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Public Preferences for Planting Genetically Improved Poplars on Public Land for Biofuel Production in Western Canada.

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Draft

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Abstract

We examine public opinion of planting genetically improved poplars on public lands in western Canada. Policy scenarios consider the use of three different breeding methods (traditional selective breeding, genomics-assisted breeding, and genetic modification), each with and without poplars being used for biofuels. We employ a choice experiment to provide alternative outcomes to policy scenarios and to investigate differences among characteristics of respondents. Overall, a majority of respondents voted in favour of policies that allowed improved poplars on public land, if fibre is used to generate biofuels. Adding biofuel production to a policy scenario increases the probability of acceptance by 17-32%. In contrast, the various types of breeding technology do not matter as much regarding public acceptance. Responses differ among segments of the population, but these differences do not greatly influence choices. Attributes that increase the probability of acceptance are: being a male, being from Alberta, and being from a population centre of 10,000-100,000 people (relative to centers > 100,000). Attributes that decrease the probability of acceptance are: age, being from British Columbia, and being from a population centre of < 10,000 (relative to centers > 100,000). Despite these significant patterns of preferences, there is substantial uncertainty underlying responses.

Key words: Biotechnology, Biofuels, Public Land, Public Preferences, Poplar Plantations

Introduction

Genomic and tree-breeding research has been conducted in hopes of achieving a variety of desired outcomes, including pest-resistance, climate-change adaptation, or increasing wood quality and volume (Genome Canada 2014). One specific project, POPCAN, aims to harness genomic information to improve the suitability of poplars (*Populus Spp.*) as a cellulosic biofuel feedstock (Genome British Columbia 2014). Canadian demand for biofuels is being spurred by the Government of Canada’s 2010 Renewable Fuel Standard, which requires an average of 5% renewable alcohol be blended into gasoline fuel to mitigate greenhouse gas emissions (Minister of Justice 2013). Though the requirements of the standard are currently being met with ethanol made from corn and wheat, there are ethical concerns about using food for fuel, as it results in higher food prices (Pimentel et al. 2009). If a new cellulosic ethanol industry were to emerge, fibre from forest resources could contribute towards meeting the requirements of the Renewable Fuel Standard. Poplars may become an even more attractive ethanol feedstock moving forward, with Canadian pulp and paper production in decline (Bogdanski 2014) and an abundance of public forest land in Canada.

As genomics research may have transformative impacts on society, Genome Canada uses a framework examining such research on ethical, environmental, economic, legal, and social (GE³LS) grounds (Genome Canada 2015). This component of genomics research is essential in identifying and understanding challenges and opportunities related to applications of genomics, and therefore the feasibility of these applications coming to fruition. For the case of POPCAN, assuming appropriate technology can be developed, using forest sources for biofuel feedstock could be controversial. In Canada 93% of forested land is publicly owned, which is subject to regulations regarding the types of trees that may be planted (Natural Resources Canada 2012).

Specifically, most provinces seek to re-establish forests similar to ones harvested, by requiring that trees planted on public land come from seed collected within a certain range of the planting site. For example, 90 seed zones are defined in Alberta (Alberta Environment and Sustainable Resource Development 2009). Such systems preclude the use of genomics technology which relies on creating improved varieties from limited sources of parent material for widespread planting. Therefore, forest policy would need to change to allow these new trees to be planted on public lands.¹

If POPCAN research were to be applied on Canadian public land, a variety of different outcomes could be realized. On one hand, POPCAN could result in a more prosperous forest industry and could aid Canada in reducing greenhouse gas emissions. On the other hand, replacing large portions of public land with non-native trees could result in genetic flow from improved poplars to native poplars, resulting in uncertain environmental consequences (Guigou-Cairas 2008). Public perceptions of the technology used to create improved poplars, and its use on public lands, will likely be important factors influencing future public land forest policy, which will ultimately determine the extent to which poplar genomics technology is adopted in Canada.

¹ Another option could be to establish poplar plantations on private agricultural lands. However, such a practice could re-ignite concerns regarding food for fuel tradeoffs. Moreover, financial analysis indicates that, given current end product prices and costs, poplar plantations will have a difficult time competing with agriculture for land (Shoostarian 2015).

This paper seeks to measure public preferences for planting various types of hybrid or genetically improved poplars on public land in the four western Canadian provinces. To assess public preferences, a number of hypothetical policies surrounding tree breeding and biofuel production were developed, along with estimates of their potential effects. The policy options and associated effects were presented to representative samples of provincial residents using internet panel surveys. The respondents were asked to vote between their province's current forest policy and the proposed policies in an iterated series of hypothetical provincial referendums. Proposed policy options were associated with one of three poplar breeding improvement methods that could be planted on public land, each with and without resulting poplar-derived biofuels. This methodological approach permits understanding of levels of acceptance between different policy options dependent on their outcomes. Specifically, preferences for different poplar breeding methods will be investigated, both within and outside the context of using poplar as a biofuel source. Further, understanding will be gained with respect to why such policies may or may not be preferred, and which members of the public are more willing to support them.

Literature Review

While there are numerous studies of public perceptions of or preferences for biotechnology applications in food and health (see reviews by Costa-Font et al. 2009, and Pin & Guttelling 2009), few have specifically examined applications to forestry. One source of incompatibility between this study and food or health biotechnology preference studies is the presence of private health concerns associated with food or medicine purchase decisions, as the products are to be ingested by humans. Thus, while underlying determinants of forest

biotechnology preferences can be informed by food-related studies, it is expected that many relationships typically found in the literature may not hold in this context.

Only two studies have examined public perceptions of applications of genomics in Canadian forestry. The first, by Harshaw (2012), examined the BC public's acceptance of poplar plantations to be used as biofuel feedstock. He found that 44% of the BC public agreed with large-scale poplar plantations being used to provide biofuel feedstock on private land (29% disagreed, and 26% were uncertain), while only 15% agreed with replacing natural forested public land with plantations aimed at biofuel production (66% disagreed, and 19% were uncertain). The second study, by Hajjar et al. (2014), gauged public acceptance of using a variety of breeding methods and strategies to adapt public forests to climate change in BC and Alberta. The authors found that a strong majority of the public accepted replanting local seedlings or selectively breeding with local seed, while higher levels of breeding technology (genomics-assisted breeding and genetic modification) and breeding with non-local seeds were accepted by approximately 50% of respondents. A general trend of decreasing acceptance was found as the level of breeding technology increased, though the Alberta and BC publics were found to be least accepting of allowing the forest to grow back naturally without replanting efforts.

One key difficulty in gauging public preferences for genomics technology and forest-based biofuel is associated with a lack of knowledge regarding what a proposed change could entail. For example, what changes would planting trees, created with advanced genetic technologies, have on forests, the forest industry, and the broader economy? Along these lines, Hajjar et al. (2014) found that many respondents would change their opinions depending on the economic, environmental, social, or aesthetic changes created by different policies. Yet no study to date has attempted to measure these public perceptions in the context of defined outcomes.

The closest example is a study by (Susaeta et al. 2010) who examined how potential outcomes associated with forest-based biofuels affect acceptability of bio-refineries. Environmental benefits (sustainability or reduction in carbon emissions) were positively linked with biofuel acceptance. In another study, Marciano et al. (2014) found that respondents who perceived forest-based bio-refineries as environmentally or economically beneficial were more likely to accept bio-refineries.

Few studies have been conducted on public preferences for forest biotechnology in relation to individual specific characteristics. Hajjar et al. (2014) detected minimal differences in forest biotechnology acceptance explained by demographic variables. Males were more likely to accept GM trees; Albertans were more likely to accept not planting seedlings post-harvest than British Columbians; and respondents living outside of major cities were more likely to accept policies involving more human intervention. In an assessment of risks to forest biodiversity, McFarlane (2005) found that more educated respondents perceived higher levels of risk related to forestry activity and land conversion, and females and older respondents perceived higher levels of risk associated with land conversion. Studies of public preferences for forest-based biofuels in the United States also found inconsistent relationships with characteristics of individuals. In a three-state sample (Arkansas, Florida, and Virginia), few results were consistent between samples (Susaeta et al. 2010). A higher education level was a significant positive predictor of forest-based biofuels in one sample, while older respondents were less likely to accept biofuels in one sample. In another American study, Marciano et al. (2014) found that more educated individuals were less likely to accept forest-based biofuels. Overall, results of forest biotechnology public opinion studies seem largely affected by specific contexts.

Further questions arise regarding how public preferences may vary among different segments of the population. In food biotechnology studies, numerous authors have found strong relationships between acceptance and factors such as sex, age, or education, while many others have found no significant links (see review by Costa-Font et al. 2008). These results may be explained by regional and product differences. However, more consistent relationships are often found between attitudes or values, such as environmental concern or trust in government and industry, and biotechnology preferences or risk perceptions (Costa-Font et al. 2008). Many studies have relied on, for instance, the Fishbein Multi-attribute Model (1963), which theorizes that perceptions of a product or policy is determined by its associated perceptions of benefits and risks, which are in turn affected by social-cultural factors, attitudes, or values. Attitudes commonly examined as determinants of benefit or risk perceptions, and therefore preferences for biotechnology, include trust in agencies and regulations, views on science or the environment. When viewing public preferences from this standpoint, it is understandable that observable individual-specific characteristics, such as age or gender, exhibit inconsistent relationships with evaluations of biotechnology, as relationships between demographics and attitudes or values often vary by region and context.

Methods

In order to address the gaps identified in the literature, we measure public preferences for different forest policies and management practices, conditional on their predicted outcomes. This method enables us to present different tree breeding options and their potential effects on society to the public; measuring policy preference while taking these effects into account.

168

169 **Questionnaire Design**

170 Questionnaire design involved numerous stages of consultation with scientific experts
171 (geneticists, botanists, and forest scientists) and the general public. First, four focus groups were
172 held to assess the public's understanding of the forest and biofuel topic and to present an early
173 draft of hypothetical referendum question formats. These formats outlined attributes and impacts
174 of various policy options relative to the current public land policy involving replanting of trees.
175 Participants for all public focus groups were recruited by telephone using random-digit-dialing
176 by Advanis Inc., an Edmonton-based market research firm. Two focus groups each were held in
177 Edmonton (16 participants) and Grande Prairie, Alberta (17 participants). Next, a survey was
178 sent to a group of forestry experts to gather data on predicted changes in poplar growth rate and
179 value arising from different breeding methods. Draft scenarios for hypothetical referendums
180 were developed based on the expert estimates of increases in growth and value of poplars using
181 different breeding methods. A discussion was then held with a group of experts involved with
182 POPCAN to ensure the information provided in the questionnaire was accurate. Following
183 further reviews, a final round of public focus groups were held; two groups in Edmonton,
184 Alberta (24 participants) and two in North Battleford, Saskatchewan (22 participants). This
185 round of focus groups aimed to ensure that all elements of the questionnaire were understood,
186 and to reduce potential sources of bias.

187 After completing these phases and resulting edits to the questionnaire, a pre-test version
188 was administered online to 102 members (51 Albertans and 51 British Columbians) of an
189 internet panel maintained by Ipsos Canada, a market research firm. The final questionnaire
190 briefly explained information about biofuels, different tree breeding methods, and the relevant
191 province's current forest composition, industry, and policy. Next, a series of hypothetical

referendum questions were presented with follow-up questions, and demographic information was collected last. Details of the questionnaire are available in Rollins (2015).

In total, six proposed policy scenarios were created for the referendum tasks. The six proposed policy scenarios were driven by two key attributes: the tree breeding method employed, and whether or not poplars would be used for biofuel production. Biofuel production (*BF*) was considered a binary variable with its presence or absence in a particular policy. The three breeding methods examined were traditional selective breeding (*Trad*), genomics-assisted breeding (*Genome*), and genetic modification (*GM*). Each breeding method appeared in one proposed policy scenario with or without biofuel production. Each voting scenario was set up as a provincial referendum, where respondents were asked to vote for the new proposed policy, or to reject the new policy and maintain the current policy. An example referendum question is presented in Figure 1.

As shown in Figure 1, supplemental information was presented for each referendum question in addition to the breeding method and biofuel production policy attributes. The additional information was selected based on focus group discussions during the survey development phase. The first row of information supplied in figure 1 involves the region where parent trees are located. All proposed policies (right-most column) involved worldwide seed selection for improved poplars, while the current policy involved a small amount of selectively bred poplars (on less than 0.1% of land) using local breeding stock to represent breeding trials in each province.

The next row of information involves how commercial public forest land is currently used, and how it would change with new policies. Estimates of commercial public forest land-use are comprised of non-harvested land (i.e. non-protected land with no future harvest plans),

and land with coniferous trees, natural poplars, and improved poplars predicted to be harvested in the future. In the referendum exercise, harvested coniferous treed land was held constant for the current and all proposed policies, while harvested natural poplar land referred to harvested land regenerated naturally via roots and seeds of harvested poplars.

Current commercial forest land-use was calculated for each province using a variety of sources, depending on data availability. British Columbia forest land-use was calculated using a collection of 40 timber supply area analysis reports prepared by the British Columbia Ministry of Forest, Lands, and Natural Resource Operations (2014), and Alberta forest land-use was calculated based on data from Alberta Environment and Sustainable Resource Development (2013). For Saskatchewan and Manitoba, data was not easily available from the provincial governments, so land-use was estimated based on information released by forestry firms². Predicted changes in land-use arising from allowing different breeding methods and worldwide seed selection on public land were derived using simulation results from Anderson et al. (2012). All policies used in the referendum exercise assumed an equal annual-allowable-cut (AAC), implying that the same volume of timber is harvested in each scenario. Technically, higher tree growth rates could imply a higher AAC instead of leaving some areas un-harvested, but a constant AAC is assumed to avoid confounding the area planted to genetically improved poplars with different tree breeding methods.

The referendum scenarios (Fig. 1) also include a row that considers impacts of proposed policies on industry. Four categories describe the impacts depending on the gains associated with different breeding methods: little to no, small, moderate, and strong positive impacts. The impact

² Reports from Mistik Management Ltd. (2013) and Saskaw Askiy Management Inc. (2013) for Saskatchewan, and reports from LP Canada Ltd. (2014) and Tolko Industries Ltd. (2014) for Manitoba

of allowing new tree breeding methods on the forest industry (jobs and income) was estimated using a combination of results from Anderson et al. (2012), the expert tree growth and value survey, and forest industry composition in each province (proportion of hardwood to softwood production from Natural Resources Canada (2009) and current land-use). The forest industry is likely to benefit from the proposed policies due to increases in poplar growth rates and values associated with higher technology breeding methods.

The last row in the referendum scenarios involved carbon emissions. Reductions in carbon emissions arising from replacing gasoline with poplar-derived biofuels were represented by the estimated equivalent in cars driven per year. Calculated reductions are based on 5% of each province's gasoline being replaced by Poplar-derived biofuel, using a low (65-70%) estimate of life-cycle analysis carbon emission reduction of second-generation biofuels from Schmer et al. (2008), forest industry production statistics (Natural Resources Canada 2009), and provincial gasoline consumption data from Statistics Canada (2013).

To avoid overwhelming respondents with excessively complicated scenarios, we aimed to keep the voting exercises simple and limited the number of new policies. Thus, while it could be informative to allow land-use, impact on industry, and changes in carbon emissions to freely vary in the policy choices, these attributes were considered to be strictly correlated with the breeding method and biofuel production attributes. Since only two policy attributes of the five listed in the hypothetical referendums freely vary (breeding method and biofuel production), only the importance of these attributes can be analyzed using a choice model (see the econometric methods section below). In order to gather information on other policy attributes, respondents were asked to indicate how important each policy attribute was when deciding on

their vote choice using a five-point Likert-type item (with options *not at all important*, *not important*, *neutral*, *important*, and *very important*).

Policy attribute levels associated with each policy for each province are listed in Table 1. Policy attribute levels associated with each policy for each province are listed in Table 1. Given the simple design where, in essence, only two policy attributes (one with three levels and one with two levels) varied with other attributes correlated with the combination of the two, a full factorial design was employed, meaning that each respondent was presented with all of the possible combinations of the two varying attributes (N=6). These referendum scenarios were presented to each respondent in a randomized order to reduce the potential for ordering effects.

A hypothetical referendum approach was chosen as it has been found to be an accurate predictor of real referendum outcomes (Vossler et al. 2003), and is considered to be incentive compatible³ (Carson & Grooves 2007). However, there are potential issues with the hypothetical referendum approach. Hypothetical means of measuring choices may lead to biased responses. To investigate the robustness of voting results, additional questions were included. After each referendum question, respondents were asked to rate how certain they were of their vote on a four-point Likert scale (*very uncertain*, *somewhat uncertain*, *somewhat certain*, and *very certain*). Past studies have found that those who are *very certain* often provide realistic results, while other responses are less reliable (Blumenschein et al. 1998; Ready et al. 2010).

Questionnaire Administration

The questionnaire was administered online to members of an internet panel maintained by Ipsos Canada, a market research firm. The goal was to obtain a representative sample of the Alberta, British Columbia, Manitoba, and Saskatchewan populations. Using an online format

³ If it is in a respondent's best interest to respond to a mechanism truthfully, the mechanism is incentive compatible.

allowed for: color graphics in the information and hypothetical referendum sections; randomized orders of hypothetical referendum questions; and hyperlinks to information and definitions to aid in answering choice questions. The internet panel maintained by Ipsos Canada consists of over 200,000 members, representative of the Canadian population based on demographic information. Participants were recruited with quotas on age, gender, and municipality population to increase each province's sample representativeness of its population demographics. To decrease sampling bias within the panel, respondents were provided with an incentive from Ipsos Canada, and were not informed of the study topic when invited to participate. Internet surveys may face issues of sampling bias, as internet access is a requirement. However, an increasing proportion of Canadians are accessing the internet at home over time. In 2012, 83% of Canadians had internet access, an increase from 79% in 2010 (Statistics Canada 2013).

Econometric Methods

Economic theory posits that individuals seek to maximize utility, and will therefore choose the policy that makes them best off. Equation 1 represents the binary choice model for respondent n evaluating choice m . With a binary dependent variable, where the observed choice $C_{nm} = 1$ implies a vote in favor of a proposed policy, and $C_{nm} = 0$ implies a vote for the current policy, U_{nm} then denotes the latent utility associated with voting in favor of a proposed policy over the current policy.

$$U_{nm} = \alpha + \beta'X_n + \gamma'P_m + v_{nm}, \quad (1)$$

where $C_{nm} = 1$ if $U_{nm} > 0$, and $C_{nm} = 0$ otherwise.

In equation 1, X_n is a vector of respondent-specific characteristics, P_m is a vector of policy-specific variables, α , β , and γ are estimated coefficients, and v_{nm} is a mean-zero, normally distributed error term. C_{nm} is the observed vote choice of respondent n evaluating vote

m , and is expected to equal one if U_{nm} is positive, and zero otherwise. That is, it is predicted that a respondent will vote in favor of a new policy if the act grants them positive utility, and will vote in favor of the current policy if a vote for the new policy grants negative utility.

Equation 1 is estimated using a binary probit model. Since there are six responses per respondent, it is expected that error terms of the responses for each person will be correlated. To address this issue, a robust cluster-corrected Huber-White sandwich estimator is employed (Huber 1967; White 1980), which allows for v_{nm} to be correlated for each cluster n , but assumes each cluster of error terms are uncorrelated with one another.

Results & Discussion

Sample and population demographics are outlined in Table 2. Sample sizes vary by province because of differing population sizes and according to the ability of Ipsos to secure participants while maintaining representativeness with respect to age, gender and location/population centre. Females were slightly over-sampled relative to males in all provinces. In AB and BC, large cities (population greater than 100,000) were under-sampled, while small and medium cities were somewhat over-sampled. Samples and populations are very similar for MB and SK with respect to population centre sizes. In general, all samples have higher post-secondary education rates than their respective populations. However, it is likely that population education rates are slightly higher than listed, as the population data refers to all Canadian residents over 15 years of age, whereas our sample is based on individuals over 18 years of age. Most respondents took between 15 and 30 minutes to complete the survey, and one observation was dropped for completing the survey in what we judged to be too quickly (less than 10 minutes).

Percentages of respondents voting in favor of a new policy over the current policy are displayed in Figure 2. New policies that assure that 5% of a province's gasoline sales would be replaced by poplar-derived biofuels (*i.e. Trad + BF, Genome + BF, and GM + BF*) are favored by a majority of respondents in most provinces, with the one exception occurring in British Columbia for *GM + BF*. If biofuels are not included in a policy scenario, numbers drop significantly with approximately 25% to 45% of respondents voting for change. Differences between the policy scenarios within each province when no biofuels are included are 5% or less, implying that the public may be indifferent between the breeding technologies. However, when comparing policy situations that involve biofuel production, GM seems to be less preferred than other breeding methods, particularly in British Columbia. This result could imply that some who support biofuel production do not support GM technology use in forestry. When comparing the provinces, Albertans voted in favor of a new policy over the current policy most often, while British Columbians voted in favor of a new policy least often.

Voting results of respondents who were very certain of their choice are outlined in Figure 3. Analyzing very certain responses is typically done in stated-preference willingness-to-pay studies, as this practice is thought to correct for response bias arising from hypothetical nature of the question (Ready et al. 2010). Depending on the province and voting scenario, respondents were very certain of their voting choice 20-25% of the time. The generally low level of certainty may indicate that the public is not very engaged in understanding forest biotechnology and breeding⁴. However, this result may also be interpreted as evidence that the public is aware of the

⁴ When asked, 60% of respondents stated that they at least "somewhat understand" the three tree breeding methods being examined, while 42.5% stated they were at least "somewhat informed" about forest management.

uncertainty of the effects of new forest policies⁵. Voting trends of very certain respondents are quite similar to the pooled results in Figure 2, but are approximately 10% lower in most cases. The largest disparity between all and only very certain respondents is in the BC sample for all policy scenarios. Very certain respondents from all provinces are less accepting of new policies resulting in no poplar-derived biofuels relative to votes of all respondents. For the *Trad + BF* policy, the reduction in public approval for very certain responses is minimal for AB, MB, and SK, but the disparity grows for breeding methods involving higher degrees of human control.

Taking the results from Figures 2 and 3 into account, there seems to be substantial support for new forest policies over the current policy when biofuels are part of scenarios. Though these policies attract support from a majority of respondents, support levels become somewhat deflated when only taking *very certain* responses into account. Excluding less certain responses is often effective in reducing bias in responses due to the hypothetical nature of stated preference methods (Ready et al. 2012), so it is possible that the *very certain* results are a more accurate reading of preferences.

Results from two probit models, one using all responses and one only using *very certain* responses, are listed in Table 3. In both models, the observed dependent variable equals 1 if the respondent voted in favor of the new proposed policy, and 0 if the current policy was chosen. The models provide statistical tests to differentiate between vote totals presented in Figures 2 and 3, and also provide insights on how respondent-specific variables affect voting likelihoods. The third column for each model lists the marginal effect. For continuous variables, the marginal effect represents the change in likelihood of voting in favor of a new policy over the current for a

⁵ In a follow-up question to the referendum questions, 50% of respondents who voted in favor of the current policy at least once stated it was partly because they required more information about the policy to consider voting for it.

one-unit change in the explanatory variable. Binary provincial and policy variables are effect-coded to ease with interpretation, so the marginal effect reflects the change in likelihood of voting in favor of a new policy for a province or policy relative to the average likelihood of voting in favor of a new policy. Explained variance (pseudo- R^2) doubles when excluding responses that are not very certain, though only 24% of responses and 45% of respondents are represented in this model. The percent of correct predictions also improves in the *very certain* model, up to 68% from 61%.

In the *all responses* model, policy scenario variables play a large role in predicting the probability of voting in favor of a new policy over the current policy, while demographic characteristics play a smaller role. Relative to the base policy scenario (*Trad no BF*), all other new policies were more preferable at or above the 95% confidence level. Adding biofuel production to the traditional breeding policy increases the likelihood of a respondent voting in favor of a new policy over the status-quo by 27%. This increased likelihood of public support decreases as more human control is involved in tree breeding, where a respondent is 25% more likely to vote for *genome + BF* and 19% more likely to vote for policy *GM + BF* in comparison to *trad + BF*. A respondent is 4% more likely to vote for either *genome no BF* or *GM no BF* compared to the *trad no BF* policy. For the model including only *very certain* responses, there is no significant difference between policies that do not include poplar-derived biofuels. The likelihood of accepting a new policy with poplar-derived biofuels relative to policy scenario *Trad no BF* is slightly higher than in the first model for policies *Trad + BF* and *Genome + BF* (32% and 27%, respectively). The *GM + BF* policy is 16.5% more likely to be chosen in comparison to *Trad no BF*, which is a smaller magnitude than in the *all responses* model.

The general lack of significant differences between *no BF* policy scenarios may be due to tradeoffs associated with policies. . It is assumed that the increased risk and uncertainty of applying biotechnology applications are inherently represented by the breeding method and seed source (worldwide) attributes. However, these risks were also packaged with increased benefits. Thus, it seems that members of the public are weighing the increased risks and benefits of proposed policies relative to the current policy, and evaluating how these factors affect their utility when choosing their preferred policy.

Wald tests were used to test the effect of using poplars as a biofuel source on policy preferences. For each model, tests were conducted with the null hypothesis that the coefficients for the *no BF* and *+ BF* policies for each breeding method are equal (e.g. equality between *Genome no BF* and *Genome + BF* coefficients). In every test, the null hypothesis was rejected at the 99% confidence level, implying that the use of poplars as a biofuel source significantly increases public preference for the application of forest biotechnology on public lands. That is, biotechnology is perceived as being more palatable if combined with an environmental benefit. Other studies have similarly shown that preferences or willingness to pay for non-food products increase in light of environmental benefits or reduced carbon footprints (Michaud et al. 2013), or that GM food products are valued more highly in light of benefits offered to the consumer (Lusk et al. 2005). Hajjar et al. (2014) also found similar results, as members of the BC and AB publics indicated they would be more willing to support forest biotechnology applications on public land if they resulted in additional benefits to society, the environment, or industry.

Males are 2.8% more likely to vote for any new forest policy over the current policy, while an additional year of age is associated with a -0.2% change in likelihood of voting for a new policy. British Columbians are 8% less likely to vote for a new policy than Manitobans,

while Albertans are 5% more likely. Last, respondents living in centres with populations under 10,000 and from 10,000-100,000 are 4% less likely and 3% more likely, respectively, to vote for a new policy relative to those living in centres with populations greater than 100,000. In the *very certain* model, all coefficients for respondent-specific variables are of a greater magnitude than in the *all responses* model. Males are 11% more likely to vote for a new policy over the status-quo relative to females. An additional year of age is associated with a 0.3% decrease in the likelihood of voting for a new policy. British Columbians are 14% less likely to vote for a new policy over the current policy relative to Manitobans, and respondents living in population centres under 10,000 are 8% less likely to vote for a new policy in comparison to those living in large urban centres.

Respondent-specific characteristics generally exhibit low-magnitude or insignificant relationships with acceptance of forest policies that include biotechnology applications. This is not surprising, based on the lack of significant results found by Hajjar et al. (2014) and generally inconsistent findings in GM food studies (e.g. Costa-Font et al. 2008). It seems that underlying attitudes and values are better predictors of preferences than demographic characteristics (Costa-Font et al.), which likely explains differences in demographic effects between different samples and contexts. The finding that males are more likely to support forest biotechnology than females is supported in some research (Hajjar et al, 2014; Costa-Font et al. 2008), although this relationship is of low magnitude in the *all responses* model and moderate in the *very certain* model. This relationship is perhaps partly explained by lesser perceptions of risk among males (McFarlane 2005; Costa-Font et al. 2008). While older individuals often have lower perceptions of risks (McFarlane 2005), the negative coefficient on age could be driven by lesser support for biofuels, as Susaeta et al. (2010) found older respondents were less likely to purchase biofuels.

However, this effect is of a low magnitude. Assuming a constant marginal effect of age on the likelihood of voting for a new policy, there is only a 6% difference between a 20 year old and 50 year old in the *all responses* model, and a 9% difference in the *very certain* model. The finding that respondents living in small centres (under 10,000) or rural areas are less likely to vote for change contradicts the findings of Hajjar et al. (2014); however, this result may be explained by differences in how the data was segmented by population. Education is insignificant in influencing forest policy acceptance, which is supported by Hajjar et al. (2014), but not MacFarlane (2005) and numerous GM food studies (Costa-Font et al. 2008). However, these differences in education level influences are likely explained by differences in context. McFarlane's study examined perceptions of risk to forest biodiversity with minimal focus on biotechnology, while GM food studies involve respondent considerations private health effects.

A number of reasons could lie behind the provincial differences in voting behaviour. Forest composition and the economic contribution of the forest industry is quite different across the provinces. For instance, the BC forest industry harvests more than 3 times the timber volume than AB in a typical year, and more than 10 times the volume harvested by SK or MB (Natural Resources Canada 2009). These differences are reflected, to some degree, in the differing questionnaires provided in each province, and are therefore part of the estimated policy impacts that rely on current situations in each province. To investigate these provincial differences, Table 4 lists mean ratings of the importance of forest policy attributes on a 5-point scale (1 = *not at all important*, 5 = *very important*) by province. Differences in importance ratings between provinces were tested using Kruskal-Wallis tests (Kruskal & Wallis 1952). Significant differences were found between provinces in importance ratings for breeding method, seed source, and the policy's impact on land-use change (increase in non-harvested area). More specifically, BC

residents, who were least likely to vote in favor of change, placed a significantly higher emphasis on seed source and breeding method, while Albertans, who were most likely to vote in favour of change, placed a significantly higher emphasis on changes to land-use.

Conclusions

This study examined public opinion of using poplars developed via genomics-assisted breeding to be used as biofuel feedstock in British Columbia, Alberta, Saskatchewan and Manitoba. Six new policy scenarios for each province were presented to respondents that considered the use of three different breeding methods (traditional selective breeding, genomics-assisted breeding, and GM), each with and without poplars being used for biofuels. We employ a choice experiment to provide alternative outcomes to policy scenarios and to investigate differences among characteristics of respondents. All proposed policy scenarios allowed worldwide seed selection for poplars in each province on public land. Respondents were asked to vote in a series of hypothetical referendums between each potential new policy and the current policy, based on changes to forest land-use, breeding method, impact on industry, and impact on carbon emissions.

Overall, there is substantial support (i.e. larger than a majority of respondents) for allowing genetically improved poplars on public land if fibre is used to generate biofuels. This support drops to approximately 25-45% of respondents if biofuels are not part of the scenario. These drops in support are even more substantial if we only consider that part of the sample that is *very certain* about their answers. In contrast, the various types of breeding technology do not matter as much regarding public acceptance. Estimates from the probit models support these general results. When all responses are considered, adding biofuels to a policy scenario increases the likelihood of acceptance by 19 - 27%, with amounts increasing as the level of breeding

technology decreases. If only the *very certain* results are considered, all of the proposed policies with biofuels are preferred relative to those with no biofuels, though there is no significant variation in the acceptance of different breeding technologies if biofuel production is not a component of the policy. Similar to the entire sample results, adding poplar-based biofuel production to a policy scenario increases the likelihood of acceptance by 16.5-32%, again, with amounts increasing as the level of breeding technology decreases. Thus, the use of poplar as a biofuel source increases the likelihood of the Canadian public choosing scenarios that allow the application of new breeding technologies, such as genomics or GM, on public land.

Responses are different for segments of the population, but these differences do not greatly influence choices. Attributes that increase the probability of acceptance are: being a male, being from Alberta, and being from a population centre of 10,000-100,000 people (relative to centers > 100,000). Attributes that decrease the probability of acceptance are age, being from British Columbia, and being from a population centre of < 10,000 (relative to centers > 100,000). Differences between provinces may arise due to two key reasons. First, the composition and importance of the forest industry varies greatly across the western provinces. These differences also resulted in different hypothetical referendum scenarios being presented in each province. Second, the residents of each province placed different levels of importance on different policy attributes. Specifically, BC residents, who were most opposed to forest biotechnology applications on public land, placed the highest emphasis on seed source and breeding method. In contrast AB residents, who were most in favor of using biotechnology on public lands, thought that changes in land use were important aspects of policies.

Although results are somewhat similar between the all responses and very certain models, substantial ambiguity remains in understanding public approval of genomic-assisted breeding in

Canada. This ambiguity may arise due to the complexity involved with the variety of impacts associated with changing policies. Despite our approach, which indicate specific attributes of policy changes, there may be an underlying lack of understanding of what a forest policy allowing genomic-assisted breeding on public land might look like, due to the variety of other policy attributes and forestry practices that must change to allow genomic breeding programs. Nonetheless, our results indicate that the public is highly responsive to policy outcomes, whether good or bad, so gaining a better understanding of how applications of genomics in forestry may impact society should allow for more clarity in understanding public preferences.

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Table 1. Outline of hypothetical referendum policy attributes for different forest biotechnology policy and management approaches for each province.

Prov.	Policy	Policy Attribute Levels			
		Commercial Forest Land-Use (%)		Impact on Industry	Carbon Emission Reduction (Cars per year)
		Non-Harvested	Improved Poplar		
AB	Current	40%	<0.1%		
	Trad no BF	46%	3%	Small	
	Trad + BF	46%	3%	Small	120,000
	Genome no BF	48%	3%	Moderate	
	Genome + BF	48%	3%	Moderate	120,000
	GM no BF	49%	3%	Strong	
	GM + BF	49%	3%	Strong	120,000
BC	Current	40%	<0.1%		
	Trad no BF	42%	1%	Little to no	
	Trad + BF	42%	1%	Little to no	90,000
	Genome no BF	43%	1%	Small	
	Genome + BF	43%	1%	Small	90,000
	GM no BF	43%	1%	Moderate	
	GM + BF	43%	1%	Moderate	90,000
MB	Current	60%	<0.1%		
	Trad no BF	63%	2%	Small	
	Trad + BF	63%	2%	Small	30,000
	Genome no BF	64%	2%	Moderate	
	Genome + BF	64%	2%	Moderate	30,000
	GM no BF	65%	2%	Strong	
	GM + BF	65%	2%	Strong	30,000
SK	Current	40%	<0.1%		
	Trad no BF	46%	3%	Small	
	Trad + BF	46%	3%	Small	50,000
	Genome no BF	48%	3%	Moderate	
	Genome + BF	48%	3%	Moderate	50,000
	GM no BF	49%	3%	Strong	
	GM + BF	49%	3%	Strong	50,000

Table 2 – Comparison of socio-demographic characteristics between the 2014 sample used for this study (N) and 2011 Canada census data (pop.) for Alberta, British Columbia, Manitoba, and Saskatchewan.

Characteristic	Province							
	AB		BC		MB		SK	
	N	Pop.	N	Pop.	N	Pop.	N	Pop.
Number of Respondents	1205	-	1248	-	502	-	500	-
Male (%)	42	51	44	49	42	49	40	50
Average Age (18+)	48	45	49	48	50	47	50	47
<i>Population of Centre of Residence (%)</i>								
> 100,000	57	68	51	68	58	60	49	46
10,000 – 100,000	22	13	31	19	13	8	16	20
< 10,000	21	18	18	12	29	32	35	34
Post-Secondary Education Attained (%)	67	55	61	56	60	47	59	47

Education data from Statistics Canada (2012b); all other data from Statistics Canada (2012a).

Table 3 – Coefficient, standard error (SE) and marginal effect (ME) estimates from binary probit models explaining the importance of factors affecting hypothetical forest policy referendum votes.

Variable	All Responses			Very Certain Responses		
	Coef.	SE	ME	Coef.	SE	ME
Male	0.071*	0.032	0.028*	0.288*	0.070	0.107*
Age	-0.005*	0.001	-0.002*	-0.009*	0.002	-0.003*
Post-Sec. Education	-0.036	0.033	-0.014	-0.037	0.074	-0.014
AB	0.126*	0.052	0.051*	0.108	0.113	0.040
BC	-0.209	0.052	-0.083*	-0.383*	0.112	-0.138*
SK	0.085	0.062	0.034	0.097	0.136	0.036
<i>Population:</i>						
<10,000	-0.096*	0.040	-0.038*	-0.214*	0.089	-0.077*
10,000-100,000	0.084	0.041	0.034*	0.038	0.089	-0.014
<i>Policy Scenarios:</i>						
<i>Trad no BF (excluded)</i>						
<i>Trad + BF</i>	0.708*	0.025	0.274*	0.832*	0.051	0.321*
<i>Genome no BF</i>	0.099*	0.021	0.040*	-0.003	0.047	-0.001
<i>Genome + BF</i>	0.652*	0.025	0.253*	0.699*	0.052	0.270*
<i>GM no BF</i>	0.110*	0.023	0.044*	-0.040	0.050	-0.015
<i>GM + BF</i>	0.488*	0.026	0.192*	0.430*	0.053	0.165*
Constant	0.155*	0.078	-	-0.172	0.170	-
McFadden's R ²		0.049			0.098	
Votes		20730			4927	
(Respondents)		(3455)			(1561)	
Log-Pseudo-Likelihood		-13626.725			-2906.0523	
% Correct Predictions		61			68	

* Denotes significance at or above the 95% confidence level.

Table 4 – Importance of policy attributes when voting by province.

Policy Attribute	Mean Importance ¹			
	Province			
	AB	BC	MB	SK
Breeding Method*	3.85	4.01	3.91	3.84
Seed Source (location)*	3.92	4.01	3.91	3.95
Land-Use Change*	3.88	3.78	3.84	3.78
Carbon Emissions (biofuels)	3.94	3.88	3.89	3.90
Impact on Industry	3.60	3.63	3.66	3.67

¹ For each policy attribute, respondents were asked, “For each factor listed, please tell us how important it was in influencing your decisions of which policy to vote for (1 being *not at all important* and 5 being *very important*)”.

* Indicates significant difference found between provinces above the 95% confidence level as determined by Kruskal-Wallis test.

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Policy and Management Features	Current Policy and Management Approaches	New Policy and Management Approaches
"Improved" Poplars On Commercial Public Forest Land in Alberta Region where parent trees are located	Parent trees come from the same region as regenerated trees	Parent trees can come from any location
Breeding method	Traditional breeding using observed traits	Breeding assisted by genetic information (DNA markers)
How <u>commercial public forest</u> land in Alberta is used	<p>Non-Harvested (40%) Harvested Coniferous Trees (40%) Harvested Natural Poplars (20%) Harvested "Improved" Poplars (less than 0.1%)</p>	<p>Non-Harvested (48%) Harvested Coniferous Trees (40%) Harvested Natural Poplars (9%) Harvested "Improved" Poplars (3%)</p>
Impact on forest industry in Alberta (jobs and income)	No change	Moderate positive impact
Reduction in carbon emissions in Alberta from using poplar biofuels	None	Equivalent to 120,000 cars off the road per year in Alberta

Above each table, respondents were asked, "Consider the two scenarios below. Would you vote for the current situation or the new policy option if you were voting in a provincial referendum?"

Figure 1 – Example of a hypothetical referendum question (*Genome + BF* scenario) used to measure public preferences for using different Poplar breeding technologies for use on public land.

Figure 2 – Percentages of all respondents voting in favor of forest policies involving different breeding methods (traditional, genomic-assisted, and genetic modification) and biofuel (BF) production over the current provincial policy situation in Alberta, British Columbia, Manitoba, and Saskatchewan.

Figure 3 - Percentages of respondents who indicated they were *very certain* of their response voting in favor of forest policies involving different breeding methods (traditional, genomic-assisted, and genetic modification) and biofuel (BF) production over the current provincial policy situation in Alberta, British Columbia, Manitoba, and Saskatchewan.