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Research paper

Growing hybrid poplar in western Canada for use as a biofuel feedstock: A financial analysis of coppice and single-stem management

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ABSTRACT

Cellulosic biorefineries require a stable supply of low-cost feedstock. In this paper we conduct a financial analysis of hybrid poplar as a purpose grown biofuel feedstock. We analyzed growth rates and costs for producing hybrid poplar in the Peace River region of western Canada – an area previously identified as a preferred location for a large biorefinery. We estimated financial returns for two hybrid poplar management systems: *(i)* a single-stem system that involves the planting and harvesting of individual trees according to optimal economic rotations of 20–26 years, and *(ii)* a coppice (multi-stem) system that involves multiple harvests of new shoots that sprout from stumps following harvest every 3–4 years. Results suggest that the coppice system is financially inferior (with estimated costs of 202 $ Mg^{-1}) to the single-stem system (with estimated costs of 125 $ Mg^{-1}), largely due to the cost of establishing the high density coppice plantations. But even the single-stem production system does not appear to be financially feasible given the current environment of high land prices and low biomass prices. In contrast to estimated costs of growing poplar, current biomass prices for agriculture and forestry residues are approximately 50 $ Mg^{-1}. However, even though purpose grown energy crops are more expensive than residues, they could be valuable in supplementing a biorefinery's feedstock supply during years when residue yields are low. If governments in Canada wish to encourage renewable energy from cellulosic feedstock, then current economic conditions suggest that subsidies aimed at biomass production are likely required.

1. Introduction

The Canadian biofuel sector has expanded rapidly since the 1980s, when the first public policies to encourage biofuel production were enacted [1]. Though food-based (first-generation) feedstock is currently the primary means of producing ethanol, there are a number of unintended consequences – environmental, social and economic – that result from first-generation production (e.g., increased demand for corn and wheat for use in ethanol production can impact food prices) [2–4]. As a result, many of the public policies focused on first-generation biofuels are being replaced by policies that encourage the production of second-generation biofuels from cellulosic feedstock [1].

Hybrid poplar is considered a promising feedstock for cellulosic biofuel production [5]. However, a review of the literature suggests that government policies are currently required for hybrid poplar to be a viable feedstock for second-generation biofuels [6]. Indeed, El Kasmioui and Ceulemans [7] reviewed 23 different financial analyses of short rotation willow and poplar plantations from around the world, and found that "although specific numerical results differed, it became clear that [plantations] are only financially feasible if a number of additional conditions regarding biomass price, yield and/or government support were fulfilled" (p. 52). However, of the 23 studies reviewed, only one was from Canada, and it was from the east. Our interest is in the Peace River region of western Canada, given that this region was identified as a preferred location for large bioenergy plants by two previous studies [8,38].

In North America, although much has been learned about the growth and yield potential of hybrid poplar, less is known about the financial viability of growing these trees for use as a biofuel feedstock. Yemshanov and McKenney [8] used a spatial bio-economic model to show that Nova Scotia and New Brunswick could produce enough hybrid poplar to support ***small*** bioenergy facilities if biomass prices rose to approximately 105 $ Mg^{-1} (all monetary values in this paper are stated as real 2013 Canadian dollars); however, they also showed that the western Prairies appear better suited to support ***larger*** bioenergy facilities (given the vast areas of suitable land), although they estimate

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such supplies would require a biomass price of at least 123 $ Mg^{-1}. The lowest breakeven price was found by Allen et al. [10], who showed that hybrid poplar plantations on agricultural land in northern Ontario required a biomass price of 86 $ Mg^{-1} to be financially viable. The highest breakeven price comes from the southern Great Lakes region of the United States, where James et al. [5] found the breakeven biomass price for hybrid poplar to be 137 $ Mg^{-1}.

In this paper we estimated the financial returns to the landowner for two hybrid poplar management systems: *(i)* a single-stem system that involves the planting and harvesting of individual trees according to optimal economic rotations of 20–26 years; and *(ii)* a coppice (multi-stem) system that involves multiple harvests of new shoots that sprout from the stumps following harvest every 3–4 years. Our approach differs from previous studies of financial analysis of poplar plantations in three major ways: First, we use detailed growth and cost data for the Peace River region of western Canada. Second, rather than treating the rotation age as constant (as was done in most previous studies), we investigate changes in rotation age with respect to changes in economic parameters such as discount rates, silvicultural costs, and biomass prices. Although some hybrid poplar analyses consider optimal economic rotations [11,12], these studies do not focus on its use as a biofuel feedstock. Finally, we compare the financial viability of the two main hybrid poplar management systems: coppice and single-stem management.

In the next section we present a financial model to estimate land expectation value under various growth and cost scenarios for hybrid poplar production. Our results show the conditions under which hybrid poplars could potentially compete with agriculture on private land (given that hybrid poplar is not allowed on much of the public land in Canada [13]). We then use preliminary cost estimates for producing cellulosic ethanol to estimate the maximum biomass price that could be paid based on current estimated costs and prices of producing ethanol. We conclude with a discussion of financial considerations regarding poplar plantations as a biofuel feedstock, with relevance to landowners, policy makers, and bioenergy investors.

2. Financial returns to the landowner for hybrid poplar production

Although exemptions in British Columbia, Newfoundland, and Quebec allow hybrid poplar to be planted on limited areas of public land, it is generally considered an exotic species and therefore prohibited from most of the public land in Canada [13] – including the Peace River region of western Canada, where we conduct this case study. We therefore assume that hybrid poplar plantations must compete with agricultural crop production within the private land market. Our approach is based on the assumption that before a landowner afforests his/her agricultural land, the profits from hybrid poplar would have to exceed the opportunity cost of the crops that are displaced. Since the average selling price for a hectare of agricultural land is a reflection of the financial returns from status-quo agricultural production – i.e., the opportunity cost – we estimated the "breakeven" biomass price that is required for the land expectation value (LEV) of a hectare of land growing hybrid poplar to be equal to the land selling price. LEV is also known as the Faustmann formula and is mathematically defined in the next section. In this case, LEV is an estimate of the value of bare agricultural land if it were managed into perpetuity as a hybrid poplar plantation. The LEV calculations consider: *i)* the value of land for growing trees in perpetuity, *ii)* changes in land values due to different growth and cost assumptions, and *iii)* the harvest age when the land value is maximized – i.e., the optimal economic rotation (OER).

Estimates of LEVs under different growth and cost scenarios for hybrid poplar production allow us to compare the value of land under poplar production with the average selling price for agricultural land. These comparisons provide a means of investigating the financial viability of hybrid poplar plantations; financially viable poplar plantations must have LEVs that exceed the land selling price. This type of opportunity cost approach is standard in the literature. A review paper comparing financial analyses of short rotation willow and poplar plantations from around the world found that almost half of the studies – 11 of 23 – compared the financial feasibility of biomass production with other agricultural activities [7]. Hence, much of the analysis below focuses on the breakeven biomass price, which is simply the biomass price where LEV is equal to the land selling price.

2.1. Land expectation value model description

Our model is based on the continuous-time version of the Faustmann formula (e.g., [14]), as follows:

$$LEV = \frac{V_t P - Ce^{rt}}{e^{rt} - 1} \tag{1}$$

where LEV is the land expectation value in $ ha^{-1}, V_t is the volume of hybrid poplar in $m^3\,ha^{-1}$ at rotation age "t", P is the price of biomass in $ m^{-3}, C is the present value of all silvicultural costs in $ ha^{-1}, e^{rt} is the compounding factor in continuous time with discount rate "r" and rotation age "t".

For single-stem production the optimal economic rotation is the rotation age "t" that maximizes LEV. As is shown in the results below, the optimal economic rotation changes according to the values of the other parameters – such as biomass price (P) and discount rate (r).

The optimal economic rotation age does not apply to the coppice production system, given that operational and biophysical constraints require the trees to be harvested first at year 4, and then every 3 years till age 22. In this case, "t" in Equation (1) is always 22 years, since this is the point where the root system of the coppice plantation becomes depleted and must be replanted. Since there are multiple harvests for the coppice system, "V_tP" is the future value of all the harvests at year 22.

In order to calculate the breakeven biomass price, we calculate the biomass price "P" that satisfies the constraint $LEV = LV$, where "LV" is the land value (i.e., the selling price).

2.2. Land expectation model data

Following from Equation (1), we require data for each variable specified. These data are described below.

2.2.1. Stand volume (V_t)

Growth trials in eastern Canada have shown hybrid poplar growth rates can range from 22 $m^3\,ha^{-1}\,yr^{-1}$ [15] to 50 $m^3\,ha^{-1}\,yr^{-1}$ [16], although these research projects are conducted under more favorable conditions than would likely occur operationally. More conservative growth rates were suggested by Anderson and Luckert [11], who analyzed field data gathered by the Prairie Farm Rehabilitation Administration and estimated that hybrid poplar in western Canadian boreal regions would yield approximately 8 $m^3\,ha^{-1}\,yr^{-1}$. Similarly, McKenney et al. [17] used hybrid poplar growth and yield scenarios of 10, 12, 14, 16 and 20 $m^3\,ha^{-1}\,yr^{-1}$ in their spatial simulations.

The Canadian Forest Service's Canadian Wood Fibre Centre manages a network of hybrid poplar field trials that form an excellent source of long-term growth and yield data. Both the coppice and single-stem yield curves used in our analysis were provided by the Canadian Wood Fibre Centre (Tim Keddy, Canadian Wood Fibre Centre, personal communication, 2013). The Canadian Wood Fibre Centre can generate yield curves for many sites in Canada by integrating its growth and yield data into the Canadian Forest Service's site suitability index (SSI) model. More specifically, the SSI model uses a fuzzy logic and Boolean methodology [18] to assess important environmental factors – such as Canadian Land Inventory Soil Classification, growing-season, precipitation, climate moisture index, growing degree days, drainage, and elevation – which it then uses to estimate site specific hybrid poplar