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Benefit-cost analysis of hybrid willow crop production on agricultural land in eastern Canada: Assessing opportunities for on-farm and off-farm bioenergy use

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ABSTRACT

The purpose of this study was to conduct a financial benefit-cost analysis of producing hybrid willow biomass on riparian, in-field, and high-sloped agricultural land in the eastern Canadian province of Prince Edward Island for use as an on-farm or off-farm source of renewable energy. The off-farm use analysis indicated that, at a current price of \$50 per dry matter tonne (DMT^{-1}) sold to a municipal biomass energy plant, the willow cropping system would not represent an attractive investment opportunity for farmers. Prices would have to increase to the range of \$81–\$116 DMT^{-1} (depending on the scenario considered) before such an investment would be profitable. On the other hand, the on-farm use analysis indicated that, at an estimated cost savings of \$375 DMT^{-1} from displacing heating oil by using a biomass boiler to burn the willow chips (at a replacement cost of \$56–\$137 DMT^{-1}, depending on the scenario), the willow cropping system would represent a very attractive investment opportunity for farmers. Using such a system could reduce heating costs on the farm in the range of 64–85%.

1. Introduction

There has been increasing interest in using short-rotation woody crops (SRWC) as a source of biomass energy in Canada [1]. This interest has largely emerged from growing concerns over energy security, volatility of fossil fuel prices, global CO_2 emissions, and the need to revitalize rural economies [2]. Hybrid willow is one SRWC that has been identified as having outstanding potential to serve as a dedicated feedstock for the production of renewable energy and other products [3,4]. It can provide a long-term, sustainable, carbon neutral replacement for fossil fuels, while promoting rural development and offering numerous environmental co-benefits related to soil, water, and wildlife [5,6].

A number of hybrid willow experiments have been conducted in Canada over the past 30 years, starting in the 1980s [7], through the 1990s [8], and more recently through the Canadian Biomass Innovation Network and the ecoENERGY Technology Initiative [9]. The focus of the experiments has

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Table 1 – Basic cost estimates of a willow production system in Prince Edward Island, Canada.

Activity	Unit cost (2012 CDN \$ ha^{-1}, or as stated)	Year(s) occurring	Assumptions
Plough (deep tillage)	\$60	1	Tractor cost (at 4 miles h^{-1}, taking 1.5 h ha^{-1}@\$30 h^{-1}) = \$45 ha^{-1}, and labour cost (1 man@\$10 h^{-1}, taking 1.5 h ha^{-1}) = \$15 ha^{-1} [17,18].
Disks (level and loosen)	\$40	1	Tractor cost (at 5 miles h^{-1}, taking 1 h ha^{-1}@\$30 h^{-1}) = \$30, and labour cost (1 man@\$10 h^{-1}, taking 1 h ha^{-1}) = \$10 [17].
Cuttings	\$2250	1	15,000 cuttings per ha, \$0.15/cutting [2,17].
Plastic mulch planting	\$1948	1	Plastic mulch sells for \$170/1500 ft. × 4 ft roll (=457.18 m). Given that 10,000 m^2 = 1 ha, and leaving 2 m spacing between rows implies the need for 11 rolls of plastic mulch = \$1870 ha^{-1}. Additionally, tractor cost (2 mph, taking 1.56 h ha^{-1}@\$30 h^{-1}) = \$47 ha^{-1}, and labour cost (2 men@\$10 h^{-1} for 1.56 h) = \$31 ha^{-1} [18].
Broadcast grass seed	\$70	1	Tractor cost (at 5 miles h^{-1}, taking 1 h ha^{-1}@\$30 h^{-1}) = \$30, labour cost (1 man@\$10 h^{-1}, taking 1 h ha^{-1}) = \$10, and grass seed = \$30 ha^{-1} [17].
Mechanical weed control	\$70	1	Tractor cost (at 5 miles h^{-1}, taking 1 h ha^{-1}@\$30 h^{-1}) = \$30, labour cost (1 man@\$10 h^{-1}, taking 1 h ha^{-1}) = \$10, and grass seed = \$30 ha^{-1} [17].
Manual coppice	\$1190	1	Labour cost (1 man with a brush saw coppicing on average 6.3 stems per minute, or taking 39.7 h ha^{-1}, @\$30 h^{-1}) = \$1190 ha^{-1} [18].
Opportunity cost of land use	\$185/\$100	Annually	Assuming the respective riparian and in-field/high-sloped land could have been used for potato production, on a 3-year rotation [20].
Harvesting (\$ DMT^{-1})[a]	\$65	4, 7, 10, 13, 16, 19, 22	Custom harvest: self-propelled forest harvester (\$45/t); chips blown into wagon pulled by a tractor (\$10/t); chips loaded into a dump truck and transported to open storage area (\$10/t) for 5–8 months for natural drying processes to effectively reduce moisture content to approximately 30% before on-farm usage or off-farm sale [2,22].
Stock removal	\$400	22	Custom stock removal: 150 hp tractor (\$180 ha^{-1}) and a grinder (\$220 ha^{-1}) [2,17].

[a] DMT = dry matter tonne.

largely been on examining growth and yield performance as well as quantifying carbon and associated environmental co-benefits.

In the eastern Canadian province of Prince Edward Island (PEI), several landowners have been participating in a recent SRWC program called the Bioeconomy Crop Initiative. This program is offered by the PEI Department of Agriculture through the Agricultural Flexibility Fund, a cost-sharing agreement between the Government of Canada and the province [10]. The intent is to evaluate SRWC systems for potential progress towards commercialization, thereby increasing the competitiveness of the agriculture sector while improving the environmental sustainability of the province.

The economics of hybrid willow crops has been studied extensively across Europe [11–13], the United States [3,14,15], and to a relatively smaller extent in Canada [2,16]. Study findings in North America often tend to support willow production as a competitive source of energy compared to other fossil fuels. For instance, Buchholz and Volk [14] examined the benefits and costs of producing willow biomass for off-farm energy-use using a 10 ha, 3-year rotation, 22-year horizon willow cropping system in upstate New York. Findings under their base-case scenario revealed an internal rate of return (IRR) in the order of 5.5%. In another study, McKenney et al. [2] examined the benefits and costs of producing willow biomass for on-farm use (i.e., displacing fossil fuel use as a heat source for greenhouse operations) using a 144–1430 ha, 3-year rotation, 20-year horizon willow cropping system in southern Ontario. Findings under their base-case scenario for displacing heating oil revealed an IRR in the range of 11–14%. Similar analysis for displacing natural gas revealed an IRR in the range of −1% to 4%.

An important question not yet addressed in the literature is the relative economic attractiveness of producing hybrid willow crops on traditional farms (i.e., crop and livestock producers) for use as an on-farm or off-farm energy source. To-date there has been no systematic comparison of these investment opportunities. Furthermore, it would be of interest to conduct this analysis in the context of planting the willow crop on marginal (i.e., high-sloped), productive (i.e., in-field) and environmentally sensitive (i.e., riparian) land. Such analysis would shed light on possible opportunities for traditional farms across Canada to play a role in revitalizing rural economies, increasing energy security, reducing reliance on volatile fossil fuel prices, and contributing to global CO_2 emission reductions.

The purpose of this study was to conduct a financial benefit-cost analysis (BCA) of producing hybrid willow