Economic Impacts of Short-Rotation Woody Crops for Energy or Oriented Strand Board: A Minnesota Case Study

William F. Lazarus, Douglas G. Tiffany, Ronald S. Zalesny Jr., and Don E. Riemenschneider

ABSTRACT

Short-rotation woody crops (SRWC) such as hybrid poplars are becoming increasingly competitive with agriculture on marginal land. The trees can be grown for energy and for traditional uses such as oriented strandboard. Using IMPLAN (Impact Analysis for Planning) software, we modeled the impacts of shifting land use from hay and pasture for cow–calf beef operations to hybrid poplars in northwest and west central Minnesota. Construction of a $175 million energy conversion facility capable of making 44 million gal of ethanol and 7.6 million gal of mixed alcohols by gasification/catalysis would create 2,412 jobs, with $158 million in value added. Facility operation, assuming establishment of 200,000 ac of hybrid poplar, did not substantially change the number of jobs relative to using the land for cow–calf operations. However, the SRWC-related jobs would likely be at higher average salary levels and business tax collections would be higher, resulting in a value-added increase of $80 million annually.

Keywords: impact analysis, ethanol, feedstock production, hybrid poplar, IMPLAN, OSB

Maintaining economical and ecological sustainability largely depends on reducing consumption of nonrenewable resources (Sims et al. 2003, Hill et al. 2006). This necessity increases pressure to produce greater amounts of woody and herbaceous renewable feedstocks from intensive cropping systems (Berndes et al. 2003, Johnson et al. 2007). Short-rotation woody crops (SRWC) such as intensively grown hybrid poplars are an important component of this renewable energy supply chain (Alig et al. 2000, Walsh et al. 2003). Increased fossil fuel prices in recent years have made production of hybrid poplars more economically viable (Sims et al. 2006, Johnson et al. 2007). Intensively managed plantations reduce pressure on native forests (Gladstone and Ledig 1990) and contribute environmental benefits (Joslin and Schoenholtz 1997, Tolbert and Wright 1998, Updegraff et al. 2004). Nonetheless, there is a need to assess the economic tradeoffs of shifting away from traditional agricultural land uses to producing SRWCs for applications such as energy, oriented strandboard (OSB), and fiber (Strauss and Grado 1997, Alig et al. 2000). This analysis is appropriate in the north central United States.

The state of Minnesota has traditionally produced native aspen (*Populus tremuloides* Michx. and *Populus grandidentata* Michx.) for fiber and wood products (Domke et al. 2008). Coupled with the recent increased demand for renewable energy sources, SRWCs are also needed because of a: (1) predicted shortage of aspen supply within 10–20 years because of a lack of suitable stumpage within harvestable diameter classes (Domke et al. 2008) and (2) projected increase of paper and paperboard construction between 1997 and 2050 of nearly 80% (Ince 1998). Hybrid poplars are suitable alternatives given their regional adaptability, agronomic-type cropping systems, and high productivity, which is six to eight times greater than native aspen in the region (Riemenschneider et al. 2001, Goerndt and

Received April 24, 2009; accepted July 22, 2010.

William F. Lazarus (wlazarus@umn.edu) is professor, and Douglas G. Tiffany (tiffa002@umn.edu) is extension educator, Department of Applied Economics, University of Minnesota, 249a ClaOff, 1994 Buford Avenue, St. Paul, MN 55108. Ronald S. Zalesny (rzalesny@fs.fed.us) is team leader, genetics and energy crop production, and Don E. Riemenschneider (rzalesny@fs.fed.us) is research geneticist, Institute for Applied Ecosystem Studies, Northern Research Station, US Forest Service, Rhinelander, WI. *The authors thank Bill Berguson, Natural Resources Research Institute, University of Minnesota–Duluth for assistance with costs of hybrid poplar planting and harvesting; Andrew McAloon, Eastern Regional Research Center, USDA Agricultural Research Service (ARS), Wyndmoor Pennsylvania for assistance in developing the conversion facility production functions; and Neil D. Nelson, Institute for Applied Ecosystem Studies, Northern Research Station, US Forest Service, Rhinelander, WI, for overall guidance and support.*

Mize 2008, Zalesny et al. 2009). Hybrid poplar clonal trials began in the 1930s in Michigan, with active breeding beginning in the 1950s (Illinois), 1960s (Minnesota), and 1980s (Iowa and Wisconsin). Since that time, more than 100,000 unique genotypes have been produced in the region (Zalesny and Bauer 2007). Currently, there are approximately 25,000 ac of hybrid poplar in Minnesota, with over 23,000 ac in commercial production (Berguson 2008). Given the vast amount of marginal crop and pastureland in the state, there is potential for increasing hybrid poplar fiber farming. For example, Husain et al. (1998) modeled hybrid poplar production in west central Minnesota and reported potential for landowners to recover more income from the SRWCs than alternate land uses.

Nevertheless, there is a shortage of published information about the economic potential of hybrid poplar in the north central United States. Previous reports from this region are meaningful to use as a baseline (Ferguson et al. 1981, Rose et al. 1981, Perlack and Wright 1995, Walsh 1998); however, market trends shift so frequently that new analyses are necessary to advance feedstock production technologies. In fact, despite that OSB production is currently absent in the state, energy production is very prominent. The opposite was true at the onset of the current study, with the OSB industry being more economically viable than using wood for energy. Therefore, our objective was to compare the potential economic contribution of these purpose-grown trees to Minnesota's economy, assuming the trees are used for energy or OSB production. This study differs from most economic impact evaluations because it extends beyond a single industry (i.e., SRWC production and processing) and focuses on the impact of a *shift* in land use, from beef to SRWCs. Minnesota has 27 million ac of land in farms, including 22 million ac of cropland and 5 million ac in other uses such as pasture. Forages such as hay and haylage are grown on 1.7 million ac of the cropland (USDA National Agricultural Statistics Service 2007). Much of the hay and pasture supports beef cow–calf enterprises, particularly in the northern part of the state where soil productivity is marginal. Thus, we consider the opportunity cost of reducing hay, pasture, and beef production on land that is shifted to SRWC production. We model the economic impact of producing wood versus hay and pasture for beef production on the same land base. These results are important for policymakers, researchers, and resource managers needing to make informed decisions about whether to produce hybrid poplars in the region.

Economic Impact Analysis Methodology

Wassily Leontief developed input–output (I-O) analysis in the late 1930s; Miller and Blair (1985) provide a detailed description. IMPLAN (Impact analysis for Planning) is an I-O model and database for the United States (Olson and Lindall 2004), developed originally by the US Forest Service in cooperation with the Federal Emergency Management Agency and the US Department of the Interior Bureau of Land Management to assist in land and resource planning.

An IMPLAN economic analysis begins with an assumption about the final demand or sales figure being supplied by one or more sectors of the economy. IMPLAN assumes that a particular sector produces and sells output to meet that demand. In the production process, inputs ("interindustry purchases") are purchased from other sectors (including from itself) and from households and government ("primary inputs"). The primary inputs are termed "value added" and include (1) employee compensation, (2) income of business proprietors, (3) other property income (such as rents), and (4) indirect business taxes. A fixed-price production function (vector of "gross absorption coefficients") defines the value-added inputs and the purchases from other industries, as cents per dollar of final demand. All industry output is assumed to be expended on either interindustry purchases or value added.

Beginning with those demand changes, IMPLAN applies a set of multipliers to calculate the impacts on the rest of the economy in the study area. Two main factors affect the size of multipliers: (1) how much of the study industry's direct impact (revenue or output) is used for purchases from other industries, relative to labor payroll, and (2) the structure of the local economy and, specifically, whether it contains industries that can supply those inputs that the study industry purchases. Multipliers are higher when the study industry spends a high percentage of its revenue on purchases from local industries, because they then generate additional payroll and household spending beyond what the study industry generates directly. The multiplier on imports is zero.

Data needed to describe the direct impacts of SRWCs include, mainly, sales revenues, employment, payroll, payments to business owners, business taxes and rents paid, and reasonable estimates of costs of the main inputs required for the production process. In addition, estimates are needed of the amounts of those purchases that will be made in the region being considered versus imported from outside the region. These estimates are referred to as "regional purchase coefficients."

IMPLAN calculates a number of economic measures. Numbers of new jobs are easy for lay audiences to understand. However, salaries vary across sectors, so numbers of jobs may not indicate economic contributions as accurately as other measures such as labor income. Proprietor income reflects earnings of sole proprietor business owners. Agriculture is dominated by owner–operators, so proprietor income tends to be larger and labor income is smaller relative to many other sectors. Corporate earnings and rents are reported by IMPLAN in a separate category referred to as other property income. "Value added" (the total of labor and proprietor income, other property income, and business taxes) indicates the overall economic contribution of a given sector. Dollars of output is a measure of overall economic activity that includes imports and interindustry purchases, as well as value added.

Scenarios

Impact analysis looks at the effects of a positive or negative change in economic activity (Hughes 2003). An economic impact analysis begins by describing a study area and one or more scenarios that will be compared. An important assumption in this study is to determine where the SRWCs will be grown and the current land uses replaced. As mentioned previously, this analysis is based on the assumption that the land uses most likely replaced are marginal cropland or pastureland that are incapable of producing very good yields of agronomic crops.

Economic impact analyses generally discuss two types of impacts: direct and secondary. Secondary impacts are of two types, indirect and induced, which are described in more detail later. The main role of the IMPLAN software is to estimate those secondary impacts. Estimates of the direct impacts are supplied by the user. The direct impacts analyzed are

Table 1. Value-added input requirements per dollar of industry output for the sectors analyzed.

IMPLAN sector	Employee and proprietor income ($ expenditures/ output $)	Property income ($ expenditures/ output $)	Indirect business taxes ($ expenditures/ output $)	Total value added ($ expenditures/ output $)	Earnings/worker ($/yr)
SRWC planting (average of first 3 yr of 17-yr stand life)	0.1992	0.1929	0.0266	0.4186	$36,000
SRWC planting and harvesting (average across 17-yr stand life)	0.1923	0.1935	0.0298	0.4156	$36,000
Energy facility construction	0.3500	0.1050	—	0.4550	$50,089
Energy facility operation	0.0719	0.1953	0.0267	0.2418	$50,408
Reconstituted wood manufacturing	0.1677	0.2335	0.0051	0.4063	$54,963
Crop farming (hay and pasture)	0.1529	0.1533	0.0185	0.3247	$26,764
Cattle ranching (cow–calf)	0.2749	—	0.0060	0.2809	$18,488

- Operation of a thermochemical ethanol processing plant in the state of Minnesota using as feedstock hybrid poplar wood grown in SRWC plantings in the state.
- Operation of an OSB industry using the same amount of hybrid poplar wood.
- Reduced agricultural output (beef calves) from the cropland and pastureland diverted to SRWCs for either of the first two scenarios.

We assume that the crops replaced are hay and pasture. Corn and soybeans are Minnesota's largest crops in terms of acreage, but hay and pasture are cheaper to grow and are more common on the marginal lands of central and northwestern Minnesota where SRWC plantings are likely to occur. The livestock enterprises that use most of the state's hay and pasture are beef cow–calf herds and dairy enterprises. For this analysis, beef cow–calf herds are assumed to use the hay and pasture rather than dairy because hay quality is less important for them and they are more common on the marginal lands of northern Minnesota.

Corn grain and soybean meal are other major ingredients fed to beef cattle. A reduction in Minnesota beef cows and calves would reduce consumption of those feed ingredients as well as hay and pasture. Corn grain and soybean meal are more easily transported than hay, however, so it is assumed that the beef reduction would not reduce corn or soybean production in the state but rather would increase exports of corn grain and soybeans out of the state. This follows the logic of Swenson's argument that in the opposite situation of a new ethanol plant in a corn-producing county, corn exports are likely to decline rather than corn production increasing (Swenson 2006, p. 5). The IMPLAN database used for the analysis is based on I-O relationships existing in the year 2006, inflated to 2008 prices.

Model Development

SRWC Planting and Harvesting

The SWRCs were assumed to produce 4 dry tn/year, based on reported productivity in the region (Graham et al. 1997, Riemenschneider et al. 2001, Goerndt and Mize 2008, Zalesny et al. 2009). Harvest is assumed to take place in the 8th year, followed by coppicing and a second harvest in the 16th year for an overall time commitment of 17 years before the site can be replanted or shifted to some other use. Although coppicing has not been used on an industrial scale in the region, it has been successful in the Pacific Northwest and throughout Europe. Given the broad variability within the genus *Populus*, there is a high probability of selecting genotypes with adequate coppicing ability in combination with other favorable traits.

The SRWC planting and harvesting costs are taken from a hybrid poplar enterprise budget (Lazarus 2008). A price of $81/dry tn at the mill would provide revenues sufficient to break even with the hybrid poplar production costs while applying an opportunity cost on capital of 6%/year. Wood purchases by the processing plant would amount to $65 million annually.

Data for the OSB scenario is from the IMPLAN sector 114, "Reconstituted Wood Product Manufacturing." Wood purchases by this sector are assumed to be 30 cents/sales dollar, based on a review of the IMPLAN data by industry experts. The $65 million in wood purchases at a breakeven price of $81/dry tn would imply total OSB sales of $216 million, or around a one-third to one-half of actual sector 114 annual sales between 2003 and 2006. Sales from the OSB sector were reduced from the 2006 level to represent the future situation where the OSB plants resume purchases of wood and other inputs and employment returns to 2006 levels but with lower profitability than was experienced during the housing bubble, which peaked around 2006. Annual plantings are assumed to be 12,500 ac/year for 16 years, resulting in a total of 200,000 ac in production. At 4 tn/ac per year, the annual physical volume available for harvest is 800,000 tn.

Table 1 shows the value-added input requirements per dollar of industry output for the scenarios analyzed. The SRWC planting and harvesting along with the energy facility construction and operation are assumed to just break even after covering normal returns to labor, capital, and land. Labor costs for SRWC planting and harvesting are based on $16/hour and 2,250 hours/year, with land rent at $50/ac and interest on capital at 6%/year. Labor, capital, and land costs for the energy facility are from Phillips et al. (2007).

IMPLAN also calculates what a sector will purchase from other industry sectors. The production function coefficients in Table 2 show how much these purchases will total during the initial poplar planting period and later when both planting and harvesting are underway. IMPLAN also requires assumptions about the percent of a given sector's interindustry purchases within the region versus outside the region. For the purpose of this study, it is assumed that all wood needs are met by Minnesota trees. IMPLAN defaults were used for crop inputs and for sector 114 inputs other than wood.

Biomass Energy Conversion Facility and OSB Facility Data Sources

Table 3 shows the production function coefficients used to calculate purchases from other sectors and the value-added amounts during construction of the energy facility. Table 4 shows those amounts for operation of the energy facility or the reconstituted wood manufacturing sector.

Capital investment, operating requirements, and purchasing patterns of future wood energy conversion facilities are based on a National Renewable Energy Laboratory (NREL) feasibility analysis of ethanol production in a thermochemical gasification process (Phillips et al. 2007) and from an analysis of alternative sources of process heat for a paper recycling plant in St. Paul, Minnesota (Rock-Tenn Community Advisory Panel 2008). The NREL plant is sized at 700,000 tn/year, or somewhat smaller than the wood products plant but of similar magnitude. The Rock-Tenn feasibility plan describes a wood gasification system that would use 267,229 wet tn of wood/year when operating on 95% wood and 5% natural gas. An accompanying report describes the wood as chips of 42–50% moisture. At the 46% moisture midpoint, Rock-Tenn would use 144,000 dry tn/year. An area of 200,000 ac of hybrid poplar plantations would supply somewhat more than six plants of that size. Phillips et al. (2007) based their plant to break even at an ethanol cost target of $1.01/gal for their plant at 2005 price levels, which they considered to be achievable by 2012 with a feedstock cost of $35/dry tn. The present analysis assumes a higher feedstock price of $81/dry tn, so the ethanol price would need to be correspondingly higher to break even, depending on the wood-to-ethanol conversion rate that is ultimately achieved. Our analysis assumes that the plant achieves an ethanol conversion rate and sale price that is sufficient to break even after covering operating costs, labor, and annualized capital costs but nothing more. If market revenues from sale of the ethanol and other coproducts are not sufficient to cover these costs, public incentives may be necessary to fill the gap. Our analysis does not specify the timing or amount of such incentives, however, or how such incentives might be allocated between growing the wood and operating the plant.

The biomass energy conversion facility would be newly constructed, in contrast to the OSB plants that already exist. So, the energy scenario includes two impact phases: (1) plant construction and (2) operation of the completed plant. Construction purchases are based on the equipment list indicated by Phillips et al. (2007) (which included costs in 2005 dollars) and the capital costs for materials and equipment in the Rock-Tenn spreadsheet. Mr. Andrew McAloon, cost engineer with the USDA Agricultural Research Service, helped assign each of the Phillips et al. (2007) equipment items to IMPLAN sectors. The Rock-Tenn sector assignments were done by the authors.

Table 2. Short-rotation woody crops production expenses by IMPLAN sector.

IMPLAN sector name	Plant poplar trees	Plant and harvest trees
Forest nursery—forest products	$0.1507	$0.0298
Petroleum refinery	$0.0866	$0.2167
Nitrogenous fertilizer manufacturing	—	$0.0585
Pesticides and other Ag. chemical manufacturing	$0.1127	$0.0223
Farm machinery and equipment manufacturing	$0.1612	$0.1675
Insurance carriers	$0.0056	$0.0063
Wholesale trade	$0.0646	$0.0832
Total interindustry purchases/dollar of output	$0.5814	$0.5844
Employee compensation	$0.1992	$0.1923
Property income	$0.1929	$0.1935
Property taxes	$0.0266	$0.0298
Total value added	$0.4186	$0.4156
Total expenditures	$1.0000	$1.0000

Table 3. IMPLAN production function for construction of energy conversion facility, cents per dollar of final demand.

	Production function (cents/$1 demand)
Inter-industry purchases by IMPLAN industry sector	
Industrial process furnace and oven manufacturing	0.1307
Metal tank—heavy gauge—manufacturing	0.0682
Manufacturing and industrial buildings	0.0640
Other communication and energy wire manufacturing	0.0627
Ferroalloy and related product manufacturing	0.0546
Conveyor and conveying equipment manufacturing	0.0532
Iron and steel mills	0.0315
Air and gas compressor manufacturing	0.0222
Turbine and turbine generator set units manufacturing	0.0129
Switchgear and switchboard apparatus manufacturing	0.0086
Other sectors	0.0364
Total interindustry purchases	0.5450
Value-added components	
Labor	0.3500
Property income	0.1050
Total value added	0.4550
Total expenditures	1.0000

The allocated purchases are shown in Table 3. Value-added components for the construction phase were assumed to be (1) labor income and (2) property income. The allocation between these two components is important because property income is assumed to leave the state totally, as in the case of stock dividends paid to shareholders of publicly traded corporations. However, labor income is assumed to be spent locally. At the time of this analysis, it was unclear which of these two facility designs might eventually be installed in Minnesota. Therefore, for the purpose of the economic analysis, the two sets of coefficients were simply averaged.

Table 4 shows the postconstruction production coefficients for the operation of the energy facility after construction is completed and for the OSB sector. Note that the energy facility numbers include only operation, not construction, and the wood manufacturing sector numbers are an aggregate of the entire industry that presumably includes both construction and operation. The OSB sector purchases from the logging and sawmill sector are shifted to the SRWC sector.

The first line of Table 4 reveals that the energy facility adds less value to the $65 million of woody crop input than the OSB plant adds. Wood represents over twice as much of total purchases for the energy facilities ($0.7181 of wood/$1 of demand) as for the OSB plant ($0.30 of wood/$1 of demand). This relationship is equivalent to the higher factor that iron ore purchases represent in steel fence post demand versus the factor that iron ore represents in finely crafted watch springs. The wood purchases then translate into $90 million of energy facility output, compared with the $216 million in OSB output, with the difference coming in the various nonwood inputs listed in the Table 4. This difference in nonwood inputs affects the overall economic impact because some of these nonwood inputs are purchased from other local industries and have impacts on the rest of the local economy. The value-added portion of total purchases is somewhat less for the energy facility than for the OSB plant—24% compared with 30%—which also affects the economic impacts. For the OSB sector, the sectors with the smallest coefficients are omitted to save space.

Table 4. IMPLAN production function for operation of energy conversion facility, compared with oriented strandboard sector, cents per dollar of final demand.

	Energy facility operation	Oriented strandboard sector
Short-run woody crop harvesting	0.7181	0.3000
Insurance carriers	0.0067	0.0016
Other basic organic chemical manufacturing	0.0048	—
Water—sewage and other systems	0.0042	—
Sand, gravel, clay, and refractory mining	0.0035	—
Miscellaneous nonmetallic mineral products	0.0026	—
Petroleum refineries	0.0156	0.0455
Natural gas distribution	0.0009	0.0107
Other basic inorganic chemical manufacturing	0.0009	0.0455
Coated and laminated paper and packaging materials	0.0007	—
Plastics packaging materials—film and sheet	—	0.1051
All other forging and stamping	—	0.0066
Management of companies and enterprises	—	0.0051
Adhesive manufacturing	—	0.0049
Monetary authorities and depository credit intermediate	—	0.0047
Commercial machinery repair and maintenance	—	0.0043
Semiconductors and related device manufacturing	—	0.0043
Rail transportation	—	0.0043
Other sectors not listed	—	0.0571
Total interindustry purchases	0.7582	0.6943
Employee compensation	0.0719	0.2798
Proprietary income	0.0000	0.0160
Property income	0.1953	—
Indirect business taxes	0.0267	0.0098
Total value added	0.2418	0.3056
Total expenditures	1.0000	1.0000

Reduced Hay, Pasture, and Beef Cow–Calf Production

The output of the cow–calf enterprises is assumed to be beef calves that are ready to be fed at a location outside of Minnesota. The data source for the cow–calf and agronomic crop production functions is the FINBIN database (Center for Farm Financial Management, University of Minnesota, undated). The cropland and pastureland being switched to poplar production are assumed to be in mixed hay and pasture, with costs and returns represented by a 3-year average of the FINBIN per acre enterprise summaries for west central and northwestern Minnesota for 2004–2006. The crop data were incorporated into a production function modified from IMPLAN sector 10, "All other crop farming." IMPLAN sector 11, "Cattle ranching and farming," was used for the cow–calf data. IMPLAN requires production function coefficients that are expressed per dollar of output while the FINBIN costs and returns are per acre or per cow, so the FINBIN costs were divided by gross returns and then assigned to the closest IMPLAN sector.

The major feed ingredients fed to beef cattle are hay, pasture, corn grain, and soybean meal (listed in the FINBIN reports as "protein supplement," which might also include ingredients such as cottonseed meal and distillers grains). The acreage switched to SRWCs was allocated between hay and pasture based on the relative acreages required to supply the average amounts of each feed in the FINBIN cow–calf summaries at the average yields in the FINBIN mixed hay and pasture summaries. In the cow–calf enterprise, hay and pasture expenditures amount to around 29% of gross value. A $14 million reduction in hay and pasture then translates to a reduction in the cattle ranching enterprise output of $49 million.

IMPLAN calculates employment impacts from employment compensation plus proprietor income divided by earnings per worker; therefore, estimates of earnings per worker were needed from the FINBIN enterprises. The FINBIN hay and pasture net returns and labor hours per acre translate to income of $31,533/worker, assuming 2,250 hours worked/year. A 10-year average was used for the beef sector costs and returns to reflect the cyclical nature of the cattle industry. Cow–calf returns over the past 10 years averaged $89/cow, with 10.8 hours of labor expended/cow. The "wages" earned by cow–calf producers average $8.22/hour or $18,488/year at 2,250 hours/year.

Results

Table 5 summarizes the output, jobs, and value-added impacts of shifting 200,000 ac of land from pasture and hay to poplar for energy or OSB. The "direct impact" column of Table 5 shows the sales or expenditures in each sector. The "total impact" column includes the IMPLAN-calculated indirect impacts on supplier industries and the induced impacts of household spending of employees in the affected industries.

The first line in each section shows the impacts of site preparation, planting, and maintenance of the plantings over the first 3 years, when input requirements are greater than they are in later years. The "Plant trees . . ." scenario would be typical of year 2 when site preparation is taking place on 12,500 ac; planting is occurring on a second 12,500 ac; and a third 12,500 ac is undergoing only weed and insect control, as the plantings move toward a steady-state situation.

Planting 12,500 ac of trees for each of the first 3 years of expenditures would involve spending $10.2 million, the direct impact on the state of Minnesota. When the indirect impacts on other supplier industries and induced household spending are considered, the overall impact is $20.9 million.

Constructing the biomass conversion facility has a considerably greater impact of $175.3 million in direct spending and $303.7 million in total impact. This is a one-time impact on the economy that Phillips et al. (2007) expected would take place over a 3-year period.

The "total tree plant/harvest and energy facility operation" scenario results would be typical of year 19 when two 12,500-ac blocks are being harvested (one block from the original planting and one coppiced block). The line shows the ongoing annual expenditures for planting and harvesting 25,000 ac of trees/year on a rotating basis to maintain the 200,000-ac stand on a 17-year cycle and the impact of processing that wood in the energy facility. This line includes labor to operate the energy facility as well as inputs such as olivine, baghouse bags, and denaturant for the ethanol. The impacts of the poplar production and wood processing activities together are comparable with facility construction: $192.9 million in direct expenditures and $324.9 million in overall impact. The wood purchases amount to 57% of the overall energy facility expenditures.

The next line shows the hay, pasture, and beef calves not produced on the land in question. That negative impact is $49.0 million in direct expenditures and $109.1 million in overall impact. The net impact of this shift is positive for output and value added, although the number of new jobs is slightly less than the beef-related jobs lost. The crop and cow–calf activity involves 1,172 jobs compared with 1,113 jobs in poplar production and processing. The net impact of the land shift to SRWCs for energy on output is a positive $215.8 million after considering the reduced beef production. This is a slightly smaller positive impact than when the wood production is used for OSB, which equals $227.6 million. The number of jobs generated in the energy scenario is less than the number lost in beef production for a net employment loss of 59 jobs in the energy scenario compared with a gain of 480 jobs in the OSB scenario. The value-added impact of the energy scenario (positive $77.8 million after netting out the $49.6 million beef reduction) is nearly the same as the $78.2 million net impact of using the poplar for OSB (considering the total impact including the direct, indirect, and induced effects).

Table 5. Impacts of shifting hay and pasture to short-rotation woody crops for energy or for oriented strandboard.

	Direct impact	Total impact
Output ($ million)		
Plant trees, expenditures during the first 3 yr, 12,500 ac each year	$10.2	$20.9
Construct biomass conversion facility, 44 million gal	$175.3	$303.7
Total tree plant/harvest and energy facility operation	$192.9	$324.9
Reduced impact from shifting away from hay and pasture fed to cow–calf enterprises	$(49.0)	$(109.1)
Net impact of shifting land away from hay/pasture and to SRWCs for energy	$143.9	$215.8
Net impact of shifting land away from hay/pasture and to SRWCs for OSB	$167.0	$227.6
Employment		
Plant trees, expenditures during the first 3 yr 12,500 ac each year	39	104
Construct biomass conversion facility, 44 million gal	1,507	2,412
Total tree plant/harvest and energy facility operation	456	1,113
Reduced impact from shifting away from hay and pasture fed to cow–calf enterprises	(809)	(1,172)
Net impact of shifting land away from hay/pasture and to SRWCs for energy	(353)	(59)
Net impact of shifting land away from hay/pasture and to SRWCs for OSB	210	480
Value added ($ million)		
Plant trees, expenditures during the first 3 yr, 12,500 ac each year	$3.5	$7.6
Construct biomass conversion facility, 44 million gal	$98.2	$158.3
Total tree plant/harvest and energy facility operation	$78.3	$127.4
Reduced impact from shifting away from hay and pasture fed to cow–calf enterprises	$(23.5)	$(49.6)
Net impact of shifting land away from hay/pasture and to SRWCs for energy	$54.8	$77.8
Net impact of shifting land away from hay/pasture and to SRWCs for OSB	$42.5	$78.2

Discussion

Wood from naturally regenerated stands of native aspen has been in high demand for use in paper and in the manufacture of wood products such OSB (Miles et al. 2007, Domke et al. 2008). While writing this paper in early 2009, the US housing sector has been ravaged due to the prevalence of poorly regulated lending practices following a general slowdown that started 2 years earlier. Throughout the north central United States and, more specifically, in Minnesota, the forest products industries have witnessed further consolidation in ownership of wood processing facilities and dampening of wood stumpage prices (Domke et al. 2008). When wood demand returns to some state of normalcy, however, SRWCs grown on marginal cropland and pastureland may be needed to supplement wood and fiber supply from natural stands and maintain the viability of local mills and related economic activities. Hybrid poplars can play a major role in reducing logistical and ecological pressures on native forests while providing local and regional environmental benefits relative to agricultural production systems (Alig et al. 2000, Perry et al. 2001).

A major practical implication of the current study is that hybrid poplars are economically competitive with traditional hay, pasture, and beef production systems on marginal cropland and pastureland in Minnesota. This economic potential is similar to that reported for SRWC pulp fiber feedstocks (Alig et al. 2000). Given that hybrid poplars are a vital component of the renewable energy supply chain (Walsh et al. 2003), it is imperative to assess their financial and ecological potential. Walsh et al. (2003) modeled land-use changes and economic impacts and found hybrid poplar was more favorable than switchgrass and willow for wildlife management practices on Conservation Reserve Program lands. Updegraff et al. (2004) modeled cropland conversions to hybrid poplars and reported potential positive environmental services. These results are promising given that woody feedstocks play a major role in achieving our national goal of 16 billion gal of cellulosic ethanol by 2022 (GovTrack.us. H.R. 6, 110th Congress 2007). In addition, SRWCs have become important feedstocks for heat and power. For example, the cities of Virginia and Hibbing, Minnesota, have each recommissioned central steam plants to produce heat and power in those communities. In addition, facilities producing ethanol and electricity at Little Falls, Minnesota; Benson, Minnesota; and Stanley, Wisconsin, are moving ahead to use wood to generate process heat.

Wood demand for heat and power generation is also strong in the state because of efforts to reduce greenhouse gas emissions and control costs by substituting biomass for fossil fuels. Wood is more favorable to use than many other biomass fuels because of low NO_x emissions and few issues of ash fusion from alkali metals, in contrast to hays or crop residues (Sims et al. 2003). The 2007 Minnesota Legislative Session witnessed the passage of a bill to require the generation of 25% of electricity from renewable sources by 2025. Wood and other biomass fuels will have an important role in meeting this objective because they can support baseload power, which will be needed to complement highly variable power output from wind farms, despite the low capital costs per unit of nameplate capacity in wind farms.

The comparison of jobs in hybrid poplar production versus hay–pasture–cow–calf jobs should be interpreted carefully because the SRWC planting and harvesting jobs are estimates based on machinery operation labor and hand labor for specific field operations directly associated with the enterprise. The hay, pasture, and cow–calf enterprise job numbers are based on labor disappearance reported by the farms in the FINBIN database. "Labor disappearance" is calculated from total annual labor hours expended by the operator, family, and hired workers. Total labor hours are generally estimated from the number of full- and part-time workers and time that each works on the farm. The farm operator allocates this total labor amount to the crop and livestock enterprises on the farm using factors that reflect judgments about the relative labor required per acre or per head. FINBIN labor disappearance hours per acre for agronomic crops are likely to be higher than estimates of machine operation labor only, because labor disappearance numbers include machinery maintenance, planning time, and other activities indirectly related to use of a machine. Hybrid poplar labor disappearance numbers from actual commercial enterprises would be preferable to the estimates used here, but will not be available until these trees are grown more widely on a commercial scale in Minnesota.

Conclusion

Use of SRWCs for either energy or OSB will have positive economic impacts on the state of Minnesota, even when netting out beef-related activities. Construction projects of all kinds are often touted for their economic impact, so it is not surprising that the largest economic impact numbers calculated in this study are for the construction phase of energy conversion facilities. Once built, operation of the facilities and planting and harvesting of the SRWCs to supply it will only minimally change employment. Value-added impacts of the energy facility, however, are greater than for beef, which are likely caused by higher salaries and taxes. If OSB production resumed at former levels in the state, the number of jobs generated would also be positive and larger than for energy production or beef. There is no clear difference in value-added impacts between the energy and OSB scenarios.

Literature Cited

Alig, R.J., D.M. Adams, B.A. McCarl, and P.J. Ince. 2000. Economic potential of short-rotation woody crops on agricultural land for pulp fiber production in the United States. *For. Prod. J.* 50(5):67–74.

Berguson, W.E. 2008. *Woody biomass crops in the midwestern United States: Past, present, and future.* US For. Serv. Gen. Tech. Rep. NRS-GTR-P-31, Newtown Square, PA. 29 p.

Berndes, G., M. Hoogwijk, and R. van den Broek. 2003. The contribution of biomass in the future global energy supply: A review of 17 studies. *Biomass Bioenergy* 25:1–28.

Center for Farm Financial Management, University of Minnesota. Undated. *FINPACK Farm Financial database*. Available online at www.finbin.umn.edu/; last accessed July 3, 2007.

Domke, G.M., A.R. Ek, M.A. Kilgore, and A.J. David. 2008. *Aspen in the Lake States: A research review.* National Council for Air and Stream Improvement, Inc. (NCASI) Tech. Bull. 955, Research Triangle Park, NC. 32 p.

Ferguson, K.D., D.W. Rose, D.C. Lothner, and J. Zavitkovski. 1981. Hybrid poplar plantations in the Lake States: A financial analysis. *J. For.* 79:664–667.

Gladstone, W.T., and F.T. Ledig. 1990. Reducing pressure on natural forests through high-yield forestry. *For. Ecol. Manag.* 35:69–78.

Goerndt, M.E., and C. Mize. 2008. Short-rotation woody biomass as a crop on marginal lands in Iowa. *North. J. Appl. For.* 25(2):82–86.

GovTrack.us. H.R. 6–110th Congress. 2007. *Energy Independence and Security Act of 2007.* Available online at www.govtrack.us/congress/bill.xpd?bill=h110–6; last accessed Apr. 15, 2009.

Graham, R.L., L.J. Allison, and D.A. Becker. 1997. ORECCL–Oak Ridge Energy Crop County Level database. P. 205–213 in *Proc. of 3rd Biomass conf. of the America: Making a business from biomass in energy, environment, chemical, fibers and materials*, Overend, R.P., and E. Chornet (eds.). Elsevier Science, Inc., New York.

Hill, J., E. Nelson, D. Tilman, S. Polasky, and D. Tiffany. 2006. Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. *Proc. Natl. Acad. Sci. USA* 103:11206–11210.

Hughes, D.W. 2003. Policy uses of economic multiplier and impact analysis. *Choices* 18(2):25–30.

Husain, S.A., D.W. Rose, and S.O. Archibald. 1998. Identifying agricultural sites for biomass energy production in Minnesota. *Biomass Bioenergy* 15(6):423–435.

Ince, P. 1998. Long-range outlook for U.S. paper and paperboard demand, technology, and fiber supply-demand equilibria. P. 330–343 in *Proc. of the Society of American Foresters*. Society of American Foresters, Bethesda, MD.

Johnson, J.M.F., M.D. Coleman, R. Gesch, A. Jaradat, R. Mitchell, D. Reicosky, and W.W. Wilhelm. 2007. Biomass-bioenergy crops in the United States: A changing paradigm. *Am. J. Plant Sci. Biotechnol.* 1:1–28.

Joslin, J.D., and S.H. Schoenholtz. 1997. Measuring the environmental effects of converting cropland to short-rotation woody crops: A research approach. *Biomass Bioenergy* 13(4/5):301–311.

Lazarus, W.F. 2008. *Energy crop production costs and breakeven prices under Minnesota conditions.* Staff Pap P08-11, Dept. of Applied Economics, Univ. of Minnesota, St. Paul, MN. Available online at www.apec.umn.edu/faculty/wlazarus/documents/EnergybudStaff_Paper.pdf; last accessed Jun. 23, 2010.

Miles, P.D., K. Jacobson, G.J. Brand, E. Jepsen, D. Meneguzzo, M.E. Mielke, C. Olson, C.H. Perry, R. Piva, B.T. Wilson, and C. Woodall. 2007. *Minnesota's forests 1999–2003 (Part A*). US For. Serv. Resour. Bull. NRS-RB-12A. 92 p.

Miller, R.E., and P.D. Blair. 1985. *Input-output analysis: Foundations and extensions.* Prentice Hall, Inc., Englewood Cliffs, NJ. 464 p.

Olson, D., and S. Lindall. 2004. *IMPLAN professional software, analysis, and data guide.* Tech. Rep. for Minnesota IMPLAN Group, Inc., Stillwater, MN. 418 p.

Perlack, R.D., and L.L. Wright. 1995. Technical and economic status of wood energy feedstock production. *Energy* 20(4):279–284.

Perry, C.H., R.C. Miller, and K.N. Brooks. 2001. Impacts of short-rotation hybrid poplar plantations on regional water yield. *For. Ecol. Manag.* 143:143–151.

Phillips, S., A. Aden, J. Jechura, D. Dayton, and T. Eggeman. 2007. *Thermochemical ethanol via indirect gasification and mixed alcohol synthesis of lignocellulosic biomass*. Tech. Rep. NREL/TP-510-41168, National Renewable Energy Laboratory, Washington, DC. 132 p.

Riemenschneider, D.E., W.E. Berguson, D.I. Dickmann, R.B. Hall, J.G. Isebrands, C.A. Mohn, G.R. Stanosz, and G.A. Tuskan. 2001. Poplar breeding and testing strategies in the north-central U.S.: Demonstration of potential yield and consideration of future research needs. *For. Chron.* 77(2):245–253.

Rock-Tenn Community Advisory Panel. 2008. *Project Economics Documents from the June 16 RCAP meeting.* Saint Paul Port Authority, St. Paul, MN.

Rose, D., K. Ferguson, D.C. Lothner, and J. Zavitkovski. 1981. *An economic and energy analysis of poplar intensive cultures in the Lake States.* US For. Serv. Res. Pap. NC-RP-196. 44 p.

Sims, R.E.H., H.H. Rogner, and K. Gregory. 2003. Carbon emission and mitigation cost comparisons between fossil fuel, nuclear and renewable energy resources for electricity generation. *Energ. Policy* 31:1315–1326.

Sims, R.E.H., A. Hastings, B. Schlamadinger, G. Taylor, and P. Smith. 2006. Energy crops: Current status and future prospects. *Glob. Change Biol.* 12:2054–2076.

Strauss, C.H., and S.C. Grado. 1997. Economics of producing Populus biomass for energy and fiber systems. P. 241–248 in *Micropropagation, genetic engineering, and molecular biology of populus*. Klopfenstein, N.B., Y.W. Chun, M.-S. Kim, and M.R. Ahuja (eds.). Gen. Tech. Rep. RMR-GTR-297, US For. Serv., Rocky Mount. Res. Stn., Fort Collins, CO. 326 p.

Swenson, D. 2006. *Input outrageous: The economic impacts of modern biofuels production.* Dept. of Economics, Iowa State Univ. Available online at nercrd.psu.edu/Biofuels/Swenson.pdf; last accessed on June 17, 2010.

Tolbert, V.R., and L.L. Wright. 1998. Environmental enhancement of U.S. biomass crop technologies: Research results to date. *Biomass Bioenergy* 15(1):93–100.

Updegraff, K., M.J. Baughman, and S.J. Taff. 2004. Environmental benefits of cropland conversion to hybrid poplar: Economic and policy considerations. *Biomass Bioenergy* 27: 411–428.

USDA National Agricultural Statistics Service. 2007. *Census of Agriculture*. Available online at www.agcensus.usda.gov/; last accessed Jun. 23, 2010.

Walsh, M.E. 1998. U.S. bioenergy crop economic analyses: Status and needs. *Biomass Bioenergy* 14(4):341–350.

Walsh, M.E., D.G. De La Torre Ugarte, H. Shapouri, and S.P. Slinsky. 2003. Bioenergy crop production in the United States: Potential quantities, land use changes, and economic impacts on the agricultural sector. *Environ. Res. Econ*. 24:313–333.

Zalesny, R.S. Jr., and E.O. Bauer. 2007. Selecting and utilizing *Populus* and *Salix* for landfill covers: Implications for leachate irrigation. *Int. J. Phytoremed.* 9:497–511.

Zalesny, R.S. Jr., R.B. Hall, J.A. Zalesny, B.G. McMahon, W.R. Berguson, and G.R. Stanosz. 2009. Biomass and genotype × environment interactions of *Populus* energy crops in the Midwestern United States. *Bioenergy Res*. 2:106–122.