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Does Inclusion of Landowners' Non-Market Values Lower Costs of Creating Carbon Forest Sinks?

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ABSTRACT

This research examines effects of various factors on farmer participation in agricultural tree plantations for economic, environmental, social and carbon-uptake purposes. Using data from a survey of Canadian agricultural landowners, a discrete choice random utility model is used to determine the probability of farmers' participation and corresponding mean willingness to accept (WTA) compensation for a tree-planting program. WTA includes positive and negative non-market benefits to landowners from planting trees. Estimates of WTA are less than foregone agricultural rents, but average costs of creating carbon credits still exceed their projected value under a CO_2-emissions trading scheme.

Key words: Willingness to accept compensation for tree planting; afforestation; climate change

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1. INTRODUCTION

As a result of the U.S.'s withdrawal from the Kyoto process, the EU relented to a much broader definition of and role for land use, land-us change and forestry (LULUCF) activities in lieu of greenhouse gas emissions in meeting targets during Kyoto's first commitment period (2008-12). At COP7 in Marrakech, November 2001, the annual cap on carbon (C) uptake in sinks for 2008-12 was set at 219 Mt C (151 Mt C if the U.S. is left out). Thus, terrestrial sinks could conceivably account for more than 80% of the 250 Mt C annual reduction from 1990 levels required of Annex B countries, although the proportion is much lower when compared to projected business-as-usual emission levels. It is not clear, however, whether carbon sink offsets are economically competitive with emissions reduction. Efficient land-use management in agriculture and forestry requires evaluation in terms of the cost-effectiveness of carbon uptake.

One option for achieving significant carbon offsets is to plant trees on marginal agricultural land. In addition to providing C-uptake and potential commercial timber benefits, tree planting could provide non-market benefits such as reduced soil erosion, improved water quality, increased wildlife habitat, riparian buffer zones and aesthetic appeal. Afforestation could be pursued regardless of concerns about climate change. Since benefits of planting trees would accrue to society, compensation would need to be provided to landowners if they are to change their land use from agriculture to forestry (Chomitz 2000).

The purpose of the current study is to determine how much landowners would need to be compensated to convert their pastures and cropland to forestry, and whether tree planting would be a cost-effective means of achieving Kyoto-type targets.[1] Determining compensation is not straightforward because: (1) there is uncertainty about the costs of tree planting, actual yields and stumpage values due to geographical differences in proximity to saw mills or pulp mills; (2) some returns to tree planting accrue in the distant future, causing disruptions in income flows that could increase compensation demanded; (3) farmers may feel that their ability to participate in current and future government agricultural programs is threatened by tree planting because capacity to produce agricultural commodities is reduced; and (4) landowners have varying preferences towards managed forests versus agricultural ecosystems. Non-market values often play a significant role in farming decisions, so compensation equal to agricultural rents (including any price support or subsidy payments) may not be the appropriate amount to convince landowners to change their land use to forestry. The compensation amount will be higher if the landowner realizes a non-market benefit from agriculture, but could also be lower if non-market (e.g., aesthetic) benefits accrue from forestry. A contingent valuation methodology can be quite valuable in this context, because it is able to incorporate non-market (particularly non-use) values and unobservable transactions costs into the compensation amount.

The current research uses data from surveys mailed to western Canadian farmers to examine their willingness to accept (WTA) compensation for participation in tree-planting programs. A discrete-choice random utility maximization framework is used to represent landowners' preferences for planting trees on marginal agricultural land. Landowners are offered a compensation bid for removal of land from production. Random utility maximization models

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[1] It is important to recognize that tree planting conducted after 2002 is unlikely to have much effect in terms of attaining Kyoto targets for 2008-12. Incremental growth at that time will be too small, but the result of ongoing negotiations regarding monitoring may enable suppliers of carbon sink credits to use expected average annual growth or MAI over the entire rotation.

the choice between rejecting the bid and keeping the land in production, and accepting the bid and removing the land from production in favor of tree planting. The landowner will accept the bid and allow conversion of the land as long as the compensation offered is at least as much as the opportunity cost of not producing, plus any positive or negative non-market value the landowner has from converting land to trees. Results from an applied probit model provide predictions of the probability of accepting a tree-planting program and WTA compensation.

The paper is organized as follows. A general overview of theory is presented followed by a discussion of the data and an explanation of the empirical model. Using estimates of compensation levels, the cost-effectiveness of potential tree planting programs is examined. The paper concludes with a discussion of policy implications and considerations for further research.

2. RANDOM UTILITY MAXIMIZATION MODEL

Hanemann (1984) derives a theoretical random utility maximization (RUM) framework for analyzing binary data that depicts an individual's decision whether or not to accept a particular option. The basic premise of RUM is that the individual's rational choice, which maximizes utility, is subject to researcher error due to unobservable characteristics.

Assuming constant prices, individual *i*'s utility function, $u_{i,a}(m, s)$, can be specified as a function of a deterministic component, $v_{i,a}(m, s)$, and an additive stochastic component, $\varepsilon_{i,a}$:

$$(1) \qquad u_{i,a}(m, s) = v_{i,a}(m, s) + \varepsilon_{i,a},$$

where a is the discrete decision $\{a = 1 \text{ if yes; } a = 0 \text{ if no}\}$, m is income, s represents observable attributes that differentiate individuals, and $\varepsilon_{i,0}$ and $\varepsilon_{i,1}$ are i.i.d. random variables with zero means and variance σ^2. RUM models the difference in the utilities of the 'yes' and 'no' alternatives as an underlying continuous index function (Greene 2000). The difference in indirect utilities of the two alternatives is directly a function of the change in income caused by the compensation amount. This amount is fixed to the individual but random in the sense that the utility function is random to the researcher. This welfare measure is developed in more detail following a description of the empirical setting.

3. SURVEY OF CANADIAN FARMERS

A questionnaire was mailed in July 2000 to 2,000 randomly selected Canadian farmers from the grain belt region of northeastern British Columbia, Alberta, Saskatchewan and Manitoba. Farmers with less than 160 acres of land were omitted from the survey sample since small landowners were unlikely to contribute significant amounts of land.[2] Dairy farmers were also excluded from the sample for their presumed high opportunity cost of tree planting due to value-added production. A total of 379 surveys were returned undelivered, due to the lack of available updates of the mailing list purchased from Watts Brokerage Listing. Reminder cards were sent out three weeks after the first mailing. The effective response rate (corrected for returned/undelivered surveys) was 13%, slightly higher than the 12% rates reported by the Environics Research Group (2000) in their study of stewardship of Canadian farmers and by Bell et al. (1994).[3]

The survey included a brief, personalized cover letter explaining the purpose of the questionnaire and a definition of carbon credits. In addition to willingness to accept compensation for tree planting, the actual survey also elicited detailed information on a farmer's

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[2] Bell et al. (1994) consider only landowners with 100 or more acres in their study of participation in Tennessee's Forest Stewardship Program.

[3] Response rates for executives of small firms are notoriously low (e.g., see Friedman and Singh 1989). Farms must be viewed as small firms, and not as individuals commonly surveyed using CVM (e.g., recreationists who tend to be avid "users" of a particular resource.)

agricultural operations including activities on marginal fields, farmers' opinions about and awareness of climate change issues and carbon credits, and personal characteristics and demographics (Suchánek 2001). Initial questions were meant to reduce information biases by familiarizing respondents with the topic and issues under investigation before asking them about their willingness to plant trees.

Landowners were presented a hypothetical tree-planting program that covers all costs of tree planting while compensating for lost agricultural production. A compensation amount or "bid" was offered with the program to convert their least productive land to forest under a 10-year contract. In the absence of *a priori* valuation information, the bid compensation levels were selected on the basis of results from a pilot study, and range from \$1 to \$60 per acre per year (see Suchánek 2001).[4] The distribution of these bids is skewed towards the lower bound of the range in order to provide more efficient estimates of WTA (Cooper 1993). The contingent contract indicates that farmers have no right to harvest the trees before the contract expires, but trees become their property at the end of the contract period. The contract provides no compensation for the conversion of land back to agriculture.

4. EMPIRICAL MODEL

Farmer i will accept a tree-planting project ($a = 1$) as long as $v_{i,1}(m+\Delta m, s) + \varepsilon_{i,1} > v_{i,0}(m, s) + \varepsilon_{i,0}$, where Δm is the compensation or "bid" (B) offered minus forgone expected annual net returns in agriculture (OC). Since utility is a random variable, the probability that a farmer's

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[4] Agricultural producers identify their least productive fields and their current use of those fields in an earlier section of the survey. They are then told of the role of tree planting in mitigating climate change and the terms of a potential contract. Finally, the farmer is asked to respond yes/no to the following question: "Suppose a block tree-planting program is available, and at least one of your fields is identified as a potential site for tree plantations. Would you be willing to accept annual compensation of \$xx per acre for a 10-year contract?"

choice to accept the bid can be written (suppressing subscript i) as

(2) $\Pr(a=1) = \Pr\{v_1(m+\Delta m, s)+\varepsilon_1 > v_0(m, s)+\varepsilon_0\} = \Pr\{(\varepsilon_1 - \varepsilon_0) > -[v_1(m+\Delta m, s) - v_0(m, s)]\}$.

Replacing $[v_1(m+\Delta m, s) - v_0(m, s)]/\sigma$ with Δv and $(\varepsilon_1 - \varepsilon_0)/\sigma$ with ε, where $\varepsilon \sim N(0,1)$ is iid because ε_1 and ε_0 are iid, yields the probit model:

(3) $\Pr(a=1) = \Pr(\varepsilon > -\Delta v) = F_\varepsilon(\Delta v)$,

where F_ε is the normal cumulative distribution function (cdf).

One simplification is made by not including timber benefits in the Δm measure even though the contingent valuation scenario stipulates that trees become a farmer's property when the contract expires. It is assumed that annualized timber benefits will not significantly impact the decision to accept the tree-planting bid as landowners are concerned about realized annual returns and not returns 40 years in the future. While it is acknowledged that positive expected forest rents could lower WTA, it is unclear by how much without significantly more information. Reversed conversion costs will at least partially offset the timber returns. Stump removal and root raking put land out of production for one to two years and require compensation for the production lost. Timber returns also occur relatively far in the future, thus creating a considerable risk premium further offsetting any timber benefits. The alternative to converting the land back to agriculture is keeping it in forestry, which requires a farmer's long-term commitment to growing trees and learning about forestry practices and timber marketing (see Plantinga 1997 for further discussion). Nonetheless, in calculating the cost effectiveness of creating carbon credits, we take into account the value of trees at harvest time (see below).

The decision to accept the proposed compensation is based on the returns from the least productive acre of land, comparing $v_1(m+B-OC, s)$ and $v_0(m, s)$, where B is the bid and OC is the opportunity cost or current per acre agricultural returns and the quantity (B-OC)=Δm. While the opportunity cost represents foregone agricultural net returns from accepting a tree planting program, the total compensation required by the farmer may be increased by other non-market values associated with keeping the land in agriculture and/or reduced by non-market (say, aesthetic) values associated with forestry.

When the least productive acre of land is considered (i.e., the first acre to be made available for tree planting) and assuming linear-in-parameters utility functions, the deterministic parts of the two utility functions can be written as:

$$(4) \qquad v_1(m+B-OC, s) = \alpha_1 + \beta'(m+B-OC) + \delta_1 s$$

$$(5) \qquad v_0(m, s) = \alpha_0 + \beta' m + \delta_0 s$$

Subtracting v_1 from v_0 and dividing by σ gives:

$$(6) \qquad \Delta v(B-OC, s) = \frac{\alpha_1 - \alpha_0}{\sigma} + \frac{\beta'}{\sigma}(B - OC) + \frac{\delta_1 - \delta_0}{\sigma} s,$$

which can be rewritten as

$$(7) \qquad \Delta v(B-OC, s) = \alpha + \beta\,(B-OC) + \delta s,$$

where $\alpha=(\alpha_1-\alpha_0)/\sigma$, $\beta=\beta'/\sigma$ and $\delta=(\delta_1-\delta_0)/\sigma$. This provides an empirical estimate of Pr(a=1) that is also the conditional mean probability of a. E[a| X] is then equal to:

$$(8) \qquad \mathrm{E}[a|\,X] = \Pr(a=1) = \mathrm{F}_\varepsilon\,(\Delta v) = \int_{-\infty}^{+\infty} \phi(\Delta v) = \int_{-\infty}^{+\infty} \frac{1}{\sqrt{2\pi}} e^{\frac{-\Delta v}{2}}\, d\Delta v\,,$$

where X is a vector of exogenous variables, F_ε is the standard normal cumulative distribution function and ϕ is the corresponding probability density function. The log-likelihood function is given generally by:

$$(9)\qquad \log \mathrm{L}(\Delta v) = \sum_{i=1}^{n}\left\{ a\log\left[\int_{-\infty}^{(\Delta v)} h(z_1)dz_1\right] + (1-a)\log\left[\int_{-\Delta v}^{(\infty)} h(z_1)dz_1\right]\right\},$$

where $h(\cdot)$ represents a standard normal distribution function.

Hanemann's approach to deriving farmers' minimum WTA compensation, denoted by B^* is determined as the amount of money needed to keep the farmer indifferent between accepting the bid and retaining marginal land in agriculture. Analogously, one can express this indifference by setting the probability of accepting a bid to 0.5 and solving for B^*,

$$(10)\qquad \Pr(\mathrm{a}=1) = \Pr\{\, v_1(m+B^*-OC, s) + \varepsilon_1 > v_0(m, s) + \varepsilon_0\} = 0.5.$$

From (10), the probability of accepting the bid, B^*, is the same as the probability of rejecting it. Given the symmetric properties of the standard normal cdf,

$$(11)\qquad \Delta v = \alpha + \beta\,(B^*-OC) + \delta s = 0 \Rightarrow B^* = \mathrm{OC} - \left(\frac{\alpha}{\beta} + \frac{\delta}{\beta}s\right).$$

These results facilitate the interpretation of two basic welfare measures, the median and the mean willingness to accept compensation. The median is the value of B that corresponds to $\Pr(a=1) = 0.5$ and is equivalent to B^*. Hanemann (1984) shows that specifying utility as in (4) and (5) results in the mean being equal to the median and ensures that no income effects occur since probabilities are independent of the individual's income.[5]

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[5] The assumption of no income effects (i.e., constant marginal utility of income) is quite common in RUM models to facilitate welfare calculations. Relaxing this assumption has been explored by Herriges and Kling (1999), for example.

5. VARIABLE DESCRIPTION

The explanatory variable of greatest interest is the level of compensation that landowners require. Compensation equals the bid minus opportunity cost ($B–OC$) as noted above. The calculation of opportunity cost deserves further attention. Farmers were asked to provide information for up to four of their least productive fields. Land uses were combined into three categories: pasture, hay and grain (which includes wheat, canola, barley, rye, oats, flax, lentils, peas and summer fallow). Average contribution margins were calculated using crop revenues and variable costs of production for these three commodities; average prices for the past four to eight years were employed.[6] Each field provided by a farmer was assigned an opportunity cost based on how it was used. The opportunity cost is simply the minimum of the value of the least productive fields. These are provided in Table 1.

Landowners could very well obtain positive non-market plus "intangible" benefits from planting trees on marginal land, where the latter might include benefits from having an assured and invariant annual payment, reduced frustration from harvesting hay in difficult-to-get at areas, and so forth. To test the effect of these benefits on the decision to accept a tree-planting program, we examined two regression models – one where the bid and opportunity cost of land are separated and the other where the opportunity cost of land was included with the bid as a single compensation variable.

In addition to compensation, a number of control variables were employed. Two provincial indicators are used to account for differences in jurisdictional factors across provinces (with policy in northeastern B.C. generally following that in Alberta). Soil zone dummy

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[6] Values are based on information supplied by provincial governments; details are found in Suchánek (2001).

variables are used to take into account weather, terrain, soil fertility and other productivity differences. One would expect farmers in the black soil zone to require greater compensation than those in the dark brown and brown soil zones. The reason is that the black soil zone demarcates the transition between the boreal forest and grain belt. While there is a greater capacity to grow trees in this zone, landowners have spent significant effort clearing trees and would likely be the most hesitant to replant (van Kooten, Shaikh and Suchánek 2002). The brown soil zone is characterized by drier conditions, so drought tolerant species will need to be planted; farmers are more likely to view tress more positively for their soil conservation benefits.

A visual scale variable is used to incorporate farmer opinions about the aesthetic benefits of tree cover, which is likely to influence acceptance positively. The value of the visual variable ranges on an integer scale from 1, if the respondent considers increased tree cover in the region to enhance the visual appeal of the landscape, to 5 if she considers additional trees to be visually unappealing.

As the number of acres of farmland covered by trees increases, we postulate that the likelihood of accepting the bid amount will increase since existing tree cover is an indicator of some preference for forest. Likewise, whether or not a respondent had previous experience with tree-planting contracts is thought to have a positive effect on the probability of accepting the bid to plant trees.

Respondents were asked to indicate whether they would adapt to climate change by leaving agriculture altogether. We postulate that those who are most likely to leave agriculture as a response to climate change would be more likely to accept the bid amount. Further, a farmer’s age would likely influence participation positively, as contracts reduce workloads while ensuring a steady income. Increased education, on the other hand, could influence the likelihood of accepting the bid amount negatively, because those with a higher education are more likely to view tree plantations as a restriction on future land-use flexibility.

A priori, one might expect that, when a farmer expects to bequeath the farm to an heir, this will increase participation in tree planting because standing timber is a form of wealth; contrariwise, contracts reduce the long-term flexibility of land use.

Finally, we employ a measure of net worth to capture a farmer's wealth and size and scale of farm operations. Net worth is measured as a categorical variable, with ten categories starting with $100,000 and less, and increasing by $100,000 to a maximum of $1million. It is hypothesized that larger and wealthier farmers are probably less likely to accept a bid to plant trees because so doing would give them greater flexibility to pursue future opportunities.

Summary statistics for the explanatory variables are provided in the last column of Table 2. Not all returned surveys were used in the probit estimation. The design of the survey did not permit those respondents unwilling to accept any compensation to answer the contingent valuation questions. While these responses could be construed as a "no" response for any bid amount, they were not included in this analysis as we are primarily interested in those willing to convert their land. Further research explores these responses as part of the relevant sample. As a result of this and some missing data, only 106 observations were used to estimate WTA.

6. RESULTS

Four regression models were estimated using STATA 7.0, and the results are provided in Table 2. The first model separates the opportunity cost of land from the bid amount, while the second includes the opportunity cost within the compensation variable. For both models, the likelihood ratio χ^2 test indicates that the restricted model is preferred over the general model. To compare the relative statistical fits of the two restricted models, we use Akaike Information

Criteria (AIC) and several goodness of fit measures – McFadden's (1974) Adjusted R^2, Cragg and Uhler's (1970) R^2 and the count R^2. These are calculated as follows:

$$\overline{R}^2_{McFadden} = \left[1 - \frac{L_w - K}{L_\Omega}\right],$$

$$R^2_{Cragg-Uhler} = \left[1 - (L_w / L_\Omega)^{2/N}\right] / \left[1 - (L_w)^{2/N}\right],$$

$$R^2_{count} = \left[\frac{\#\ \ correct\ \ predictions}{N}\right],$$

$$AIC = \frac{-2L_w + 2K}{N},$$

where L_Ω is the log-likelihood in the null case (where all coefficients other than the constant are assumed to be zero), L_w is the unrestricted log-likelihood, N is the number of observations and K equals to the number of parameters in the model. Higher values of R^2 and lower values of AIC indicate better goodness of fit. The results from these comparisons are provided in the last four rows of Table 2, which indicate that the model where opportunity cost is considered as a separate variable is consistently preferred to the model where *OC* is subtracted from the bid amount.[7] Finally, opportunity cost has no statistical impact on the probability of accepting the hypothetical tree-planting program.

In Table 2, the marginal effect of a continuous variable *x* is also computed as:

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[7] Further, the combined compensation (*B–OC*) model is preferred if there is no statistical difference between the coefficients on bid and opportunity cost in the "separated" model. However, this is clearly not the case, indicating that the "separated" model is statistically preferred.

(12) $$\frac{\partial E[y \mid x]}{\partial x} = \left\{ \frac{\mathrm{d}F(\beta x)}{\mathrm{d}(\beta x)} \right\} \beta = f(\beta \bar{x})\beta ,$$

where $f(\,\cdot\,)$ is the standard normal probability density function. As usual, the slope is evaluated at the sample mean $\bar{x}$ since the marginal effect is a function of x. The appropriate marginal effect of a dummy variable (*dum*) is equal to

(13) $$\frac{\partial E[y \mid dum]}{\partial dum} = \Pr[Y = 1 \mid \bar{X}, dum = 1] - \Pr[Y = 1 \mid \bar{X}, dum = 0] ,$$

where the matrix $\bar{X}$ represents all the other variables in the probit model evaluated at their sample means.

Three coefficient estimates are significant at the 1% significance level (Table 2). As expected, per acre compensation (or compensation minus forgone agricultural returns) has a significant positive effect on the probability that a respondent accepts the bid amount. A one-dollar increase in the difference between the offered bid and forgone agricultural returns implies an increase of between one and nearly two percent in the probability of accepting the bid. The more trees a farmer already has, the more likely she is to accept the opportunity to plant more trees, as hypothesized. However, the effect of an additional acre of tree cover produces only a small (less than 0.5 percent) increase in the likelihood that the respondent accepts the bid to plant more area to trees.

The variable that has the greatest positive impact on the probability of accepting a tree-planting program is whether land is located in the brown soil zone as opposed to the black soil zone. The effect of being in the dark brown soil zone is similar to that of being in the black soil zone, as the estimated coefficient of dark brown soil zone is statistically insignificant. Trees occur naturally and are common in the black (most northerly) and dark brown soil zones, but are less common in the (most southerly) brown soil zone. It is not surprising, therefore, that landowners in the brown soil zone who have spent less time removing trees, are more likely to accept the bid amount. As shown by van Kooten, Shaikh and Suchánek (2002), farmers in the black soil zone even appear negative towards tree planting because these are seen as an obstacle to farm operations, while in the drier brown soil zone they act as shelterbelts and watersheds.

Older agricultural producers are more likely to accept a tree-planting program that provides more secure and consistent annual payments. The coefficient on age is statistically significant at the 5% significance level. An increase in age category increases the probability of accepting the offered compensation by about 1½ percent.

The visual variable is negative and statistically significant at the 10% level. This implies that, for a farmer who perceives further increases in local tree cover as visually unappealing, the probability of accepting a bid to plant trees is lower than for a farmer who is fond of trees. The marginal effect on the probability to accept for a one-step increase on the scale of the visual variable is approximately 11 percent. So the difference in probabilities of accepting a bid to plant trees between a farmer who very much enjoys the visual aesthetics of trees and one who prefers a more open landscape can be as high as 22%.

Whether or not a respondent indicated she would leave agriculture if projected climate change became a reality was statistically significant at the 10% significance level.[8] As expected, those indicating they would consider leaving agriculture were more likely to accept the stated bid, with the probability of accepting the bid increasing by some 15-17 percent.

Surprisingly, the proxy income variable, net worth, does not appear to affect the

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[8] Respondents were provided a future climate scenario where average temperatures were 3oC higher, soil moisture was 10% lower on average, the growing season averaged 15% longer, and variability around the new means was similar to current experience.

probability of accepting a tree-planting program. While a higher net worth leads to a lower likelihood of accepting the bid, as expected, the estimated coefficient is not statistically significant except at the 10% level in the general model with *OC* treated as a separate variable.

Provincial dummy variables turned out to be statistically insignificant, possibly because soil zone captures some of this impact, but also because agricultural programs tend to be similar across the Canadian Prairies, despite the different political jurisdictions and separate agricultural ministries. Whether the landowner will pass the farm to an heir does not appear to be a significant variable, suggesting that continuation of the family farm is unimportant in explaining the decision to accept a tree-planting program – the benefit of passing along added wealth in the form of standing timber may be offset by the loss of flexibility in the way offspring can use land. Further, neither previous experience with a tree-planting program nor education affects the likelihood of accepting the proposed bid.

Finally, the estimated results can be used to compute the minimum amount of compensation required to make the respondent just indifferent between accepting and rejecting a tree-planting program (as discussed above). This amount is both the mean and median WTA and is, therefore, referred to as the expected WTA. It can be calculated as:

$$(14) \qquad B^{*} = -\left(\frac{\hat{\alpha}}{\hat{\beta}} + \frac{\hat{\delta}}{\hat{\beta}}s\right) \qquad \text{or} \qquad B^{*} = OC - \left(\frac{\hat{\alpha}}{\hat{\beta}} + \frac{\hat{\delta}}{\hat{\beta}}s\right),$$

depending, respectively, on whether or not opportunity cost of land is separated from or included in the compensation variable. Using (14), it is possible to calculate the expected compensation level for each respondent in the sample. We calculate median WTA for each respondent and provide the mean, standard deviation, minimum and maximum values in Table 3 for each of the two restricted models. The average compensation required to get farmers to plant blocks of trees is \$33.54 per acre (or \$34.93/ac if estimated parameter values are random and Monte Carlo simulation is used) if *OC* is treated separately and \$36.23 per acre if it is not. The estimated maximum compensation required, on the other hand, could be as high as \$105.33 per acre (or higher). It is important to keep in mind, however, that this pertains to the least productive acres and that compensation to plant large blocks of trees might well be much higher as increasingly better agricultural land is converted to tree cover.

7. COST-EFFECTIVENESS OF TREE PLANTING ON AGRICULTURAL LANDS

Using data from Table 3, it is possible to determine whether it would be cost-effective to pay farmers in western Canada to plant trees to mitigate climate change. To do so, we employ a 40-year time horizon using the growth functions illustrated in Figure 1.[9] The growth functions represent a fast-growing species (hybrid poplar) and a mix of native species (see van Kooten et al. 2000; van Kooten, Binkley and Delcourt 1995). Native species are generally more attractive from a visual and ecological perspective. Carbon in wood biomass amounts to 0.187 metric tons of carbon (tC) per m^3 for hybrid poplar and 0.203 tC/m^3 for the slower growing native species. In addition, a factor of 1.57 is assumed to account for total above ground biomass, while soil carbon is assumed to increase at a rate of 0.96 tC per ha per year when marginal agricultural land is converted to forest (van Kooten et al. 2000).

Unlike a reduction in CO_2 emissions, which results in a permanent decrease in the rise of atmospheric CO_2, carbon uptake in sinks is not permanent (land can easily be converted back to agriculture releasing stored carbon). To take into account the ephemeral nature of tree planting,

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[9] We recognize that, in the WTA question, tree-planting contracts were specified to run for 10 years, not 40 years. Yet, we assume the longer time horizon, implicitly assuming contracts are renewed under the same conditions, in order to estimate the costs of creating carbon credits.

the IPCC (2000) recommends using ton-years, with the conversion factor ranging from one permanent ton being equivalent to 50 to 150 ton-years of temporary storage. Many observers have condemned the ton-year concept on various grounds, and it has been rejected by most countries, primarily because it disadvantages carbon sinks relative to emissions avoidance (Dutschke 2002, p.395).

A second method that has been proposed is the use of temporary carbon emission reduction credits, which under an EU proposal would last for a period of five years. A country claiming such credits during Kyoto's first commitment period would be held responsible for them in ensuing commitment periods.

A third proposal for dealing with the ephemeral nature of biological carbon sinks is due to Marland, Fruit and Sedjo (2001), and Sedjo and Marland (2003). They suggest that the temporary nature of carbon uptake in sinks can be addressed via a rental market for credits, where the rental rate (r) is simply the price of a permanent emission credit (P) multiplied by the discount rate (δ), which equals the established financial rate of interest adjusted for the risks inherent to carbon uptake (e.g., fire risk, slower than expected tree growth, etc.). Thus, $r = P \times \delta$, which is the well-known bond formula. If emissions trade for \$15 per t CO_2, say, and the risk-adjusted discount rate is 10%, then the annual rental for a metric ton of CO_2 in a terrestrial sink would be \$1.50. Like the ton-year concept, this approach may make terrestrial sink projects less attractive than they might be under some other political solution.

Since we do not know the value at which CO_2 emissions trade, we employ the ton-year concept, using a conservative conversion factor of 50 ton-years of temporary to one ton of permanent removal of atmospheric CO_2. Costs of carbon uptake are calculated using estimated planting costs of \$1,050 per hectare and costs half that amount (see Agricultural Utilization

Research Institute 1997), and annual payments to landowners (in lieu of opportunity costs) from Table 3. Costs are discounted at 4%, while physical carbon is discounted at rates of 0%, 2% and 4%. Krcmar et al. (2003) estimate stumpage rates in Alberta (using Government of Alberta methodology) of $8.52 per cubic meter for coniferous wood used in lumber production and $0.50/m^3 for deciduous timber used for oriented strand board (OSB). Since these are conservative as they are rates intended to capture the resource rent, we also assume higher net stumpage value (returns after harvest costs) of $20/m^3 and $30/m^3 for conifers (natives) and $10/m^3 and $20/m^3 for poplar (van Kooten et al. 2000).

In Table 4, we provide estimates of the costs of carbon uptake in Canadian dollars per metric ton of CO_2 for low, medium and high stumpage values, three different rates for discounting future CO_2 removals from the atmosphere (above and below ground biomass are included in calculations of carbon uptake), two tree planting options, and alternative plantation establishment costs. In addition, we compare results where the landowner is paid according to willingness to accept compensation and an opportunity cost of land of $50 per acre, with the latter determined as a weighted average of land in pasture (40%), hay (40%) and grain (20%). The costs of carbon uptake by afforestation in western Canada range from net benefits from tree planting to a cost of nearly $70 per t CO_2 for fast-growing hybrid species, to some $30–$106 per t CO_2 for slow-growing native species, and then only if compensation is based on landowners' WTA. If landowners are compensated according to the opportunity cost of land, costs rise to $34.33–$84.09 per t CO_2 for hybrid species under a low (but perhaps most realistic) stumpage value scenario, to $5.31–$30.10 per t CO_2 for the most optimistic stumpage value scenario.

Emission reduction permits are expected to trade in the range of $15 to $30 per t CO_2, or even lower if sufficient "hot air" is available from Russia and the U.S. stays out of carbon markets.

In that case, the results suggest that landowners in western Canada are unlikely to make a major contribution to Canada's Kyoto targets even if marginal agricultural lands are planted to fast-growing hybrid species. If stumpage prices for poplar are similar to those of conifers or higher, planting costs are not "too high", and landowners are compensated according to their willingness to accept compensation as opposed to the opportunity cost of land, then some planting of hybrid poplar will be competitive with emissions reductions for mitigating climate change. Clearly, there is no room to plant native species as these will not be able to compete with emissions reduction strategies. Nonetheless, our cost estimates for native species are not outside the range of estimates of the costs of carbon uptake in forest sinks found in the literature (Manley, van Kooten and Smolak 2003).

One important result of our analysis is that, if governments or large industrial emitters seeking carbon credits through biological sinks wish to minimize outlays, they should consider compensating landowners according to their WTA instead of the opportunity cost of land. This could save between one-third and two-thirds of the costs of implementing an afforestation program. However, it will require identifying those landowners who would be willing to participate in tree-planting programs, which could be done through a bidding process.

8. CONCLUSIONS

An empirical random utility maximization model was used to examine factors affecting farmers' decisions to accept a tree-planting program on their marginal land. The proposed program provides economic, social, environmental and carbon-uptake benefits and is implicitly paid for by the government. Results show that, in addition to personal characteristics such as age, attitudes toward climate change and visual amenities, the probability of acceptance of a hypothetical tree-planting contract is affected by the compensation offered, net worth and existing tree cover. While farmers are unwilling to plant blocks of trees on their land without financial incentives, these incentives appear to be less than the average opportunity cost of land (compare Tables 1 and 3). This is because some farmers receive non-market benefit from growing trees.

This research provides useful information for policy makers interested in comparing the costs of various strategies for reducing CO_2 emissions. First off, the research demonstrates the need for contingent valuation to address unobservable non-market benefits that could reduce the compensation needed to entice farmers to cease production on marginal and/or environmentally sensitive land. Further, it demonstrates that, even when landowners have some preference for forestry, the cost of providing carbon offset credits by planting native species of trees on marginal agricultural land in western Canada is likely higher than socially desirable: estimates of the costs of creating carbon credits by planting trees are more than likely to exceed the price projected under CO_2 emissions trading schemes. This is generally but not always true even if farmers' WTA compensation is below the opportunity cost of land, because they receive other benefits (environmental amenities, reduced risk, potential earnings from sale of timber) from planting trees.

Finally, further research needs to examine other important factors that influence farmer decisions and, in turn, the amounts of land available for tree planting in Canada. Critical in this regard is the attitude of landowners and environmental groups to large-scale planting of fast-growing hybrid species, an object of future contingent valuation research. Also critical are the mechanisms and institutions used to compensate landowners, such as whether farmers receive direct payments from government, a private corporation or an environmental NGO, whether they can sell emission offset in open markets, and/or whether they form cooperatives to market carbon credits or tree plantations (see van Kooten, Shaikh and Suchánek 2002).

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Table 1: Opportunity Cost Values For A Given Land-Use.

Land Use	Opportunity Cost
Pasture	$42. 00/acre
Hay	$47. 25/acre
Grain	$71. 85/acre

Table 2: Probit Estimation Results (106 observations)[a]

	Separate opportunity cost			Opportunity cost subtract from bid		
	General	Restricted		General	Restricted	
Explanatory Variable	Est. coef.	Est. coef.	Mar.eff.	Est. coef.	Est. coef.	Mar. eff.
Constant	-3.303**	-4.206***	—	-1.080	-1.585	—
	(-2.04)	(-3.30)		(-0.85)	(-1.50)	
Compensation offered	0.050***	0.048***	0.018***	0.034***	0.030***	0.012***
	(4.50)	(4.62)		(3.89)	(3.86)	
Opportunity Cost	-0.008	—	—	—	—	—
	(-0.61)					
Alberta (=1; =0 otherwise)	-0.256	—	—	-0.327	—	—
	(-0.64)			(-0.88)		
Manitoba (=1; =0 otherwise)	0.024	—	—	0.380	—	—
	(0.967)			(0. 71)		
Brown soil zone (=1; =0 otherwise)	1.298**	1.262***	0.471***	1.192**	1.047***	0.399***
	(2.40)	(2.94)		(2.36)	(2.57)	
Dark Brown soil zone(=1;=0 otherwise)	-0.005	—	—	0.021	—	—
	(-0.01)			(0.05)		
Forest landscape visually unappealing	-0.269	-0.293*	-0.110*	-0.260	-0.301*	-0.115*
	(-1.48)	(-1.66)		(-1.49)	(-1.79)	
Acres of farmland covered with trees	0.008**	0.007***	0.003***	0.007***	0.006***	0.002***
	(2.49)	(2.58)		(2.58)	(2.61)	
Respondent would leave agriculture if climate change became a reality (=1; =0 otherwise)	0.390	0.443*	0.167*	0.353	0.386*	0.147*
	(1.53)	(1.84)		(1.41)	(1.66)	
Respondent previously participated in a tree-planting program (=1; =0 otherwise)	-0.224	—	—	-0.291	—	—
	(-0.62)			(-0.86)		
Number of years of post-secondary education	-0.099	—	—	-0.123	—	—
	(-1.03)			(-1.34)		
Age (median category variable from 33 to 68 years with 5-year intervals)	0.041**	0.040**	0.015**	0.038**	0.036**	0.014**
	(2.34)	(2.40)		(2.26)	(2.28)	
Respondent expects a heir to continue farming (=1; =0 otherwise)	-0.113	—	—	-0.095	—	—
	(-0.31)			(-0.28)		
Net worth	-0.859*	-0.792	-0.298	-0.683	-0.569	-0.217
	(-1.63)	(-1.59)		(-1.36)	(-1.20)	
# of observations	106	106		106	106	
Log likelihood	-44.216	-45.177		-48.080	-50.011	
Likelihood ratio χ^2(df)		1.92(7)			3.86(6)	
McFadden Adjusted R^2		0.264			0.197	
Cragg-Uhler R^2		0.538			0.461	
Count R^2		0.774			0.755	
AIC		1.003			1.095	

[a] z-statistics in parentheses: *** indicates statistical significance at the 1% level or better; ** indicates significance at 5% level or better; * indicates significance at 10% level or better.

Table 3: Estimated Median Willingness to Accept a Tree-planting Program ($/acre)[a]

Model	Average of Median	Standard Deviation	Minimum	Maximum
Separate opportunity cost				
Estimated parameter values fixed; WTA based on farmers' covariates	\$33.54	\$18.17	\$–21.85	\$72.51
Estimated parameter values random; representative farmer covariates (Monte Carlo simulation: *n*= 10,000)	\$34.93	\$41.14[b]	\$–145.98	\$874.18[b]
Compensation equals bid minus opportunity cost[b]				
Estimated parameter values fixed; WTA based on farmers' covariates	\$36.23	\$29.95	\$–29.44	\$105.33

[a] Estimated using restricted models in Table 2.

[b] Based on a single spike in the Monte Carlo simulation

[c] Monte Carlo simulation was not used as the model with separate opportunity costs is preferred.

Table 4: Estimated Costs of Carbon Uptake from Tree-planting in Western Canada (C\$ per t CO_2) [a]

Item	Low Stumpage (\$8.52/m^3 natives; \$0.50/m^3 poplar)			Medium Stumpage (\$20/m^3 natives; \$10/m^3 poplar)			High Stumpage (\$30/m^3 natives; \$20/m^3 poplar)		
C discount rate[b]	0%	2%	4%	0%	2%	4%	0%	2%	4%
WTA = \$33.54 per ha per year									
Planting cost of \$1050 per ha									
Slow growth	58.59	90.64	134.96	50.18	77.63	115.58	42.85	66.30	98.71
Rapid growth	36.40	51.24	68.68	22.46	31.62	42.38	7.79	10.96	14.69
Planting cost of \$525 per ha									
Slow growth	46.24	71.53	106.50	37.83	58.57	87.13	30.50	47.19	70.26
Rapid growth	26.16	36.82	49.35	12.22	17.19	23.05	++	++	++
Opportunity cost = \$50.00 per ha per year									
Planting cost of \$1050 per ha									
Slow growth	78.28	121.11	180.30	69.87	108.10	160.94	62.54	96.76	144.07
Rapid growth	44.57	62.73	84.09	30.63	43.11	57.79	15.96	22.46	30.10
Planting cost of \$525 per ha									
Slow growth	65.93	102.00	151.86	57.52	88.99	132.49	50.19	77.65	115.61
Rapid growth	34.33	48.31	64.76	20.38	28.69	38.46	5.71	8.04	10.77

[a] For hybrid-poplar, trees are harvested after 20 years and again after 40 years, with the ton-years of carbon adjusted accordingly. ++ indicates benefits of tree planting so there are no carbon uptake costs.

[b] Discounting is combined with the ton-years conversion factor as follows: In 1 tC is stored during the first year of growth, it is assumed to remain stored for 40 years (for natives) and is thus counted as 40 ton-years C. In the second year, storing 1 tC is counted as 39 ton-years C, but it is discounted by one period (if the discount rate > 0%). The same is true for subsequent years.

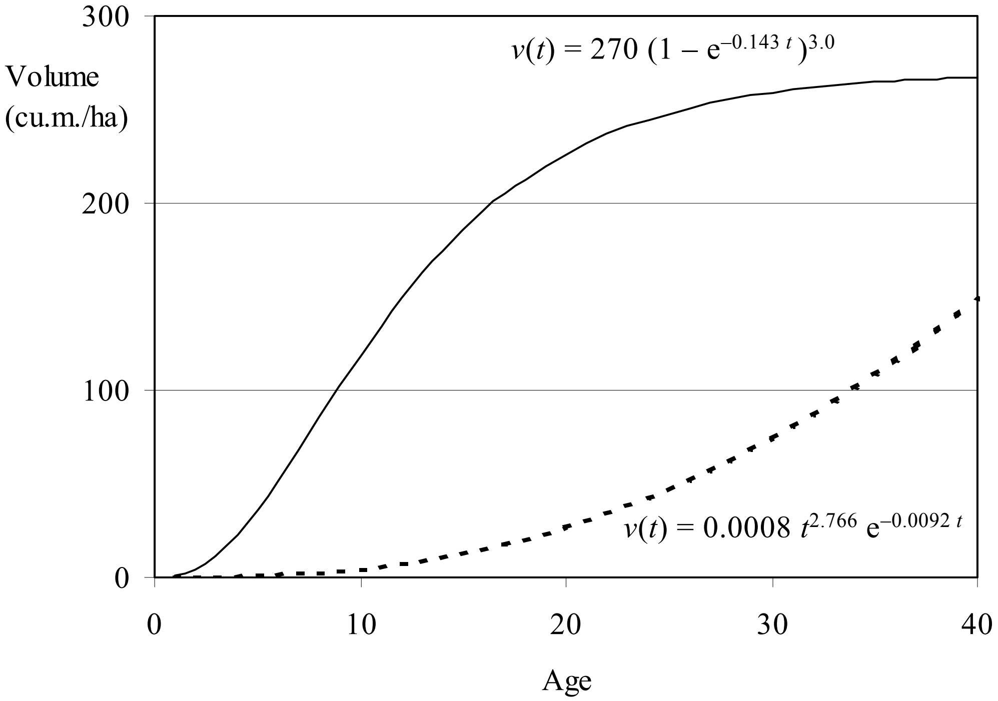

Figure 1: Tree Growth Functions