenarios were created by adjusting the real discount rate and the adoption factor assumptions for SRWC in POLYSYS. In the base case, the real discount rate for SRWC in the agricultural sector was set at 6%, while the adoption factor was set at 3% (not more than 3% of cropland area available for crop transfer in any ASD would be planted to SRWC). In general, it was observed that lowering the discount rate or raising the adoption factor tended to increase projected supply of SRWC, as expected. However, raising the adoption factor also tended to introduce market volatility by making the SRWC planting and harvest levels more highly variable over time. The base case, 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

The projected cumulative sum of agricultural SRWC harvests for pulpwood under different scenarios over the projection period (from the year 2000 to 2036) is illustrated in Figure 5. The projected sum of SRWC harvest for the base case at 6% discount rate (HWM_DR6) is only about 15 million cubic meters over the entire projection period, a quantity equivalent to less than one-half of 1% of projected total pulpwood consumption in the United States. However, when the discount rate assumption for SRWC was reduced to 3% (leaving the discount rate at 6% for all other agricultural crops), the projected sum of SRWC harvest exceeded 50 million cubic meters over the projection period (HWM_DR3).

Significantly greater supply and harvest of SRWC for pulpwood occurs under the low hardwood (LHW) scenarios, with a cumulative harvest over the projection period of around 100 million cubic meters under the conventional 6% discount rate assumption (LHW_DR6). A cumulative harvest of around 200 million cubic meters occurred with a 3% discount rate (LHW_DR3). A cumulative harvest of 300 million cubic meters occurred with a 3% discount rate and the adoption factor raised from 2% to 5% (LHW_DR3_AF5). Finally, with low hardwood supply and low paper recycling (LHW_DR6_LR), the projected cumulative harvest of SRWC exceeded 800 million cubic meters over the projection period.

Projected annual equilibrium harvest levels for SRWC fluctuate from year to year but generally increase under all scenarios. Figure 6 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 to 60 million cubic meters per year beyond the year 2020, or upwards of 15% of projected annual U.S. pulpwood consumption.

In addition to projected nationwide trends in harvest and supply of agricultural SRWC for pulpwood, the NAPAP/POLYSYS system projects regional supply and demand trends, including projections of SRWC harvest by ASD. For example, Figures 7 and 8 respectively illustrate the projected SRWC harvest by ASD in the year 2025 for the low hardwood scenario (LHW_DR6) and the low hardwood scenario with low recycling (LHW_DR6_LR). In general, in all scenarios, projected SRWC supply and harvest

volumes are the greatest in the south, particular in the South Central region (where the largest concentration of pulp and paper industry capacity exists in the United States). In those scenarios where higher levels of SRWC supply and harvest are projected (e.g., LHW_DR6_LR (particularly in the North Central region). In some years, there is some projected supply in the West (exclusively in the Pacific Northwest states of Oregon and Washington), although not as large or consistent as projected supply in the eastern regions of the United States.

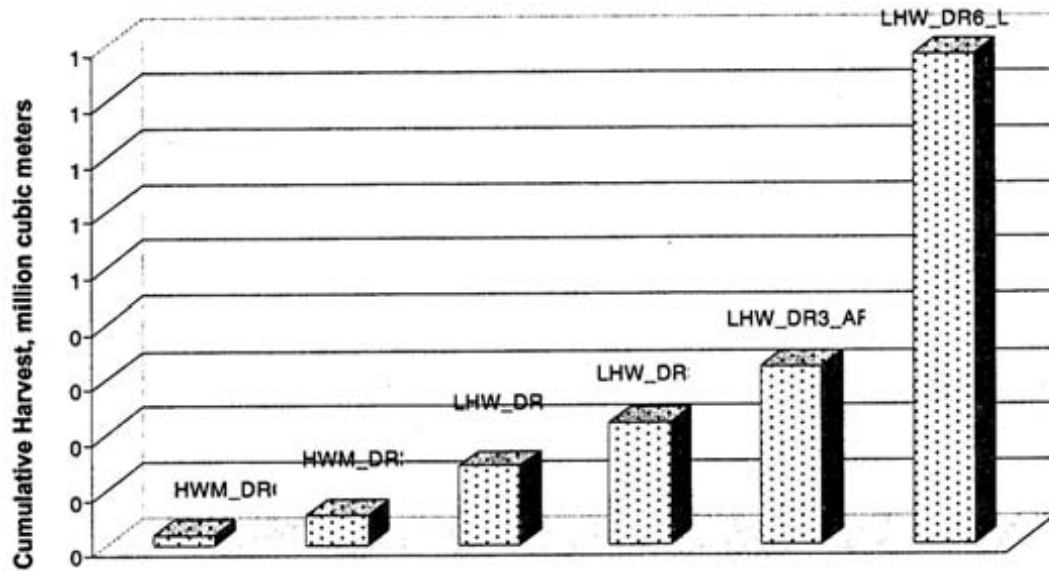


Figure 5. Cumulative projected harvest of agricultural SRWC. HWM = hardwood medium supply; LHW, hardwood low supply; LR, low recycling scenario; DR6 and DR3, 6% and 3% discount rates, respectively; and AF5, adoption factor raised from 2% to 5%.scenario), a considerable volume is also projected in the north

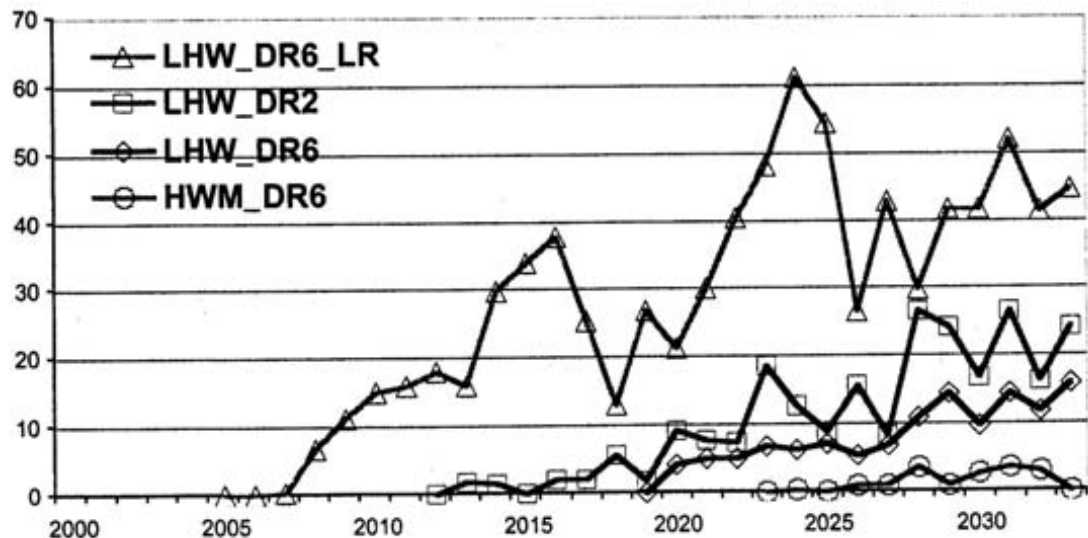


Figure 6. Projected annual harvest of agricultural SRWC.

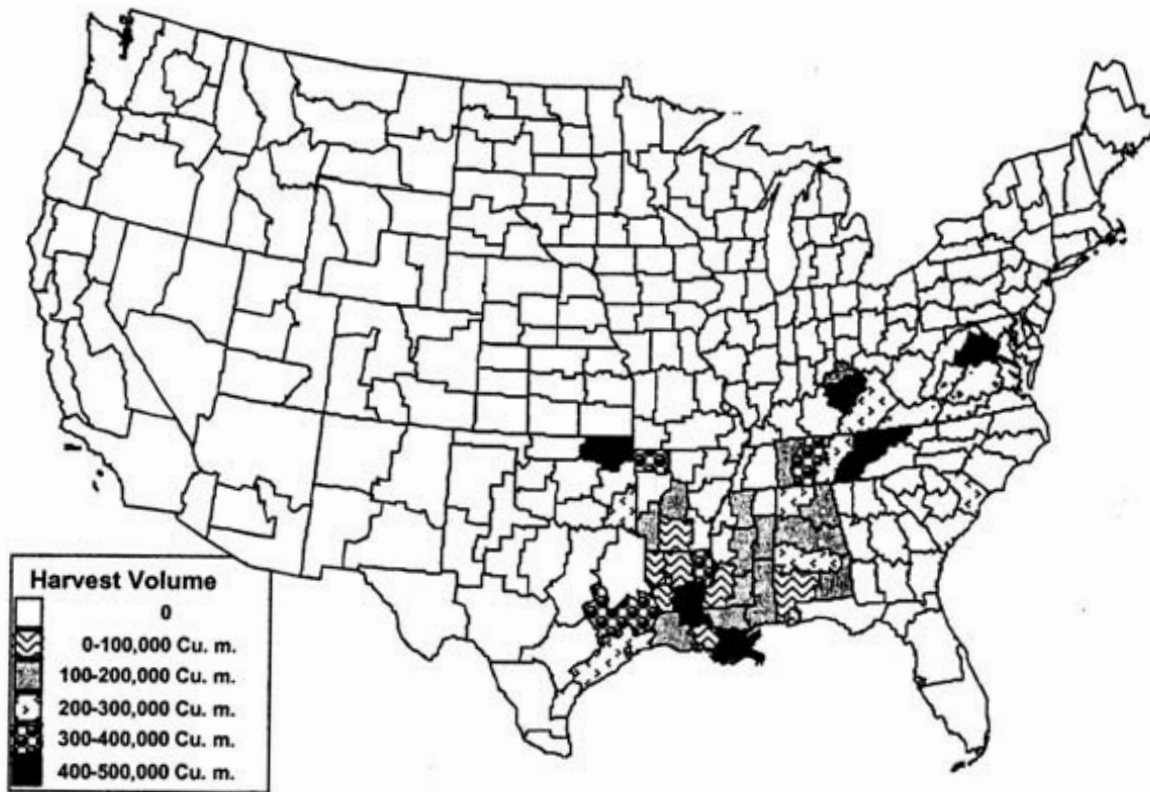


Figure 7. Projected SRWC harvest by Agricultural Statistical District in 2025 for low hardwood scenario (LHW_DR6).

Figure 8. Projected SRWC harvest by Agricultural Statistical District in 2025 for low hardwood scenario with low recycling (LHW_DR6_LR).

CONCLUDING REMARKS

The results of the NAPAP/POLYSYS analysis suggest that pulpwood supply from fast-growing hybrid poplars and cottonwoods will become marginally economical but fairly limited in the next several decades. This supply could become significant under scenarios such as reduced hardwood pulpwood supply from natural forests or more limited future expansion in paper recycling. It is also recognized that woody crops (or other types of crops) may be developed as feedstock for fuels or chemicals. However, at present, the value of whole-tree chip wood fuel in the United States is only approximately half the market value of pulpwood and therefore much less likely to support development of hybrid poplar or cottonwood crops for fuel than for pulpwood. Competitive development of hybrid poplars for fuel or chemical feedstock markets in the United States would require biomass feedstock values several times higher in real prices than current market values for wood biomass fuel.

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REFERENCES

- Ince, Peter J. 1999. Long-range outlook for U.S. paper and paperboard demand, technology, and fiber supply-demand equilibria. In: Proceedings of the Society of American Foresters 1998 National Convention; 1998 September 19–23; Traverse City, MI. Bethesda, MD: Society of American Foresters, 330–343.
- Ray, Daryll E., Daniel G. De La Torre Ugarte, Michael R. Dicks, and Kelly H. Tiller. 1998 (Draft). The POLYSYS Modeling Framework. Agricultural Policy Analysis Center. University of Tennessee: Knoxville, Tennessee. 175 p.
- Zhang, Dali, Joseph Buongiorno, and Peter J. Ince. 1996. A recursive linear programming analysis of the future of the pulp and paper industry in the United States: changes in supplies and demands, and the effects of recycling. *Annals of Operations Research* 68: 109–139.



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