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Heterogeneity in Attitudes Underlying Preferences for Genomic Technology Producing Hybrid Poplars on Public Land

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1 **Title:**

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3 **Heterogeneity in Attitudes Underlying Preferences for Genomic Technology**
4 **Producing Hybrid Poplars on Public Land**

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Abstract

We investigate the public preference heterogeneity of planting genetically improved poplar tree on public land for biofuel production in Western Canada. Using a sample of the public from British Columbia, Alberta, Saskatchewan, and Manitoba, respondents were asked to vote in a series of hypothetical referenda comparing the new proposed forest policies to the current policy (base scenario). Proposed policies varied based on poplar breeding method (traditional, genomics, or genetic modification) and whether poplars may be used for biofuel production. A respondents' segmentation framework with cluster analysis and probit model was applied to data of respondents to uncover the heterogeneity of public's perception. The results of this study reveal that positive and negative perceptions about planting genetically improved poplar tree in the region create a division of respondents of environmentalists, knowledgeable, challengers and supporters. British Columbians and Manitobans are identified as environmentalists and challengers, respectively, of the new policy of planting genetically improved poplar trees on public land. Conversely, Saskatchewanians and Albertans are identified as supporters and knowledgeable, respectively, of the new policy.

Key words: Genomic Technology, Preferences Heterogeneity, Hybrid Poplars, Cluster Analysis, Probit Model

46 Introduction

47 The forest industry is important to Canada making significant contributions to
48 regional development, job creation, community stability and foreign exchange.
49 Accordingly, governments have developed and implemented forest policies to enhance
50 public welfare ([Tindall et al. 2013](#)). In recent years, however, the Canadian forest
51 industry has experienced decline. This decline has been a result of many structural
52 changes in world markets. For example, the world timber production is now using
53 exotic trees which grow faster and significantly increase profitability (see [Payn et al.](#)
54 [2015](#); [Carpenter et al. 2004](#))²; but Canada's forest industry is not following this trend.
55 Moreover, the rise of electronic media has decreased the demand for paper by the
56 communication industry. These factors have contributed to the decline in the forest
57 sector; because paper production has been an important driver of the Canadian forest
58 industry. To combat the forestry sector, decline the government is trying to transform
59 the sector by encouraging the development and production of new forest products. One
60 of the new products being considered is the production of cellulosic biofuel from trees.
61 This could involve planting genetically improved poplar trees on public land to produce
62 biofuel ([Natural Resources Canada, 2014](#)).

63 Several constraints impede planting genetically improved poplar trees on public
64 land in western Canada. The most important is that most provincial policies about
65 public land management require that forest regeneration needs replanting native trees
66 which are to be produced from the collection of seeds harvested from parent trees

² [Payn et al. \(2015\)](#) show that the Canadian annualized rate of change in planted forest area has decreased from 3.6% in 2010 to 2.5% in 2015. Similarly, [Haldane and Lyon \(2015\)](#) suggests that air pollution (mainly acid rain) and global warming significantly decline the amount of timber production, and thereby reduce the contribution of forest sector to the Canadian economy.

67 growing locally. In British Columbia, Alberta, Saskatchewan, and Manitoba harvesting
68 seeds and planting them on public land is rigorously controlled; provincial criteria only
69 authorize the use of native species in which seeds are chosen from neighbouring areas
70 ([Johnston et al. 2012](#); [Natural Resources Canada, 2012](#))³. While it is possible to plant
71 non-native trees on private land, many economic and social factors deter the
72 development of plantations of non-native trees on private land. Perhaps the most
73 important factor is that private lands are costlier to acquire and manage than public
74 lands in Canada, making exotic tree plantations on private lands financially infeasible
75 ([Anderson et al. 2007](#)).

76 Reforming policies that prohibit planting of exotic trees on public forest lands to
77 give feedstock for biofuels may enhance the profitability of Canada's forest sector.
78 Such reformation would need an understanding of the degree of public support for the
79 public land policy change as well as support for the development of the biofuel
80 industry. However, extant empirical studies which aim at measuring public preferences
81 for the application of biotechnology in forestry give mixed findings. Some of the
82 studies show that citizens are *against* the use of technology; while others uncover
83 support or neutrality. [Kazana et al. \(2016\)](#) show that the advocates of the applications of
84 biotechnology in forestry argue that this technology has various benefits; such as it
85 increases forest tree productivity through, for example, accelerating tree growth, it
86 restores contaminated soils, and it lowers the demand of pesticides. The authors also
87 reveal that opponents of the application of biotechnology in forestry argue that this
88 technology has various risks to the forest sector; for example, it potentially reduces

³ [Rayner et al. \(2013\)](#) state that Canadian provinces extensively control and regulate forestry activities, derive substantial direct and indirect revenues from these activities.

89 biodiversity though gene flow between transgenic and wild trees, it generates adverse
90 effects on biotrophic processes of host ecosystems, and it foments the costs of
91 controlling pest eruptions and force cultural adaptation to changing biodiversity
92 conditions due to transgene escape.

93 Further, [Lucht \(2015\)](#) argues that environmental NGOs promote protests about
94 genetically modified products, particularly GM foods, by sending “gene detectives”
95 into supermarkets to look for GM labels, and then put strong pressure on shops to
96 immediately remove these legal, authorized and correctly labeled products. Similarly,
97 [Kaiser \(2001\)](#) shows that protests over the use of forest biotechnology have served to
98 motivate individuals to destroy experimental tree plots and even laboratories involved
99 in genetic research relating to forest industries.

100 Several existing studies argue that *inter alia* knowledge, gender, presence of
101 various information sources, perceived benefits and risks, and trust in government and
102 scientists are major determinants of preferences towards biotechnology. These factors
103 positively or negatively affect the acceptance of biotechnology and resultant products
104 and commodities. Moreover, lack of genuine information about genetically modified
105 products reduces the acceptance of these products even though they may bring potential
106 environmental and economic benefits. Lucht, 2015; [Wieczorek, 2003](#) shows that
107 environmentalists portray biotechnology as having negative impacts on animal and
108 human health, and on the environment⁴. Similarly, [Marques et al. \(2015\)](#) and [Gaskell et](#)
109 [al. \(2010\)](#) find that public acceptance of biotechnology is significantly dependent on

⁴ An environmentalist is an advocate of the goals of the environmental movement. This movement generally embraces political and ethical motives that seek to improve and protect the quality of the natural environment through changes to environmentally harmful human activities ([Tesch and Kempton, 2004](#)).

110 their perceptions of risks and benefits, moral and ethical views of genetically modified
111 foods. Therefore, understanding interests and concerns of different segments of the
112 public, and the underlying factors that drive them to support or oppose biotechnology,
113 is important to make good decisions for the application of the technology in forestry⁵.

114 **Prior Literature Review**

115 While many studies examine public preferences towards the application of
116 biotechnology in food and health (e.g. [Costa-Font et al. 2009](#); [Pin and Gutteling, 2009](#)),
117 few have been conducted that measure preferences for applications of biotechnology in
118 forestry. This gap likely emanates from the novelty of applying biotechnology in
119 forestry. Moreover, forestry has less direct links with the public compared to food and
120 medicines.⁶ However, [Tait \(2007\)](#) suggests that the public perceives relatively lower
121 levels of risk of applying genetic modification technologies in forestry and food than
122 other ecological risks.

123 Existing empirical studies show many factors affecting the acceptance of
124 biotechnology. For example, [Lucht \(2015\)](#) claims that perception of risks and benefits,
125 knowledge and trust, and personal values significantly influence individuals'
126 acceptance of GM products. Similarly, [Kazana et al. 2105](#); [Aleksejeva, 2014](#) show that
127 the acceptance of biotechnology is higher from individuals who have higher knowledge
128 about biotechnology than those who have lower knowledge of biotechnology. Further,

⁵ [Jessica and Cheng \(2011\)](#) argue that understanding public value orientations, attitudes and preferences towards national forests is of critical importance for the development and implementation of effective forest policies.

⁶ [Rollins et al. \(2015\)](#) argue that individuals are more concerned about the application of genetic modification in food or health due to the presence of private health concerns associated with food or medicine purchase decisions, as the products are to be ingested by humans.

129 based on a large survey of individuals, [Zechendorf \(1994\)](#) documents that knowledge
130 about genetic modification increases the acceptance of biotechnology.

131 The work of [Wunderlich and Gatto \(2015\)](#) show that perceptions of risk, lack of
132 trust in government, scientists, and confidence in controlling organisations may reduce
133 the level of acceptance of biotechnology. [Heller, 2003](#); [Sanderson et al. 2003](#) suggest
134 that general attitudes, and ethical and environmental concerns towards science and
135 technology have significant impacts on accepting genetic modification. They also find
136 that ecocentric individuals argue that genetically modified trees are not environmentally
137 friendly and have long run negative environmental impacts. [Barrows et al. \(2014\)](#)
138 individuals have positive attitudes about the applications of biotechnology in the
139 agricultural sector claiming that agricultural biotechnology reduces uncertainty and
140 breeding time and to transfer traits from more distantly related plants. [Gamble et al.](#)
141 [\(2008\)](#) show that there is significant variation among males and females in accepting
142 genetically modified products in which females have less preference for these products.

143 Many studies try to categorise individuals based on their reactions to genetically
144 modified products. [Heller \(2003\)](#) finds three clusters of individuals based on their
145 attitudes towards genetically modified foods from a national survey in the UK. These
146 are: (1) Implacably opposed to biotechnology; (2) Somewhat opposed to biotechnology
147 and (3) No fixed position on genetic engineering. Similarly, [Bredahl \(1999\)](#) finds that
148 consumers' reaction to genetic modification fell into three categories labelled as
149 refusers, undecideds, and triers. [Voss et al. \(2009\)](#) categorised farmers into five clusters
150 based on their preferences for growing genetically improved oil-seed canola in

151 Germany as supporters, economic skeptics, environmentally and socially influenced,
152 die-hards and strongly opposed.

153 A large survey conducted in the U.S. empirically clustered respondents into
154 three groups based on their attitudes towards biotechnology. These are: (1) Supporters -
155 those who feel that biotechnology is useful, not risky, and acceptable; (2) Risk tolerant
156 supporters - those who argue that biotechnology is useful but risky, and morally
157 acceptable; and (3) Opponents - those who claim that biotechnology is risky and
158 unacceptable. Similarly, a result of a large European survey identified four groups of
159 individuals based on perceived risks of biotechnology on human health and
160 environment as: trade-off respondents who saw risks and benefits from genetic
161 modification; relaxed respondents who saw benefits and no risks; skeptical respondents
162 who saw risks and no benefits; and uninterested respondents who saw neither risks nor
163 benefits ([Gaskell et al., 2009](#)).

164 There are few studies that systematically measure public preferences for
165 applying biotechnology in forestry (see e.g. Kazana, V et al. 2016; Tsourgiannis et al
166 2016). More specifically, the literature is almost silent about the preference
167 heterogeneity of individuals about the applications of biotechnology in forestry which
168 aim at biofuel production. To this end, our analysis tries to fill the gap in the literature
169 by examining public preferences heterogeneity for planting genetically modified poplar
170 trees on public land for biofuel production in western Canada. Our analysis also gives
171 important understandings of measuring public preferences for the applications of
172 biotechnology in forestry for policy-makers working in provincial and federal
173 governments.

174

175 **Questionnaire Design**

176 Public acceptance information was gathered using a questionnaire administered
177 to internet panels of randomly sampled citizens in the four western provinces of
178 Canada. The development of the questionnaire included many stages of consultation
179 with scientific experts (such as geneticists, botanists and forest scientists), and
180 individuals from the public. Four focus groups were held to assess lay public levels of
181 understanding of forest management and biofuels and to give feedback on early drafts
182 of the hypothetical referendum question formats. These formats outlined attributes and
183 impacts of various policy options compared with the current public land policy
184 involving replanting of trees. Participants for all public focus groups were recruited by
185 telephone using random digit dialing by Advanis Inc. (an Edmonton-based market
186 research firm). Two focus groups each were held in Edmonton, Alberta (16
187 participants), and in Grande Prairie, Alberta (17 participants) to further assess the
188 public's understanding of the forest and biofuel topic. Next, a survey was sent to a
189 group of forestry experts to gather data on predicted changes in poplar growth rate and
190 value arising from different breeding methods. Draft scenarios for hypothetical
191 referendums were developed based on the expert estimates of increases in growth and
192 value of poplars using different breeding methods. A discussion was then held with a
193 group of experts involved with POPCAN⁷ to ensure that the information provided in the
194 questionnaire was accurate. Following further reviews, a final round of public focus

⁷ POPCAN is a project which aims to harness genomic information to enhance the appropriateness of poplars as a cellulosic biofuel feedstock ([Genome British Columbia, 2014](https://www.genome.ca/press-releases-and-news/2014/04/23/poplar-genome/)).

195 groups was held, with two groups in Edmonton, Alberta (24 participants), and two
196 groups in North Battleford, Saskatchewan (22 participants). This round of focus groups
197 aimed to ensure that all elements of the questionnaire were understood by respondents
198 and to reduce potential sources of bias.

199 After completing these stages, a pretest version was administered online to 102
200 respondents (51 Albertans, and 51 British Columbians) of an internet panel maintained
201 by Ipsos Canada, a market research firm. The final questionnaire gave a brief
202 explanation about biofuels, various tree breeding methods, and information about the
203 prevailing forest composition, industry, and policy in each of the four provinces. This
204 was followed by a series of hypothetical referendum questions which were framed as a
205 binary choice in terms of a vote for the current policy about public land reforestation
206 and current tree breeding methods or a vote for a new policy option which allowed the
207 planting of exotic trees on public land using more sophisticated breeding technologies.
208 The referenda were followed with some follow-up questions and the collection of
209 demographic information.

210 The hypothetical referenda involved six proposed policy alternatives, each of
211 which was driven by two main attributes which were the tree breeding method
212 employed, and whether poplars would be used for biofuel production. The breeding
213 method was based on three tree breeding methods: traditional selective breeding,
214 genomics-assisted breeding, and genetic modification. The three breeding methods
215 appeared with and without a biofuel production attribute i.e. traditional breeding with
216 and without biofuel, genomics-assisted breeding with and without biofuel and genetic
217 modification with and without biofuel production. Each respondent was given a chance

218 to vote between the current policy (i.e. traditional breeding without biofuel production)
219 and the new proposed policy.

220 An example referendum question is shown in *Figure 1*. In each policy
221 alternative, participants were given information about the location of parent trees,
222 breeding methods, how commercial public land in their province is used, impact on the
223 forest industry and the estimated amount of carbon emission reduction from using
224 poplar derived biofuels in their province. The respondents were also given colored
225 graphical and hyperlink information that provided definitions of each tree breeding
226 method. In the base scenario, parent trees would come from the same region as
227 replanted trees; trees would be bred using traditional breeding methods and there would
228 be no impact on jobs, income and carbon emission reduction. The new proposed
229 policies' parent trees could come from anywhere; they may have impacts on jobs,
230 income and carbon emission reductions in the province. Furthermore, assessments of
231 commercial public forest land-use were given that consisted of four elements: land with
232 non-harvested forest and land with harvested coniferous trees, natural poplars, and
233 improved poplars. There was a fixed (40%) harvested level of coniferous treed land in
234 the referendum for both current and the new proposed policies.

235 Current commercial forest land-use was calculated for each province using a
236 variety of sources, depending on data availability. British Columbia forest land-use was
237 calculated using a collection of 40 timber supply area analysis reports prepared by the
238 BC Ministry of Forest, Lands, and Natural Resource Operations (2014). Alberta forest
239 land-use was calculated using data from Alberta Environment and Sustainable Resource
240 Development (2013). For Saskatchewan and Manitoba, data was not easily available

241 from the provincial governments, so land-use was estimated based on information
242 released by forestry firms. For example, reports from Mistik Management Ltd. (2013)
243 and Tolko Industries Ltd. (2014) were used to calculate the current commercial forest
244 land-use in Saskatchewan and Manitoba respectively. Simulation results from [Anderson
et al. \(2012\)](#) were used to decide the expected changes in land-use due to allowing
246 different breeding methods and seed selection on public land. In all proposed policy
247 alternatives, equal annual-allowable-cut (AAC) was taken into consideration where the
248 same volume of timber would be harvested under each policy alternative. Technically,
249 higher tree growth rates might show a higher annual-allowable-cut (AAC) instead of
250 leaving some areas unharvested, but a constant AAC was assumed to avoid
251 confounding the area to be planted with genetically improved poplars using different
252 tree breeding methods.

253 Insert Figure 1

254 The Expert opinion on tree growth rates and economic impacts, forest industry
255 composition and current land-use in each province was combined with the results from
256 [Anderson et al. \(2012\)](#) to estimate the impact of allowing new tree breeding methods on
257 the forest industry, specifically on the levels of income and job opportunities. Based on
258 5% of Alberta's gasoline being replaced by poplar-derived biofuel, estimates of life-
259 cycle analysis carbon emission reduction of second-generation biofuels from [Schmer et
al. \(2008\)](#), and gasoline consumption data from Statistics Canada (2013) were used to
261 estimate potential reductions in carbon emissions per year by planting genetically
262 improved poplar trees on public land.

263 Questionnaire Administration

264 The questionnaire was administered online to members of a provincial internet
265 panels maintained by Ipsos Canada⁸. The main aim was to gain representative samples
266 of the BC, Alberta, Saskatchewan and Manitoba general populations⁹. Using an online
267 format allowed use of color graphics in the information and hypothetical referendum
268 sections. It also permitted randomised orders of hypothetical referendum questions, and
269 the provision of hyperlinks to information and definitions to help in answering
270 questions. The internet panels maintained by Ipsos Canada contained more than 200,
271 000 individuals, who are representative of the Canadian population based on
272 demographic information. Respondents were recruited with quotas on age, gender, and
273 municipality to increase the likelihood of each province's sample representativeness. To
274 minimise sampling bias within the panel, participants were given an incentive from
275 Ipsos Canada and they were not informed of the study topic when invited to
276 participate¹⁰. Internet based surveys may face sampling bias issues in the sense that
277 internet access is a requirement. However, internet accessibility is increasing through
278 time in all provinces of Canada. According to Statistics Canada (2013), 83% of
279 Canadians, who were above the age of 18, had internet access at their home, which was
280 greater than the level in 2010 (79%).

281 Cluster Analysis

282 Following the work of Schiopu (2010), we clustered respondents using a two-
283 step cluster analysis. The first step of this clustering procedure is pre-clustering

⁸ The data were collected in 2015.

¹⁰ The respondents could win valuable cash prizes or goods, while making their opinion known.

284 respondents into small sub-clusters. Then, the procedure categorises the sub-clusters
285 into the optimal number of clusters based on similarities of the underlying variables,
286 which were, attitudinal variables in this study. This two-step clustering procedure has
287 various advantages over other traditional clustering algorithms such as K-means, K-
288 median and Hierarchical techniques where all of them involve researcher selected
289 determination of the number of clusters. Some of the advantages of the two-step
290 clustering are: (1) it can create clusters based on both categorical and continuous
291 variables; (2) it selects the number of clusters automatically without any human
292 intervention that might create bias in the number of clusters; and (3) it is able to handle
293 and analyse large datasets efficiently. We used SPSS version 24.0 to generate distinct
294 clusters of respondents.¹¹

295 For clustering variables, we used a series of measures from respondents. These
296 included: attitudes towards science and research; New Ecological Paradigm (NEP)
297 scores;¹² measures of trust in federal and provincial governments, in scientists, the
298 forest industry, and in environmental non-government organizations (ENGOS); and
299 measures of knowledge of forest operations and biotechnology. Each clustering
300 variable had a variable number of items. For example, respondents' attitude towards
301 science and research were measured using a 7-item Likert scale developed by Bauer et
302 al. (2000). (see Appendix 1¹³). Environmental values were measured by the 15-item

¹¹ SPSS software is highly efficient to conduct two-step clustering procedures (Bacher et al. 2004).

¹² Stern et al. (1995) conclude that the NEP scale measures generalised beliefs about the nature of human-environment interactions which include individuals' valuations and attitudes about specific environmental conditions.

¹³ Appendix 1 shows indicators of NEP and attitudes towards science and research. Other clustering factors' items are available from the senior author upon request.

303 New Ecological Paradigm scale (Dunlap et al. 2000). Trust in the federal government,
304 provincial government, industry, scientists, and environmental non-government
305 organizations were each measured using a four-item scale developed by Lang &
306 Hallman (2005). Knowledge of forests and forest management was measured by six
307 indicators compiled by McFarlane & Boxall (2000). Biotechnology knowledge was
308 measured using a scale of 10 items from the Eurobarometer 58.0 questionnaire (Gaskell
309 et al. 2003).

310 We applied statistical techniques such as factor analysis (FA), sum of scale
311 items and principal component analysis (PCA) to minimize the number (dimension) of
312 items which had strong *correlations* among them to reduce redundancy (duplication) of
313 items. However, PCA and FA have some limitations, as they can compress many scale
314 items to fewer items which in turn may cause loss of important information from the
315 original items as suggested by [Karamizadeh et al. \(2013\)](#). On the other hand, [Comrey et](#)
316 [al. \(1992\)](#) state that employing the sum of each item (summed scale) does not lose
317 potential information from the original items. Moreover, [Hair et al. \(2006\)](#) argue that
318 the summed scale is the simplest and desirable method of reducing items by preserving
319 the variation in the original data. It is also a well-accepted approach for most
320 exploratory analysis ([Tabachnick et al., 2001](#)). Hence, we used the sum of items of each
321 clustering factor in our analysis. The scales of clustering factors are normalised using
322 standardized scores as it is the default standardisation technique in SPSS two-step
323 clustering analysis (see [Bacher et al. 2004](#)).

324 **Other Statistical Methods Employed**

After generating distinct clusters of respondents, a probit model was applied to the referenda information associated with the respondents in each cluster to examine the likelihood of choosing a specific policy option relative to the current policy. Random utility theory proposes that individuals choose policy alternatives that yield the greatest utility compared to other policy alternatives. Therefore, the probability of choosing an alternative policy increases as the utility associated with them increases (Burton et al. 2001). Based on this argument, we applied a binary probit choice model for each cluster (see equation 1). With a binary outcome variable, where the observed choice $C_{nkm} = 1$ shows a vote by respondent n in cluster k in favour of a newly proposed policy alternative m , and $C_{nkm} = 0$ denotes a vote for the current policy. Equation 1 posits that U_{nkm} then implies the latent utility of respondent n in cluster k related to voting for the newly proposed forest policy m over the current policy:

$$U_{nkm} = a_k + \theta'_k P_m + v_{nm}. \quad (1)$$

Where; $C_{nkm} = 1$ if $U_{nkm} > 0$ and $C_{nkm} = 0$ otherwise. P_m is a vector of policy attributes associated with alternatives, a_k and θ'_k are estimated coefficients, and v_{nm} is mean-zero, and normally distributed error term. The parameters in equation (1) were estimated using a binary probit model for each cluster. Since there are multiple clusters of respondents and six votes per respondent, it is possible that the errors in each cluster can be correlated. To solve this issue, a robust cluster-corrected Huber–White sandwich estimator was applied which allows v_{nm} to be correlated within clusters, but not across clusters (Huber 1967; White 1980).

Findings and Discussion

Table 1 presents the comparison of sample and population demographics. Males were slightly under-sampled as compared to females in all provinces. In Alberta and British Columbia, cities with the population greater than 100,000 were under-sampled. However, cities with the population 10,000–100,000 and less than 10,000 were over-sampled. In Manitoba and Saskatchewan, samples and populations are very close in terms of population sizes of residences. In all provinces, samples have higher post-secondary education rates than their respective populations. However, it is more likely that the population education rates are slightly larger than listed as the population data refers to all Canadian residents over 15 years of age, while our sample is based on individuals over 18 years of age. Thus, it is not surprising that the sample has higher post-secondary education rates than the population. Most respondents took between 15 and 30 minutes to complete the survey.

Insert Table 1

The overall quality of our clustering procedure falls in the *good* range.¹⁴ Further, two-step clustering uses a silhouette algorithm to measure cluster *cohesion and separation* and shows how closely related the objects within each cluster, and how distinct a cluster is from other clusters. It also shows the average dissimilarity of an observation i with all other observations within the same cluster; where a smaller average value shows the better assignment of the observation to a given cluster. Let $a(i)$ be the average dissimilarity of observation i in one cluster and $c(i)$ be the lowest average dissimilarity of observation i to any other cluster, of which i is not a member.

¹⁴ The two-step clustering technique provides three ranges (poor, fair and good) to measure the overall quality of the clustering process.

368 The cluster with this lowest average dissimilarity is said to be the neighbouring cluster
 369 of i because it is the next best fit cluster for this observation. Hence, the silhouette of
 370 observation i , $s(i)$, can be defined as:

$$371 \quad s(i) = \frac{c(i) - a(i)}{\max\{a(i), c(i)\}}. \quad (2)$$

372 This can also be written as:

$$373 \quad s(i) = \begin{cases} 1 - a(i)/b(i), & \text{if } a(i) < c(i) \\ 0, & \text{if } a(i) = c(i) \\ c(i)/a(i) - 1, & \text{if } a(i) > c(i) \end{cases} \quad (3)$$

374 From equations (2) and (3), it is possible to conclude that $-1 \leq s(i) \leq 1$. When
 375 $s(i)$ is close to 1, observation i is well matched to a given cluster; which in turn shows
 376 that the clustering procedure was proper; and vice versa when $s(i)$ approaches -1
 377 (Kaufman et al. 2009). Hence, the quality of clustering process in this study falls in the
 378 *good* range (approaches to 1), as depicted in Figure 2. This shows that respondents
 379 within each cluster have closely similar patterns of characteristics, and those across
 380 clusters have different characteristics.

381 Insert Figure 2

382 We labelled each cluster based on characteristics of respondents in each cluster;
 383 this consisted of the mean values of the clustering factors (see Table 3) and the relative
 384 percentage of members voting for new policies (see Table 4). Members of cluster 1 are
 385 labelled as *Environmentalists* since they have the highest mean value for the New
 386 Ecological Paradigm scale which assesses a measure of environmentalism attitudes.
 387 Respondents in cluster 2 are labelled as *Knowledgeable* as they have the highest mean

388 values of knowledge of biotechnology. Those respondents in cluster 3 are labeled as
389 *Challengers* as they have the highest voting percentages of traditional breeding
390 compared to DNA breeding and genetic modification both with and without biofuel
391 production. Finally, members of cluster 4 are labelled as *Supporters* of the new policy
392 alternatives because they have the lowest voting percentage for the current policy-
393 traditional breeding methods.

394 In Table 2, we show the total number and percentage of respondents in each
395 cluster. For example, the *Environmentalists* cluster holds the highest and lowest
396 percentages of British Columbians and Saskatchewanians respectively. *Figure 3* shows
397 the importance of clustering factors in each cluster. *Environmentalists* show high
398 tendencies of trust in environmental non-governmental organisations (ENGOS).

399 Insert Table 2

400 This factor takes the highest share in the formation of *Environmentalists'* cluster. The
401 NEP score is the second most important element in the formation of *Environmentalists*
402 cluster. Other clustering factors including trust in scientists, forest industry and federal
403 and provincial governments have lower importance in the formation of
404 *Environmentalists* cluster.

405 NEP score is the most important factor in the formation of *Challengers'* cluster.
406 This shows that *Challengers* have similar environmental perceptions with
407 *Knowledgeable* respondents. However, attitudes towards science and research and trust

408 Insert Figure 3

409 in forest industry and scientists are the least important factors in the formation of
410 *Challengers'* cluster. Finally, trust in the forest industry, federal and provincial
411 governments are the most important factors in the construction of *Supporters'* cluster. It
412 is important to note that in *Figure 3* the NEP score, knowledge of forest operations and
413 biotechnology seem to be the highest mean value in the formation of all clusters.

414 The main reason is that the NEP has 15 questions which are scaled in a five-
415 point Likert scale from *strongly disagree* (with the value 1) to *strongly agree* (with the
416 value 5). Thus, the minimum and maximum *sums* of the scale items are 15 and 75
417 respectively. Similarly, the percentages of *correctly answered* facts were considered for
418 knowledge of forest operations and biotechnology in which the minimum and
419 maximum percentages are 16 % and 100% (for knowledge of forest operations) and
420 10% and 100% (for knowledge of biotechnology), respectively. However, there are
421 significant differences in the values of these clustering factors across clusters.

422 Insert Table 3

423 In Table 3 we present the exact values of each clustering factor in all clusters.
424 Table 4 shows the demographic variables in each cluster. In all clusters, the number of
425 females is higher than the number of males. The *Challengers* cluster has the highest
426 percentage of respondents whose age is between 35 and 64.

427 Insert Table 4

437 Insert Table 5

447 *Environmentalists* have higher level of trust in ENGOs which could be
448 emanated from the fact that most of environmental organisations are continuously

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449 promoting the negative consequences of biotechnology. For example, [Wieczorek](#)
450 [\(2003\)](#) shows that environmentalists usually argue that inadequate effort has been made
451 to understand the risks of using transgenic crops. They further demand rejection of
452 genetic modification R&D activities. This potentially implies that if individuals higher
453 trust in these organisations, they may rely on the information provided by these
454 institutions and tend to have “reluctant” attitudes for biotechnology. Moreover,
455 *Environmentalists* have higher mean values of knowledge of biotechnology and forest
456 operations suggesting that accepting biotechnology and knowledge have an inverse
457 relationship. This is compatible with the finding of [Sholdere \(2003\)](#) which shows that
458 high level of knowledge encourages individuals to ask more critical questions about the
459 technology which in turn induces scepticism among individuals. In contrast, [Hoban](#)
460 [\(1997\)](#) finds that individuals with higher level of knowledge tend to accept the
461 application of biotechnology. [Klerck and Sweeney \(2007\)](#) show that knowledge about
462 genetically modified food significantly reduces psychological risks. They further
463 suggest that cooperation among government, scientific institutions, and the food
464 industry to foster effective communication strategies that increase consumers'
465 knowledge, reduce their risk perceptions, and encourage consumer adoptions of
466 biotechnology. British Columbians and Saskatchewanians form the highest and lowest,
467 respectively, percentages of Environmentalists. Most of the respondents in this cluster
468 are engaged in non-farming activities and live in urban areas.

469 *Knowledgeable* respondents have higher mean values of the NEP score,
470 knowledge of forest operations and biotechnology. The main reason for having some
471 hesitations about biotechnology may associate with these factors as showed by large

472 empirical studies. For example, [Kaiser \(2001\)](#) argues that tree engineering is coming
473 *under fire* from environmental groups as it has moved from the laboratory into the
474 field-testing stage. [Mann et al. \(2002\)](#) show that planting transgenic trees has arrived at
475 a critical juncture now that environmental concerns are becoming the main obstacles to
476 get public acceptance of these trees. Further, [Campbell et al. \(2001\)](#) uncover that
477 opponents are calling for suspension of commercial release of genetically modified
478 food and plants until the long-term environmental impacts are better assessed and
479 understood. Manitobans hold the lowest percentage of the *Knowledgeable* respondents.

480 All clustering factors, except the NEP score, have lower mean values in cluster
481 *3-Challengers*. The higher mean value of NEP score may significantly show that the
482 environmentalism attitude reduces the level of accepting genetically modified products.
483 [Blay \(2005\)](#) finds that environmentalists argue that genetically modified plants
484 negatively affect the nature through massive and long-run intoxication of the
485 environment. [Ganiere et al. \(2006\)](#) find that rejecting genetic modification have strong
486 correlation with the loss of trust in different stakeholders, lack of information,
487 perceived risks and lack of knowledge about the biotechnology. Moreover, [Nelson](#)
488 [\(2001\)](#) and [Onyango et al. \(2006\)](#) show that opponents of biotechnology argue that
489 genetically modified products contaminate organic seeds and foods through various
490 mechanisms including pollination. Manitobans form the highest percentage of
491 respondents in the *Challengers'* cluster.

492 Finally, respondents in the *Supporters'* cluster have lower mean value of NEP
493 score; and this may infer that members of this cluster have optimistic attitudes about

494 biotechnology as reported by IPCC (2001)¹⁶. IPCC shows that supporters of
495 biotechnology in forestry argue that the technology restores species which are severely
496 damaged by pests and disease. It also mitigates the build-up of atmospheric greenhouse
497 gases (including carbon) that believed to be the main causes of global warming.
498 Respondents in *Supporters'* cluster have higher mean values of trust in federal and
499 provincial governments. This may in turn show that supporters of biotechnology in
500 forestry have more confidence about formulating and enforcing different types of rules
501 and regulations related to the technology as documented by [Hossain et al. \(2003\)](#); and
502 [Onyango, et al. \(2006\)](#). Moreover, trust in scientists plays an important role in the
503 make-up of the *Supporters'* cluster. Similar with this finding, [Siegrist et al. \(2012\)](#)
504 suggests trust in scientists significantly increases the acceptance of biotechnology.

505 Around 37% of members of *Supporters'* cluster are from Saskatchewan.
506 According to Pew Research Centre (2010) Saskatchewan is recognised as hosting one
507 of the world's leading ag-biotech research centres. It also shows that 30% of Canadian
508 ag-biotech industries are in Saskatchewan. These research centers created the world's
509 first genetically modified commercial canola variety and the first genetically engineered
510 animal vaccine. In addition, the research center pays significant attention to creating
511 public awareness about biotechnology and genetically modified products. This may
512 show that Saskatchewanians have advantages, compared with residents of other
513 provinces, of accessing updated information and acquiring different types of
514 information regarding biotechnology and resultant products. Hence, this might be
515 considered as one of the main factors that induces the level of accepting the application
516 of biotechnology in forestry ([Hamstra, 1998](#)).

¹⁶ Intergovernmental Panel on Climate Change

517 We used a binary probit model to examine the likelihood of voting the newly proposed
518 policy alternative relative to the current policy. The *vote* for policy alternative takes the
519 value 1 if a respondent, who is assigned in a specific cluster, chooses the newly
520 proposed policy alternative; and 0 otherwise. The covariates are the three types of
521 breeding methods TB, DNA and GM in which all of them are accompanied with and
522 without biofuel production. Table 6 provides parameter estimates of the models, and
523 Table 7 shows the associated marginal effects of changes in the variables relative to a
524 base scenario in each cluster.

525

Insert Table 6

526 The marginal effect of DNA breeding shows that the probability of voting for
527 DNA breeding by *Environmentalists* declines by 3.2% relative to the base scenario.
528 Employing GM technologies seems less impactful, as the marginal effect associated
529 with this policy alternative is -1.6%. However, if any new policy employing
530 biotechnology is used to produce biofuels, the probability of voting for this new policy
531 increases by 32.4%.

532 Table 7: A summary of marginal effects from probit model estimates in each cluster in
533 terms of a percent change in the probability of voting to support a new policy with a
534 one unit change in the variable.

535

Insert Table 7

536 *Knowledgeable* respondents are more likely to vote for a new policy when the
537 new poplar breeding method employs DNA breeding as the likelihood of voting for it
538 increases by 1.7%. Applying GM has lower impacts on voting as the marginal effect

539 related to the policy choice declines by 6.1%. Conversely, if the new forest
540 management strategies applying biotechnology is used to produce biofuels, the
541 likelihood of voting for the new forest policy increases by 38.4%. The negative opinion
542 towards GM might be caused by the higher value of NEP score. [Peelle \(2000\)](#) suggests
543 that individuals with environmental attitudes seek more information about the
544 environmental impacts and net benefit of applying biotechnology. This evidence
545 indicates that if *Knowledgeable* respondents get more information about biotechnology,
546 the probability of voting for applying the technology would increase in a significant
547 rate.

548 The probability of voting for DNA breeding is less likely in the *Challengers'*
549 cluster as the marginal effect associated with this breeding method is declined by -
550 3.6%. Applying GM appears to be less effective, as the marginal effect of this
551 technology is declined by 5.1%. Moreover, if the new policy employing biotechnology
552 to forest policy is used to produce biofuels, the probability of voting for the new policy
553 will decline by 27.5%. The lowest mean values of the indicators of trust in scientists,
554 forest industries, provincial and federal government can be considered as one of the
555 main drivers of *Challengers* for not voting the newly proposed policies. This result is
556 similar with the finding of Snow et al. (2005) which reveals that opponents of
557 genetically modified trees argue that the uncertainties and ecological impacts of these
558 trees need higher engagement of different civil societies and governments. Thus, the
559 federal and provincial governments should formulate and implement various regulatory
560 frameworks to reduce the negative impacts of genetically improved trees and increase
561 the public acceptance of biotechnology (see e.g., [Curtis et al. 2004](#)).

562 The marginal effect of DNA breeding in *Supporters'* cluster shows that if the
563 newly proposed policy employs this breeding method, the probability of respondents to
564 vote for the new policy will be enhanced by 0.4%. Similarly, applying GM seems more
565 impactful in which the probability of voting for the new forest policy increases by 2.7%
566 compared to the base scenario. Finally, if the new policy is accompanied by biofuel,
567 supporters would vote this policy in which the probability is increased by 29.3%
568 percent.

569 **Conclusion and Policy recommendations**

570 This study examines aspects of public preferences for introducing new genomic
571 technologies to produce hybrid poplars to be used as biofuel feedstock from public
572 forest lands in western Canada. Six new policy scenarios for each province were
573 provided to respondents that considered the use of three different breeding methods
574 (Traditional, DNA breeding, Genetic Modification), each with and without poplars
575 being used for biofuels. We use a referendum format to present alternative policy
576 scenarios to examine the differences between characteristics of the group of
577 respondents. All proposed policies allowed unrestricted seed choice for reforestation of
578 poplars in each province on public land. Respondents were asked to vote in a series of
579 hypothetical binary referenda among with each new policy and the current policy,
580 based on changes to forest land use, breeding methods, impacts on industry, and
581 impacts on carbon emissions.

582 We found four clusters of respondents in our samples (*Environmentalists*,
583 *Knowledgeable*, *Challengers* and *Supporters*) based on their preferences towards the
584 application of breeding technologies in forestry for biofuel production using the two-

585 step clustering procedure. Overall, we found large support across all clusters but one
586 (*Challengers*) for policies that allowed genetically improved poplars to be planted on
587 public land if the policies were accompanied by biofuel production. For example, the
588 likelihood of accepting the newly proposed policies increases from 2.7% to 29.3% if
589 biofuel production goes with these policies, particularly in the *Supporters* cluster. There
590 is no significant variation in the acceptance of different breeding technologies if biofuel
591 production is not a part of the policy (see Table 7). Thus, the use of poplar as a biofuel
592 source increases the likelihood of the western Canadian public choosing scenarios that
593 allow the application of new breeding technologies such as genetic modification on
594 public land. These variations in relation to the presence or absence of biofuel
595 production within newly proposed allowances for planting exotic poplars on public
596 forest land may potentially help policy-makers to reform Canadian forest policies.

597 Our findings show that individuals have different preferences for changes in
598 forest operations in western Canada. We also try to show some of the conditions which
599 have significant effects on individuals' preferences for the application of biotechnology
600 in forestry. Individuals' environmentalism attributes and attitudes towards science and
601 research appear important determinants of accepting the application of biotechnology in
602 Canadian forest sector. Knowledge of biotechnology also plays an import role
603 increasing the probability of accepting genetically modified poplar trees. Thus, policy
604 makers should guarantee the dissemination of biotechnology scientific knowledge to
605 assure a high level of knowledge among individuals. Trust in government has salient
606 contribution in giving information to individuals to allow them to undertake informed
607 and ideally reasoned choices.

Moreover, it is a combination of how individuals perceive, learn and process information on new technology developments that eventually determines acceptance. Therefore, policies that aim at maximizing the acceptance of new developments in the forest sector should operate in various aspects including the media, the education system, and a correct population analysis to determine information availability and processing through individuals transmission of values and societal trust enhancing factors. These policies need to create awareness about the benefits of the newly developed technologies which potentially avoid ambiguities concerning the potential perceptions of risk associated to the technologies.

Although forest products from genetically modified trees might not be in the market soon, marketing claims concerning the non-GM nature of forest products should be administered, as it may upsurge individuals' perception of risk. Further, scientifically based information on the expected purchasing behaviour of individuals has important contribution for developers and policy makers. For the developers this type of information is imperative, as the anticipation of feasible markets will stimulate investments. For the policy makers, such information will support them to develop proper decision-making positions and respond more effectively through rules and regulations.

However, further investigations need to be conducted to gain better understanding of why individuals' preferences are *heterogeneous* in voting for the application of biotechnologies in forestry. For example, examining the heterogeneity of preferences for the application of biotechnology to forestry in *other* provinces using different measures of preferences would give important contributions to understand

631 why individuals' preferences for the application of biotechnology in forestry are
632 different. Empirically, this is an interesting and open area for further research.

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References

- Aldrich, G.A., Grimsrud, K.M., Thacher, J.A., and Kotchen, M.J., 2007. Relating environmental attitudes and contingent values: how robust are methods for identifying preference heterogeneity? *Environmental and Resource Economics*, 37: 757.
- Aleksejeva, I., 2014. Latvian consumers' knowledge about genetically modified organisms. *Organizacijų vadyba: sisteminiai tyrimai*, 72: 7-16.
- Anderberg, M.R., 2014. Cluster analysis for applications: probability and mathematical statistics: A series of monographs and textbooks. Academic press.
- Anderson, J.A., Armstrong, G.W., Luckert, M.K., and Adamowicz, W.L. 2012. Optimal zoning of forested land considering the contribution of exotic plantations. *Mathematical and Computational Forestry & Natural-Resource Sciences*, 4: 92–104.
- Anderson, J.A., and Luckert, M.K., 2007. Can hybrid poplar save industrial forestry in Canada? A financial analysis in Alberta and policy considerations. *The Forestry Chronicle*, 83: 92-104.
- Anderson, J.C., Wachenheim, C.J. and Lesch, W.C., 2005. Perceptions of genetically modified and organic foods and processes: North Dakota college students. Department of Agribusiness and Applied Economics, Agricultural Experiment Station, North Dakota State University.
- Bacher, J., Wenzig, K., and Vogler, M., 2004. SPSS Two-step Cluster-a first evaluation.
- Barrows, G., Sexton, S. and Zilberman, D., 2014. Agricultural biotechnology: the promise and prospects of genetically modified crops. *Journal of Economic Perspectives*, 28: 99-120.
- Bauer, M. W., Petkova, K., and Boyadjieva, P., 2000. Public knowledge of and attitudes to science: Alternative measures that may end the “science war”. *Science, Technology & Human Values*, 25: 30-51.
- Blay, S., 2005. International regulation of biotechnology: Problems and prospects. *Journal of International Biotechnology Law*, 2: 245-251.
- Bredahl, L., 1999. Consumers' cognitions with regard to genetically modified foods: Results of a qualitative study in four countries. *Appetite*, 33: 343-360.
- British Columbia Ministry of Forest, Lands, and Natural Resource Operations (2014). Timber supply review: TSR and TSA schedule. <http://www.for.gov.bc.ca/hts/aactsa.htm>.
- Burton, M., Rigby, D., Young, T., and James, S., 2001. Consumer attitudes to genetically modified organisms in food in the UK. *European Review of Agricultural Economics*, 28: 479-498.
- Campbell, F.T., and Asante-Owusu, R., 2001. GE trees: proceed only with caution. In *Proceedings of the First International Symposium on Ecological and Societal Aspects of Transgenic Plantations*, 158-167
- Carpenter, F. L., Nichols, J. D., and Sandi, E., 2004. Early growth of native and exotic trees planted on degraded tropical pasture. *Forest Ecology and Management*, 196: 367-378.
- Comrey, A.L., and Lee, H.B., 1992. *A First Course in Factor Analysis* (2nd edn.) Lawrence Earlbaum Associates. Publishers: Hillsdale, New Jersey.
- Costa-Font, M., Gil, J.M., and Traill, W.B., 2008. Consumer acceptance, valuation of and attitudes towards genetically modified food: review and implications for food policy. *Food Policy*, 33: 99–111.

- Curtis, K.R., McCluskey, J.J., and Wahl, T.I., 2004. Consumer acceptance of genetically modified food products in the developing world.
- Dunlap, R. E., Van Liere, K. D., Mertig, A. G., & Jones, R. E., 2000. New trends in measuring environmental attitudes: measuring endorsement of the new ecological paradigm: a revised NEP scale. *Journal of Social Issues*, 56: 425-442.
- Duran, B.S. and Odell, P.L., 1974. Cluster analysis, a survey, volume 100 of lectures notes in economics and mathematical systems.
- Finlay, K., Susan, M., Jane, L., and Trevor, W., 1999. The Impact of Information and Trust on Consumer Perceptions of Biotechnology. *Canadian Journal of Marketing Research*, 18: 15-30.
- Gamble, J., and Elsa, K., 2008. The use of selected community groups to elicit and understand the values underlying attitudes towards biotechnology. *Public Understand of Science*, 17: 245-259.
- Ganieri, P., Chern, W.S., and Hahn, D., 2006. A continuum of consumer attitudes toward genetically modified foods in the United States. *Journal of Agricultural and Resource Economics*, 129-149.
- Gaskell, G., Stares, S., Allansdottir, A., Allum, A., Castro, P., and Esmer, Y., 2010. Europeans and biotechnology in 2010: Winds of Change? The 7th series of Eurobarometer surveys on life sciences and biotechnology.
- Gaskell, G., Allum, N. C., Bauer, M. W., Jackson, J., Howard, S., and Lindsey, N., 2009. Ambivalent GM nation? Public attitudes to biotechnology in the UK, 1991-2002. Life Sciences in European Society Report: London School of Economics and Political Science.
- Gaskell, G., Allum, N., and Stares, S., 2003) Europeans and biotechnology in 2002: Eurobarometer 58.0. Brussels: European Commission. Hair, J.F., Black, B., Babin, B., Anderson, R.E., and Tatham, R.L., 2006. Multivariate data analysis, 6. Baski. Upper Saddle River, NJ: Pearson Prentice Hall).
- Haldane, J.B.S. and Lyon, K.S., 2015. The long-term adequacy of world timber supply. Routledge.
- Hambrick, D. C., S. Finkelstein, T.S. Chove, E.M. Jackson (2005). Isomorphism in Reverse: Institutional Theory as an Explanation for Recent Increases in Intraindustry Heterogeneity and Managerial Discretion. *Research in Organizational Behavior*, 26: 307-350.
- Hamstra, A., 1998. Public opinion about biotechnology: A survey of surveys. European Federation of Biotechnology, Task Group on Public Perceptions of Biotechnology.
- Heller, R., 2003. GM Nation? The findings of the public debate. UK Department of Trade and Industry.
- Hoban, T.J., 1997. Consumer acceptance of biotechnology: an international perspective. *Nature biotechnology*, 15: 232.
- Hossain, F., Onyango, B., Adelaja, A., Schilling, B., and Hallman, W., 2002. Uncovering Factors Influencing Public Perceptions of Food Biotechnology. Food Policy Institute. Working Paper 0602-003.
- Huber, P.J., 1967. The behavior of maximum likelihood estimates under nonstandard conditions. *In* Proceedings of the 5th Berkeley Symposium on Mathematical Statistics and Probability, Berkeley, California, 21 June-18 July 1965 and 27 December 1965, 1967 January 1966. *Edited by* Lucien M. Le Cam and Jerzy Neyman. Statistical Laboratory of the University of California, Berkeley, California, 221-233.
- Intergovernmental Panel on Climate Change (IPCC), Annual report (2014).

- James, H.S., 2005. Trust in scientists and food manufacturers, with implications for the public support of biotechnology.
- Jessica, C. M., and Cheng, A.S., 2011. Using analyses of public value orientations, attitudes and preferences to inform national forest planning in Colorado and Wyoming. *Applied geography*, 31: 393-400.
- Johnston, M.H., Williamson, T.B., Price, D.T., Spittlehouse, D.L., Wellstead, A.M., Gray, P.A., Scott, D., Askew, S.E. and Webber, S.L., 2006. Adapting forest management to the impacts of climate change in Canada.
- Kaiser, J., 2001. Words (and axes) fly over transgenic trees. *Science*, 292: 34-36.
- Kamakura, A. W., Kim, D. B., and Lee, J. (1996). Modeling preference and structural heterogeneity in consumer choice. *Marketing Science*, 15: 152-172.
- Karamizadeh, S., Abdullah, S.M., Manaf, A.A., Zamani, M. and Hooman, A., 2013. An overview of principal component analysis. *Journal of Signal and Information Processing*, 4: 173.
- Kaufman, L., and Rousseeuw, P.J., 2009. Finding groups in data: an introduction to cluster analysis (Vol. 344). John Wiley & Sons.
- Lang, J. T., and Hallman, W. K., 2005. Who does the public trust? The case of genetically modified food in the United States. *Risk Analysis*, 25: 1241-1252.
- Lucht, J.M., 2015. Public acceptance of plant biotechnology and GM crops. *Viruses*, 7: 4254-4281.
- Mann, C. C., and Plummer, M. L., 2002. Forest biotech edges out of the lab. *Science*, 295: 1626–1629.
- Marques, M.D., Critchley, C.R. and Walshe, J., 2015. Attitudes to genetically modified food over time: How trust in organizations and the media cycle predict support. *Public Understanding of Science*, 24: 601-618.
- McFarlane, B. L., and Boxall, P. C., 2000. Factors influencing forest values and attitudes of two stakeholder groups: The case of the Foothills Model Forest, Alberta, Canada. *Society & Natural Resources*, 13: 649-661.
- Mistik forest management agreement area (2013). <http://www.mistik.ca/fma.htm>.
- Natural Resources Canada (2012). The state of Canada's forests: Annual Report 2012.
- Natural Resources Canada (2014). The state of Canada's forests: Annual Report 2014
- Nelson, C.H., 2001. Risk perception, behavior, and consumer response to genetically modified organisms toward understanding American and European public reaction. *American Behavioral Scientist*, 44: 1371-1388.
- Onyango, B., Govindasamy, R., Hallman, W., Jang, H. and Puduri, V.S., 2006. Consumer acceptance of genetically modified foods in South Korea: Factor and cluster analysis. *Journal of Agribusiness*, 24: 61.
- Peelle, E., 2000. Stakeholder views and concerns about bioenergy: organizational focus, driver issues and uncertainty. In *Proceedings, Bioenergy*

Pew Research Centre (2010). <https://cbt20.wordpress.com/tag/saskatchewan/>

Pin, R.R., and Gutteling, J.M., 2009. The development of public perception research in the genomics field: an empirical analysis of the literature in the field. *Sci. Commun.* 31: 57–83.

Payn, T., Carnus, J.M., Freer-Smith, P., Kimberley, M., Kollert, W., Liu, S., Orazio, C., Rodriguez, L., Silva, L.N. and Wingfield, M.J., 2015. Changes in planted forests and future global implications. *Forest Ecology and Management*, 352: 57-67.

Priest, S.H., Bonfadelli, H. and Rusanen, M., 2003. The “trust gap” hypothesis: Predicting support for biotechnology across national cultures as a function of trust in actors. *Risk Analysis*, 23: 751-766.

Rollins, C., Boxall, P. C., and Luckert, M. K., 2015. Public preferences for planting genetically improved poplars on public land for biofuel production in western. *Canadian Journal of Forest Research*, 45: 1785–1794.

Rayner, J., McNutt, K. and Wellstead, A., 2013. Dispersed capacity and weak coordination: The challenge of climate change adaptation in Canada's forest policy sector. *Review of Policy Research*, 30: 66-90.

Sanderson, K., Saunders, C., Nana, G., Stroombergen, A., Campbell, H., Fairweather, J. and Heinemann, A., 2003. Economic risks and opportunities from the release of genetically modified organisms in New Zealand. Ministry for the Environment, Wellington.

Șchiopu, D., 2010. Applying Two-step cluster analysis for identifying bank customers' profile." *Buletinul*, 62: 66-75.

Schmer, M.R., Vogel, K.P., Mitchell, R.B. and Perrin, R.K., 2008. Net energy of cellulosic ethanol from switch grass. *Proceedings of the National Academy of Sciences*, 105: 464-469.

Sheehy, H., Legault, M., and Ireland, D., 1998. Consumers and biotechnology: A synopsis of survey and focus group research. *Journal of Consumer Policy*, 21: 359-386.

Sholdere, J., 2003. The biotechnology communication paradox: Experimental evidence and the need for a new strategy. *Journal of Consumer Policy*, 26: 125-157.

Siegrist, M., Connor, M. and Keller, C., 2012. Trust, confidence, procedural fairness, outcome fairness, moral conviction, and the acceptance of GM field experiments. *Risk Analysis*, 32: 1394-1403.

Snow, A.A., Andow, D.A., Gepts, P., Hallerman, E.M., Power, A., Tiedje, J.M. and Wolfenbarger, L.L., 2005. Genetically engineered organisms and the environment: current status and recommendations. *Ecological Applications*, 15: 377-404.

Tabachnick, B.G., Fidell, L.S. and Osterlind, S.J., 2001. Using multivariate statistics.

Tait, J. D., Bruce, A., and Chataway, J., 2007. OECD International Futures Project on the Bio-economy to 2030: Designing a Policy Agenda. Health Biotechnology to 2030. OECD International Futures Programme.

Tindall, D. B., Ronald, L. T., and Pamela, P., 2013. Aboriginal Peoples and Forest Lands in Canada. Vancouver, British Columbia: UBC Press.

Voss, A.G.J., Spiller, A. and Enneking, U., 2009. Farmer acceptance of genetically modified seeds in Germany: Results of a cluster analysis. *International Food and Agribusiness Management Review*, 12: 61-80.

White, H., 1980. A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica*, 48: 817–838.

- Wieczorek, A., 2003. Use of biotechnology in agriculture: Benefits and risks. Cooperative Extension Service. BIO, 3: 1-6.
- Wunderlich, S. and Gatto, K.A., 2015. Consumer Perception of Genetically Modified Organisms and Sources of Information-. Advances in Nutrition, 6: 842-851.
- Zechendorf, B., 1994. What the public thinks about biotechnology. Nature Biotechnology, 12: 870-875.

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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 (Source: Rollins et al. 2015)

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 land</u> 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

Figure 2: Overall model level quality of clustering

Figure 3: Cluster predictors in each cluster

Table 1: 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.

Characteristics	Province							
	Alberta		British Columbia		Manitoba		Saskatchewan	
	N	Pop.	N	Pop.	N	Pop.	N	Pop.
Number of respondents	1205	-	1249	-	502	-	500	-
Male (%)	42	51	44	49	42	49	40	50
Average age (18+)	48	45	49	48	50	47	50	47
Population of Centre of residence (%)								
> 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

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

Table 2: The number and percentages of respondents in each cluster

Variables	Cluster				
	Environmentalists	Knowledgeable	Challengers	Supporters	Total
Number of Respondents	1,079	1,056	439	882	3,456
Percentage of total sample	31.2	30.6	12.7	25.5	100
Rural dwellers	340	292	149	294	1,075
Urban dwellers	739	764	290	588	2,381
Number of farmers	40	66	14	33	153
Non-farm	1,039	990	425	849	3,303
Albertans (%)	29.8	41.6	17	34.2	30.6
British Columbians (%)	41.6	23.7	34.4	15.7	28.8
Manitobans (%)	16.1	13.2	38.2	11.1	19.7
Saskatchewanians (%)	12.5	21.5	10.4	39	20.9

Notes: The response rate is sufficient in the sense that all participants have provided answers to each question

Table 3: A summary of mean values of clustering factors used in defining clusters

Clustering factors	Mean			
	Environmentalists	Knowledgeable	Challengers	Supporters
Attitude towards science & research	25.1	24.4	20.85	24.32
New Ecological Paradigm (NEP)	59.45	52.56	53.87	50.79
Trust in federal government	7.85	12.8	6.89	13.67
Trust in provincial government	7.39	12.39	6.7	13.56
Trust in scientists	16.23	16.07	9.77	15.63
Trust in forest industry	12.38	13.49	9.36	15.02
Trust in ENGOs	60.07	13.38	9.5	14.47
Knowledge of forest operations	46.25	60.07	39.03	38.05
Knowledge of biotechnology	50.06	69.88	39.95	25.91

Notes: The values of NEP, knowledge of forest operations and biotechnology have the highest values compared with other clustering factors

Table 4: A summary of demographic variables in each cluster

Variables		Cluster				
		Environmentalists	Knowledgeable	Challengers	Supporters	Total
Age distribution (%)	18-34	19.5	23.4	20.1	28	22.7
	35-64	62.4	60.8	64.5	58.2	61.5
	65 ⁺	18.1	15.8	15.4	13.8	15.8
Education level distribution (%)	High School	19	16	26.8	27	22.2
	College	50	42.4	47.6	48	47
	Undergraduate	22	28.8	18.9	18	21.9
	Graduate	9	12.8	6.7	7	8.9
No. of male		369	526	195	376	1,466
No. of female		710	530	244	506	1,990

Table 5: Relative percentage of vote in support of new forest policy alternatives in each cluster

Policy alternatives	Relative percentage of votes			
	Environmentalists	Knowledgeable	Challengers	Supporters
Vote for tradition breeding (excluded)				
Vote for DNA breeding (%)	40.22	50.38	40.09	50.11
Vote for genetic modification (%)	39.57	47.50	37.29	51.53
Vote for biofuel (%)	53.39	61.14	42.52	59.45

Table 6: Description of dependent and independent variables

Variable name	Descriptions
<i>Dependent variable:</i>	
Vote	1 if respondent in cluster 'c' chooses the new policy; 0 else
<i>Independent variables:</i>	
Traditional breeding (TB)	1 if respondent in cluster 'c' chooses TB; 0 else
DNA breeding (DNA)	1 if respondent in cluster 'c' chooses DNA; 0 else
Genetic modification (GM)	1 if respondent in cluster 'c' chooses GM; 0 else
Biofuel production (BF)	1 if respondent in cluster 'c' chooses BF; 0 else

Table 7: A summary of marginal effects from probit model estimates in each cluster in terms of a percent change in the probability of voting to support a new policy with a one unit change in the variable.

Variables	Cluster			
	Environmentalists	Knowledgeable	Challengers	Supporters
DNA	- 3.2**	1.7**	-3.6**	0.4**
GM	- 1.6*	- 6.1*	-5.1**	2.7**
BF	34.2*	38.4*	-27.5**	29.3*
TB ⁺				

Notes: * & ** denote statistical significant at the 5% and 10% levels respectively. ⁺ denotes traditional breeding without biofuel production is considered as the base scenario. All values are given in %.

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