



# An economic analysis of the financial viability of switchgrass as a raw material for pulp production in eastern Ontario<sup>☆</sup>

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## Abstract

This paper examines the economic viability of producing switchgrass (*Panicum virgatum*) to be used as pulp in fine paper production. Pulp mills in eastern Ontario and western Quebec are considered to be the potential market for switchgrass. The potential size of the market for switchgrass pulp is assessed. Budgets for switchgrass are constructed and various measures of the potential market value of switchgrass are calculated. Based on these preliminary findings, it appears that switchgrass could be an attractive crop for farmers in eastern Ontario and western Quebec. The total land area required to satisfy the potential demand for switchgrass fibre for pulping in eastern Ontario is estimated to be between 22,000 and 48,000 hectares. Further agronomic research to examine the productivity of switchgrass on economically marginal and erosion prone lands is indicated. © 1999 Elsevier Science Ltd. All rights reserved.

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## 1. Background

Research efforts to date on the production economics of switchgrass (*Panicum virgatum*) in southern Ontario and western Quebec has focused on switchgrass as a possible feedstock

for biomass based energy production [1–3]. Estimates of production costs for switchgrass in the United States of about US \$30.00 per metric ton have been reported in the literature. Girouard et al. [2] estimate that switchgrass could be produced for Cdn \$38.00 to \$51.00 per metric ton in eastern Canada. At the present time, however, findings from this research indicate that energy production from switchgrass is not financially competitive with fossil fuels. It is possible, however, that switchgrass may prove to be a financially viable alternative to hardwood

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fibre in pulp production. Current yield experiments have emphasized the production of biomass, but this goal may not be consistent with optimizing yield of fibre for pulp production. The potential size of the market for switchgrass as an input in pulp production and the costs of meeting the demand for pulp are not known. Data on fibre yields, pulp prices, the size of the hardwood pulp market in eastern Ontario and western Quebec would inform strategic planning of research and technology transfer regarding the agricultural production of this crop in this region.

The purpose of this project was to assess the long term commercial viability of the agricultural production of switchgrass for use in the pulp and paper industry on the land base of eastern Ontario. The objectives of the study were to describe the size of the hardwood pulp market in eastern Ontario and western Quebec and to estimate fibre production, transportation and processing costs from switchgrass on a basis comparable to the costs of hardwood for pulp.

## 2. Current trends in hardwood pulp production and prices in eastern Ontario and western Quebec

Pulp and paper and allied industries continue to be an important sector in the Canadian economy, even though the share of Canadian GDP

generated in this sector has been falling since the mid-1970 s. About 4% of Canadian GDP originated in these industries [4, 5] two decades ago, compared to about 1.2% in the early 1990 s. Nevertheless, pulp and paper and allied industries contributed over \$7 billion (in constant 1991 dollars) in 1993.

Even though value added has been falling in the sector since the mid-1970 s, the total volume of woodpulp production has been growing steadily. About 15 million metric tons of woodpulp were produced in Canada in 1975. This had increased to almost 25 million metric tons by 1994 [4, 6]. Exports of pulp have grown dramatically since 1950, from less than 2 million metric tons to over 10 million metric tons in 1994. Ontario has maintained a relatively constant 15 to 20% share of national woodpulp production over the last 20 years [4, 7].

Hardwood fibre has become an increasingly important component of Canadian pulp production since 1975 (Table 1). About 7% of total pulpwood nationally was hardwood in 1975. This had increased to almost 25% by 1992. Similar trends were observed in the pulpwood market in Ontario. Hardwood accounted for about 12% of Ontario production in 1975, but this share had increased to over 28% by 1992. Improvements in technology have made it possible to increase the amount of hardwood fibre used in paper production in the last 25 years. Cost considerations

Table 1  
Hardwood and softwood pulpwood consumption in Canada and Ontario—selected years

Year	CANADA					ONTARIO				
	Total Pulpwood Consumption			Percentage of Total		Total Pulpwood Consumption			Percentage of Total	
	Softwood (000 m <sup>3</sup> )	Hardwood (000 m <sup>3</sup> )	Total (000 m <sup>3</sup> )	Softwood (%)	Hardwood (%)	Softwood (000 m <sup>3</sup> )	Hardwood (000 m <sup>3</sup> )	Total (000 m <sup>3</sup> )	Softwood (%)	Hardwood (%)
1975	36,617	2886	39,503	92.69	7.31	6739	933	7672	87.84	12.16
1980	40,435	4027	44,462	90.94	9.06	10,278	1432	11,709	87.77	12.23
1985	35,178	5244	40,422	87.03	12.97	9624	1912	11,536	83.43	16.57
1990	32,756	7516	40,272	81.34	18.66	7771	2292	10,063	77.22	22.78
1992	28,959	9287	38,246	75.72	24.28	6739	2665	9404	71.66	28.34

Sources: Ghebremichael [8]. Table 4.3 and Table 4.4. Statistics Canada [5].

Notes: Pulpwood consumption does not include consumption of wood residue and wood chips.

and changes in the availability of softwood fibre may also have played a role in this trend.

Pulp yields also appear to have improved in the last two decades [5, 8]. The ratio of wood-pulp produced to the volume of pulpwood consumed has increased from 38% nationally in 1975 to 60% by 1992. Wood residues from sawmills have become an increasingly important source of fibre supply to pulp mills in Canada since 1975 [9, 10].

The value of hardwood fibre is an important factor influencing the financial viability of switchgrass production for pulp in Ontario. Current research and development efforts are exploring the possibility of using switchgrass fibre as a substitute for 20% of the hardwood fibre currently

used in fine paper production (e.g. photocopy paper). A common mixture for this type of paper currently combines 20% softwood fibre with 80% hardwood fibre. If the pulping qualities of switchgrass fibre are appropriate, a mixture of 20% softwood fibre, 64% hardwood fibre and 16% switchgrass fibre could be employed. Switchgrass would therefore need to provide comparable fibre quality to the hardwood it would be replacing at a competitive cost.

In the long run, trends in the availability of hardwood could increase the price of hardwood fibre making switchgrass a more attractive alternative. The trend in hardwood and softwood pulp prices is stable or declining in constant dollar terms (Table 2). The connection between the

Table 2

C.I.F. U.S. domestic nominal and constant-dollar prices for bleached kraft hardwood and softwood market pulp—1975 to 1995

	Nominal Price <sup>1,2</sup>		1991 Constant \$ Price <sup>3</sup>	
	Northern Bleached Softwood Kraft (C\$/MT, delivered)	Northern Bleached Hardwood Kraft	Northern Bleached Softwood Kraft (C\$/MT, delivered)	Northern Bleached Hardwood Kraft
1975	422.06	429.24	1046.59	1064.39
1976	404.26	326.37	921.87	744.24
1977	363.55	293.39	780.08	629.54
1978	427.88	390.22	865.42	789.27
1979	538.66	507.04	991.24	933.06
1980	619.57	572.81	1030.84	953.04
1981	656.45	574.32	985.10	861.85
1982	542.96	459.05	749.96	634.05
1983	542.08	511.28	713.17	672.65
1984	660.45	602.18	842.22	767.91
1985	546.00	470.93	678.42	585.13
1986	666.72	652.83	809.39	792.53
1987	808.86	762.45	940.70	886.73
1988	935.56	867.86	1039.21	964.01
1989	982.72	893.92	1041.84	947.70
1990	940.89	774.60	966.66	795.81
1991	658.38	517.40	658.38	517.40
1992	674.02	612.06	634.21	575.91
1993	583.73	495.04	530.08	449.54
1994	774.64	696.15	679.72	610.85
1995	1140.47	1061.93	968.15	901.47

Source: Pulp and Paper 1996—North American Factbook [11].

Notes: 1) Nominal C.I.F. prices delivered in the U.S. market. An average annual exchange rate from Statistics Canada is used in converting US\$ to C\$.

2) Market pulp contains 10% moisture.

3) World Bank's GDP-deflator for Canada is used in converting the nominal prices to constant 1991 \$ prices (Source: World Bank [12])

Table 3  
F.O.B. nominal- and constant-dollar export price of Canadian bleached sulphate softwood pulp—1975 to 1995 (\$/MT)

Year	Prices <sup>1,2</sup>	
	Nominal Price (C\$/MT)	Constant 1991- Dollar Price <sup>3</sup> (C\$/MT)
1975	380.00	942.30
1976	371.00	846.03
1977	369.00	791.78
1978	333.00	673.53
1979	445.00	818.88
1980	547.00	910.10
1981	580.00	870.37
1982	534.00	737.58
1983	452.00	594.66
1984	571.00	728.15
1985	484.00	601.38
1986	540.00	655.55
1987	678.00	788.51
1988	790.00	877.53
1989	885.00	938.25
1990	818.00	840.40
1991	570.00	570.00
1992	586.00	551.39
1993	471.16	427.86
1994	599.36	525.92
1995	976.52	828.98
Average	570.48	739.01

Sources: Forest Product Prices—FAO Forestry Paper 125 [13]. Statistics Canada—Cat. No. 62-011 [14].

Notes: 1) Both are f.o.b. prices. The price quoted is an average for the year.

2) For 1975 to 1992 the prices data are gathered from FAO Forestry Paper 125 [13], while 1993 to 1995 prices are estimated from Commodity Price Index for bleached sulphate pulp.

3) World Bank's GDP-deflator is used in converting nominal prices to constant 1991 \$ prices.

price of hardwood in eastern Ontario and western Quebec and the price of pulp, however, is complex. Because the Canadian pulp industry has come to rely increasingly on sawmill residues as a source of pulp fibre, this source of supply is linked to supply and demand conditions in the lumber market. Furthermore, the pulp market is global. We would expect that price movements in world pulp markets would come to be reflected in changes in the derived demand and ultimately in the price of hardwood for pulp, although these

effects may be subject to long and variable lags. The Cost, Insurance and Freight (C.I.F.) price of bleached softwood kraft pulp in the U.S. market has fluctuated around Cdn \$1000.00 per metric ton, in 1991 constant dollars, since 1975. Hardwood pulp prices have exhibited a slight downward trend. Data on Freight On Board (F.O.B.) prices for Canadian bleached sulphate softwood pulp destined for export markets are available (Table 3), and show that prices of soft-

Table 4  
U.S. and Canadian transportation margin for northern bleached softwood kraft (in constant 1991 dollars)

Year	U.S. Price <sup>1</sup> (C\$/mt)	Canadian Price <sup>2</sup> (C\$/mt)	Transportation Margin <sup>3</sup> (C\$/mt)
1975	1046.59	942.30	104.29
1976	921.87	846.03	75.85
1977	825.70	791.78	33.92
1978	865.42	673.53	191.90
1979	991.24	818.88	172.35
1980	1030.84	910.10	120.74
1981	985.10	870.37	114.73
1982	749.96	737.58	12.38
1983	713.17	594.66	118.51
1984	842.22	728.15	114.07
1985	678.42	601.38	77.04
1986	809.39	655.55	153.84
1987	940.70	788.51	152.19
1988	1039.21	877.53	161.69
1989	1041.84	938.25	103.60
1990	966.66	840.40	126.26
1991	658.38	570.00	88.38
1992	634.21	551.39	82.82
1993	530.08	427.86	102.22
1994	679.72	525.92	153.81
1995	968.15	828.98	139.17
Average	853.28	739.01	114.27

Sources: Pulp and Paper 1996—North American Factbook [11]. Forest Product Prices—FAO Forestry Paper 125 [13]. Statistics Canada—Cat. No. 62-011 [14].

Notes: 1) U.S. price is delivered price of northern bleached softwood kraft estimated in Table 2 (in constant 1991-dollar prices).

2) Canada price is f.o.b. price unbleached softwood sulphate pulp estimated in Table 3 (in constant 1991-dollar prices).

3) Assume the difference between the two prices represents the pulp transportation costs from Canada to the U.S. market.

wood pulp for export averaged about \$740.00 (Cdn) between 1975 and 1995.

For the purposes of this paper, we would like to have a measure of the value of hardwood pulp in the Canadian market. We have located price data for softwood pulp in the domestic market and in the U.S. market. Data on C.I.F. prices of Canadian hardwood pulp prices in the U.S. market are also available. We have elected to use the difference between C.I.F. prices for Canadian softwood pulp in the U.S. market and F.O.B. prices in the domestic market as a measure of the transportation margin for pulp exports. This margin is calculated in Table 4 for the period 1975 to 1995. It averaged about Cdn \$114.00, in

1991 constant dollars over this time period, but as the data in the table indicate, there has been a considerable level of volatility in this value. Applying this margin to the published C.I.F. price for Canadian hardwood pulp in the U.S. market (Table 5), we obtain a series of estimated F.O.B. prices for Canadian hardwood pulp in the domestic market, averaging about Cdn \$650.00 per metric ton from 1975 to 1995 in constant 1991 dollars. A slight downward trend was observed in these estimated prices during this time period, although there has been considerable variation around this trend.

Projections of the domestic market F.O.B. price of hardwood pulp are reported in Table 6. The ability of switchgrass to compete with hardwood as a pulp fibre source will depend on its cost relative to the future cost of hardwood fibre. Predicting trends in the price of hardwood fibre is a difficult exercise, and the development of a rigorous model is beyond the scope of this study. We have calculated projections based on linear trends from the period 1975 to 1995. Three approaches were used. In each case, the U.S. C.I.F. price for Canadian hardwood pulp was projected from the data series in Table 2. A transportation margin was deducted from this price, based on a linear projection of the transportation margins presented in the second column of Table 5. The first approach to projecting the domestic F.O.B. price for Canadian hardwood pulp, identified as “Model 1” in Table 6, is calculated as the difference between the projected U.S. C.I.F. price and this projected transportation margin. The second approach, identified as “Model 2” in Table 6, projects a linear trend from the estimated prices reported in the last column of Table 5. The third approach, identified as the “Mean” in Table 6, is the annual average of the first two approaches.

Each of the three approaches reported in Table 6 project a downward trend for domestic market hardwood prices. The trend is stronger with the second approach. The third approach projects an average price of about Cdn \$525.00, in constant 1991 dollars, over the next decade. Clearly, there are limitations to this approach to predicting the value of hardwood fibre, but in the

Table 5  
Estimated price of Canadian bleached hardwood kraft pulp—  
1975 to 1996 (constant 1991 dollars/metric ton)

Year	U.S. Price <sup>1</sup> (C\$/mt)	Transportation Margin <sup>2</sup> (C\$/mt)	Estimated Canadian Price <sup>3</sup> (C\$/mt)
1975	1064.39	104.29	960.11
1976	744.24	75.85	668.40
1977	629.54	33.92	595.62
1978	789.27	191.90	597.37
1979	933.06	172.35	760.70
1980	953.04	120.74	832.30
1981	861.85	114.73	747.12
1982	634.05	12.38	621.68
1983	672.65	118.51	554.14
1984	767.91	114.07	653.84
1985	585.13	77.04	508.10
1986	792.53	153.84	638.69
1987	886.73	152.19	734.54
1988	964.01	161.69	802.32
1989	947.70	103.60	844.10
1990	795.81	126.26	669.55
1991	517.40	88.38	429.02
1992	575.91	82.82	493.09
1993	449.54	102.22	347.32
1994	610.86	153.81	457.05
1995	901.47	139.17	762.30
Average	765.58	114.27	651.30

Notes: 1) U.S. Prices are delivered prices of northern bleached hardwood kraft estimated in Table 4.

2) Transportation Margin is defined in Table 4.

3) Estimated Canadian Price of bleached hardwood pulp is estimated from the difference between U.S. price and the transportation cost from Canada to the U.S. market.

Table 6  
 Predicted price of Canadian bleached hardwood kraft pulp—1996 to 2005 (1991 constant \$)

	U.S. Price <sup>1</sup> (C\$/mt)	Transportation Cost <sup>2</sup> (C\$/mt)	Canadian Prices		
			Model I <sup>3</sup> (C\$/mt)	Model II <sup>4</sup> (C\$/mt)	Mean <sup>5</sup> (C\$/mt)
1996	742.59	126.67	615.92	535.23	575.58
1997	732.53	127.79	604.73	524.68	564.71
1998	722.46	128.92	593.54	514.13	553.84
1999	712.40	130.05	582.35	503.58	542.97
2000	702.34	131.17	571.16	493.03	532.09
2001	692.28	132.30	559.97	482.47	521.22
2002	682.21	133.43	548.78	471.92	510.35
2003	672.15	134.55	537.59	461.37	499.48
2004	662.09	135.68	526.41	450.82	488.61
2005	652.02	136.81	515.21	440.27	477.74
		Mean	565.57	487.75	526.66

Notes: 1) Estimation of U.S. price is based on a linear trend fitted to data in Table 3 (last column). The equation is:  $\text{Price}(t) = 963.97 - 10.06 \text{ Time}(t)$ ; with  $R^2=0.16$ . 2) Estimated transportation cost is based on a linear trend from data in Table 6 (second column). The equation is:  $\text{Cost}(t) = 101.87 + 1.12 \text{ Time}(t)$ ; with  $R^2=0.03$ . 3) Estimated Canadian price (Model I) is the difference between U.S. price and transportation cost. 4) Estimated Canadian price (Model II) is based on a linear trend from data in Table 6. The equation is:  $\text{Price}(t) = 767.37 - 10.55 \text{ Time}(t)$ ; with  $R^2=0.18$ . 5) The mean is the average of the two predicted prices

future this will determine whether the cost of switchgrass fibre is a competitive alternative in Canadian pulp and paper production.

### 3. What is the potential size of demand for switchgrass for pulp production in eastern Ontario and western Quebec?

If it turns out that switchgrass can compete on a cost basis with hardwood fibre in pulp and paper production in eastern Ontario and western Quebec it would be valuable to know what the potential size of the demand for switchgrass fibre might be. Projections for the Ontario market are reported in Tables 7 and 8. Total hardwood consumption is projected linearly from the data reported in Table 1. These consumption data are reported in thousands of cubic metres of wood. Twenty percent of this projected volume is converted at a rate of 0.529 oven dry metric tons per cubic metre, based on the findings of a Department of Energy, Mines and Resources study [16]. This weight of wood is converted to pulp weight at an assumed pulp yield of 44% for hardwood, based on Keays [17] and Ontario

Ministry of the Environment [18]. Ontario production requirements would range from about 310,000 to 380,000 oven dry metric tons of switchgrass production in the province annually. This would require anywhere from 22,000 hectares of land with yields of 14 metric tons/ha 48,000 hectares if yields were only 8 metric tons/ha. Total cropland area in the 12 counties and districts of eastern Ontario in 1991 was about 480,000 hectares (OMAFRA, Agricultural Statistics for Ontario [19]). About 285,000 hectares were dedicated to hay production and an additional 90,000 hectares were used for grain and fodder corn production in this region in 1994 [19]. Hardwood consumption capacities of selected pulp and paper mills in eastern Ontario and western Quebec are reported in Table 8. Conversion of 20% of this capacity to switchgrass fibre would require approximately 280,000 oven dry metric tons of switchgrass production annually. These data indicate that about 5% to 10% of the cropland area of eastern Ontario would be needed to supply 20% of the hardwood pulp volume from switchgrass.

Table 7  
Projected switchgrass production requirements in Ontario—1996 to 2005

Year	Hardwood Consumption <sup>1</sup> (000 m <sup>3</sup> )	20 per cent of Hardwood Consumption <sup>2</sup> (000 m <sup>3</sup> )	Biomass Equivalent Weight <sup>3</sup> (000 ODMT)	Equivalent Pulp Weight <sup>4</sup> (000 ODMT)	Required Switchgrass Biomass <sup>5</sup> (000 ODMT)
1996	2651.13	530.23	280.49	123.42	308.54
1997	2721.66	544.33	287.95	126.70	316.75
1998	2792.19	558.44	295.41	129.98	324.96
1999	2862.72	572.54	302.88	133.27	333.16
2000	2933.25	586.65	310.34	136.55	341.37
2001	3003.78	600.76	317.80	139.83	349.58
2002	3074.31	614.86	325.26	143.12	357.79
2003	3144.84	628.97	332.72	146.40	366.00
2004	3215.37	643.07	340.19	149.68	374.21
2005	3285.90	657.18	347.65	152.97	382.41

Notes: 1) Hardwood consumption is predicted by using a linear trend from Table 2, the equation is: Consumption(t) = 1099.47 + 70.53t,  $R^2=0.86$ .

2) Assume a 20% of hardwood consumption is to be replaced by switchgrass.

3) Average weight per 1 m<sup>3</sup> of hardwood is assumed 0.529 oven dry metric ton (ODMT) (Dept of Energy, Mines and Resources [16]).

4) Average pulping yield is assumed to be 44% for hardwood fibre (Keays [17]). 5) For switchgrass, average pulping yield is predicted from that of wheat straw, i.e. 40%.

Table 8  
Potential market size of switchgrass fibre in eastern Ontario and western Quebec

Type of Plant	Annual Pulp or Paper Production Capacity (mt) <sup>1</sup>	Potential Switchgrass Pulp Content (ADMT/yr) <sup>2,3</sup>	(ODMT/yr) <sup>4</sup>	Equivalent Switchgrass Weight (ODMT/yr) <sup>5</sup>
(1) Fine Paper Plants				
—Domtar Inc. in Cornwall	288,750	46,200	41,580	103,950
—Domtar Inc. in Beauharnois	21,000	3360	3024	7560
—E.B. Eddy Forest Products Ltd. in Ottawa	108,500	17,360	15,624	39,060
—Rolland Inc. in St. Jerome	126,000	20,160	18,144	45,360
Sub Total	544,250	87,080	78,372	195,930
(2) Pulp Plants				
—Industries James MacLaren Inc. in Thurso	234,500	37,520	33,768	84,420
Total	778,750	124,600	112,140	280,350

Sources: REAP—Canada [15].

Notes: 1) Assume paper and pulp mills are operating 350 days per year.

2) Assume 1 mt of fine paper is made of 1 ADMT (air dry metric ton) of pulp, in addition to some amount of fillers (e.g. chalk) to provide very specific properties to the paper.

3) Assume both paper and pulp contain 16% switchgrass, i.e. Switchgrass replaces 20% of the 80% of the pulp mixture derived from hardwood fibre.

4) Air-dry pulp contains 10% moisture.

5) Switchgrass pulp yield is assumed to be 40%.

#### 4. Production budgets for switchgrass

Switchgrass production for pulp fibre would be undertaken as an annual harvest from a permanent grass plantation. The costs of this production can be disaggregated into plantation establishment costs, and annual operating, harvesting and storage costs. Transportation costs to pulp mills, also need to be acknowledged in an assessment of the ability of switchgrass fibre to compete with hardwood fibre in pulp production. Our assessment considers the value of switchgrass at the farm gate, out of on-farm storage. It is important to keep this perspective in mind when we discuss the value of switchgrass later in this report.

Establishment costs were amortized over the life of the plantation in order to obtain an annual cost to be charged against annual biomass production. Material or ingredient costs as well as operation and machinery costs are included. Materials include herbicides and seed. According to Tayara [20] and Girouard [21], materials costs to establish a hectare of switchgrass plantation amount to \$98.38. Operation and machinery costs necessary to establish a plantation, including labour, fuel, depreciation, interest on machinery and insurance costs total, again according to Tayara [20] and Girouard [21], would be

\$121.36 per hectare. If these operations were done through custom work, according to the Burgess [22] survey of custom work rates in eastern Ontario 1990, the cost would amount to \$145.45 per hectare. The sum of the Tayara's and Girouard's budget estimates is \$219.74 per hectare. At a 5% discount rate, this cost, amortized over the life of the plantation varies from \$50.76 per hectare per year if the plantation remains in production for just 5 years to \$15.59 per hectare per year if it remains in production for 25 years. It is clear that the life expectancy of a stand of switchgrass is an important determinant of the cost competitiveness of switchgrass fibre in pulp production. At a yield of 10 metric tons per hectare per year, a stand that lasts for 5 years would cost approximately \$3.52 per metric ton of switchgrass produced more than a stand that lasts for 25 years.

Material costs include fertilizers and twine for baling. Operation and machinery costs again include labour, fuel, depreciation on machinery, interest and insurance costs. Custom rates for field operations are reported in the table when available. Annual material, operating and machinery costs total \$160.53 per hectare per year.

We assume that switchgrass bales would be stored on the farm until shipped to the pulp mill. The storage facility consists of a gravel pad

Table 9  
Average cost of switchgrass production under different life expectancies and yields

Cost Component	Unit	Value	Average Cost of Switchgrass Production (\$/ODMT)					
			Life Expectancy: 10 Years Yield			Life Expectancy: 20 Years Yield		
			8 ODMT (\$/ODMT)	10 ODMT (\$/ODMT)	12 ODMT (\$/ODMT)	8 ODMT (\$/ODMT)	10 ODMT (\$/ODMT)	12 ODMT (\$/ODMT)
Establishment Cost <sup>1,4</sup>	\$/ha	219.74	3.56	2.85	2.37	2.20	1.76	1.47
Annual Operating Cost <sup>1</sup>	\$/ha	160.53	20.07	16.05	13.38	20.07	16.05	13.38
Transportation Cost <sup>2</sup>	\$/mt	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Cost of Storage Facilities <sup>3,4</sup>	\$/ODMT/yr		4.04	3.65	3.38	3.25	2.86	2.60
Average Cost of Switchgrass Production:	\$/ODMT/yr		35.66	30.55	27.13	33.52	28.68	25.45
	\$/ha/yr		285.31	305.49	325.55	268.16	286.76	205.36

Notes: 1) Establishment cost estimate is based on Tayara [20] and Girouard [21].

2) Transportation cost from farm to the mill (with average distance 40 km) is assumed to be \$8.00/ODMT.

3) Annualized cost of storage facilities is based on Tayara [20].

4) Discount rate is assumed to be 5%.



Table 10  
Projected value of switchgrass biomass and switchgrass plantation: hardwood biomass price approach

	Unit	Low Price	High Price
Assumed Price of Hardwood (at Mill)	\$/ODMT	80.00	100.00
Hardwood Cost of Producing 1 ODMT Pulp <sup>1</sup>	\$/ODMT	181.82	227.27
Switchgrass Biomass Equivalent Value <sup>2</sup>	\$/ODMT	72.73	90.91
Value of Switchgrass Plantation:			
—Switchgrass Productivity = 8 ODMT/ha	\$/ha/yr	581.82	727.27
—Switchgrass Productivity = 10 ODMT/ha	\$/ha/yr	727.27	909.09
—Switchgrass Productivity = 12 ODMT/ha	\$/ha/yr	872.73	1090.91

Notes: 1) Pulping yield is assumed to be 44%, then to produce 1 ODMT of pulp requires 2.272 (=1/0.44) ODMT of hardwood biomass.

2) Calculated price of switchgrass based on hardwood cost of producing 1 ODMT pulp switchgrass pulping yield is assumed to be 40%.

under the bales and a tarpaulin covering the bales. Annualized cost of these inputs depends on the life expectancy of the storage equipment and yields.

Estimated average annual production costs, inclusive of annualized establishment, operating, transportation and storage costs are reported in Table 9. Costs are reported on a per hectare as well as a per ton of biomass basis. Yields from 8 to 12 oven dry metric tons are considered. On an oven dry metric ton basis, costs range from \$24.38 to \$34.06, depending on yields. Land rents are not included in these costs. Land rents for crop land in this region of Ontario vary with land quality and also change from year to year in response to fluctuations in commodity prices. Rents for corn land in this area have ranged from \$24.00 to \$100.00 per hectare in recent years [23, 24]. For switchgrass production to be attractive to farmers, they would have to receive a price for switchgrass that covered these budgeted costs plus at least the competitive annual rents on land that would be used to grow switchgrass. For example, if land rents are \$100.00 per hectare annually and a yield of 10 oven dry metric tons per hectare per year is achieved, a farmer would need a price for switchgrass of at least \$39.27 per oven dry metric ton for a plantation with a life expectancy of 10 years. This would fall to \$37.40 per oven dry metric ton if a plantation could remain in production for 20 years.

## 5. Estimating the potential value of switchgrass

Based on production budgets, it would appear that farmers could at least break even on switchgrass if they received a price of at least \$50.00 per metric ton at the mill. There are some informal indications that this price is reasonable. But it is possible that switchgrass could be worth more than \$50.00 per metric ton in pulp production. We used two approaches to derive potential values for switchgrass. The first approach begins with the delivered price of hardwood at the pulp mill. The results of this approach are reported in Table 10. The second approach works backwards from the market price of hardwood pulp estimated earlier (Table 5). The results of this approach are reported in Table 11.

The hardwood biomass approach (Table 10) begins with the price of hardwood delivered to the mill. Delivered hardwood prices are not published, but informal data sources suggest that prices in the range of \$80.00 to \$100.00 per oven dry metric ton at the mill are common. Assuming a pulping fibre yield of 44% for hardwood, this price translates to \$181.82 to \$227.27 per oven dry ton of actual fibre. If switchgrass fibre, as fibre, is equal in value to this hardwood fibre, and if pulping yields from switchgrass are assumed to be 40%, then this would translate into switchgrass prices in the range of \$72.73 to \$90.91 per oven dry metric ton of switchgrass. If pulping yields of switchgrass turn out to be

Table 11  
Projected value of switchgrass biomass and switchgrass plantation: hardwood kraft pulp price approach

	Unit	Value
Average Hardwood Kraft Pulp Price <sup>1</sup>	\$/ADMT	651.30
	\$/ODMT	723.67 <sup>2</sup>
Value of Hardwood as Raw Material <sup>3</sup>	\$/ODMT	295.00
Equivalent Value of Switchgrass Biomass <sup>4</sup>	\$/ODMT	118.00
Projected Value of Switchgrass Plantation:		
—Switchgrass Productivity = 8 ODMT/ha	\$/ha/yr	943.99
—Switchgrass Productivity = 10 ODMT/ha	\$/ha/yr	1179.99
—Switchgrass Productivity = 12 ODMT/ha	\$/ha/yr	1415.99

Notes: 1) Average hardwood pulp price is estimated in Table 5.  
2) Assume the market pulp (in air dried form) contains 10% moisture.  
3) Value of hardwood material is estimated at 40.76% of average manufacturing cost (Dept of Industry, Trade and Commerce [25]).  
4) Average pulping yield is assumed to be 40%.

higher than 40%, these prices would be higher. If switchgrass fibre is less than a perfect substitute for hardwood fibre in the pulping process, then this would put downward pressure on these prices.

The second approach begins with the estimated market price of hardwood pulp (Table 11). Assuming a 10% moisture content in market pulp, the average pulp price of \$651.30 from Table 5 would be the oven dry weight equivalent of \$723.67 per metric ton. According to some old estimates of the cost share of various inputs in pulp production [25], the value of hardwood material in the cost of producing pulp is 40.76%. This would mean that the value of the actual

fibre in the hardwood market pulp would be \$295.00 per oven dry metric ton. Using the same pulp yield assumptions as in Table 10, this would give a switchgrass price of \$118.00 per oven dry metric ton of switchgrass biomass. Two caveats should be acknowledged regarding this second approach. First, as our earlier data indicated, the price series for hardwood price is cyclical. Price risk is an important factor that should be considered in the financial viability of switchgrass production for pulp. Secondly, the Department of Energy Mines and Resources study upon which this approach is based is dated. We were not able to locate more recent data.

Table 12  
Effect of variation in hardwood material cost share on the value of switchgrass: hardwood kraft pulp price approach

	Unit	Share of Hardwood Material Cost to the Price of Hardwood Kraft Pulp		
		25%	30%	40%
Value of Hardwood Material <sup>1</sup> (As Proportion to Pulp Price)	\$/ODMT	180.92	217.10	289.47
Equivalent Value of Switchgrass Biomass <sup>2</sup>	\$/ODMT	72.37	86.84	115.79
Value of Switchgrass Plantation:				
—Switchgrass Productivity = 8 ODMT/ha	\$/ha/yr	578.94	694.72	926.30
—Switchgrass Productivity = 10 ODMT/ha	\$/ha/yr	723.67	868.40	1157.87
—Switchgrass Productivity = 12 ODMT/ha	\$/ha/yr	868.40	1042.08	1389.45

Notes: 1) Values of hardwood material are assumed to be 25, 30 and 40% of the hardwood kraft pulp which is calculated in Table 25 (= \$723.67/ODMT).

2) Switchgrass pulping yield is assumed to be 40%.

Depending on yields achieved, the first approach to estimating the potential value of switchgrass would give gross revenues on a per hectare basis of \$581.82 to \$1090.91. The second approach gives estimates ranging from \$943.99 to \$1415.99 per hectare. Sensitivity analysis of the effect of variations on the value of hardwood fibre as a share of the value of market pulp (Table 12) indicates how switchgrass prices would change if fibre accounted for 40%, 30% and 25% of the value of market pulp, instead of the 40.67% reported in Table 11. Even at these lower percentages, switchgrass prices in the range of \$70.00 to \$85.00 per oven dry metric ton of switchgrass biomass would be possible.

## 6. Summary and conclusions

Our findings indicate that switchgrass has the potential to become a valuable crop in eastern Ontario and western Quebec. Depending on the yields obtained, from 22,000 to 48,000 hectares would be required to grow the projected volume of switchgrass needed to replace 20% of the hardwood fibre used in fine paper production in the region. For per hectare yields of 10 metric tons and a \$50.00 per metric ton price for switchgrass, 22,000 hectares would produce \$11 million in gross revenue to produce annually.

There are several topics on which further research is indicated regarding the feasibility of switchgrass in pulp production. Switchgrass is a perennial grass and may prove to be an especially attractive crop on erosion prone lands or on economically marginal lands. At the present time, data on the performance of switchgrass on these types of lands in eastern Ontario and western Quebec are limited. Further trials are needed. The proportions of hardwood, softwood and switchgrass pulp assumed in this study are based on some preliminary small scale production trials. Further sensitivity analysis of the implications of variations in this recipe is needed. Finally, more detailed analysis of agricultural land use and land rental values around existing pulp mills in the region is needed to

further assess production and transportation costs.

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