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Abstract

This research examines effects of various factors on participation in agricultural tree plantations for economic, environmental, social and carbon-uptake purposes. Using survey data from a survey of Canadian agricultural landowners, a discrete choice random utility analysis is used to determine the probability of farmers' participation and corresponding mean willingness to accept compensation for a tree-planting program. Estimation results show that the required compensation for accepting a tree-planting program is higher than the compensation suggested by a normative approach.

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Introduction

Climate change will likely remain a widely debated issue on the agenda of many concerned governments in the world. On scientific grounds, there appears to be consensus that emissions of greenhouse gases, carbon dioxide in particular, are responsible for increasing global temperatures. To mitigate climate change, some countries may increase carbon stored in forest sinks rather than incurring costly emissions reductions. Despite disagreement over the role of terrestrial carbon (C) sinks, management of terrestrial biomass in forests, grasslands and agricultural land could play a role in a country's comprehensive land-use policy. Efficient land-use management in agriculture and forestry requires evaluation in terms of 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 benefits and potential commercial timber benefits, tree planting could provide extra-market benefits such as reduced soil erosion, improved water quality, increased wildlife habitat, riparian buffer zones and aesthetic appeal. Afforestation could thus 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. This is not straightforward for several reasons: (1) there is uncertainty about the costs of tree planting, actual yields and stumpage values due to geographical differences in proximity to saw mills, pulp mills or biomass burning facilities; (2) returns to current investments may accrue in the distant future causing disruptions in income flows that could increase the required compensation; (3) landowners may perceive the financial risks of planting trees to be too great for lack of knowledge and skills; and, (4) by planting trees, farmers may feel that their ability to participate in current and future government agricultural programs is threatened because of their reduced capacity to produce agricultural commodities.

In addition, the compensation amount should include forgone agricultural returns (including any price support or subsidy payments) from the land and any other associated non-market values that the landowner realizes from agriculture. Since non-market values often play a significant role in farming decisions, compensation equal to agricultural rents may not be enough to convince landowners to change their land use. A contingent valuation methodology allows for the incorporation of non-market values and other unobservable opportunity 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 framework is constructed to represent landowners' preferences towards adopting tree planting on their most marginal land. Landowners are offered a compensation bid for removal of land from production. The random utility framework models 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. The applied probit model estimates the probability of accepting a tree-planting program.

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. The paper concludes with model results and discussion of policy implications.

Random Utility Model

Hanemann (1984) derives a theoretical random utility maximization (RUM) framework for analyzing binary data that usually depict an individual's yes or no stand on a particular issue. The basic premise of RUM is that an individual chooses rationally the option that yields the highest utility. Assuming constant prices, the utility of individual *i* can be written as

(1) $u_{i,a}(m, s)$,

where a is the discrete decision $\{a = 1$ if yes; $a = 0$ if no$\}$, m is income, and s represents other observable attributes that set individuals apart.

Hanemann (1984) assumes that an individual knows her utility with certainty, but the yes/no outcome is probabilistic as the researcher will never be able to account for all relevant exogenous variables and variations among individuals. The 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, $\varepsilon_{i,a}$, with

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

where $\varepsilon_{i,0}$ and $\varepsilon_{i,1}$ are i.i.d. random variables with zero means and variance σ^2. The utility function (2) is itself a random variable with mean $\overline{u}_{i,a}(m,s)$. RUM models the difference in utilities of the 'yes' and 'no' alternatives as an underlying continuous index function (Greene 1997). Hanemann (1984) applies the difference in indirect utilities of two alternatives and thus proposes a way of calculating the compensating surplus welfare measure.

Survey of Canadian Farmers

A questionnaire was mailed in July, 2000, to 2,000 randomly selected farmers from the grain belt region of Canada, which includes northeastern British Columbia and all of 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.[1] 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, casting doubt on the overall reliability 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). For a copy of the survey and additional details, see Suchánek (2001).

The survey included a brief, personalized cover letter explaining the purpose of the questionnaire and a definition of carbon credits. In addition to willingess to accept (WTA) compensation for tree planting, the actual survey elicited detailed information on a farmer's agricultural operations, including in particular activities on marginal fields, opinions about and awareness of climate change issues and carbon credits, personal data and so on (Suchánek 2001). Some of the questions were meant to familiarize respondents with the topic and issues under investigation before asking them about their willingness to plant trees.

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

Landowners were presented a hypothetical tree-planting program that covers all costs of tree planting while compensating for lost agricultural production, and offered a “bid” 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). 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. No compensation is provided for conversion of land back to agriculture. The farmers were also asked to respond to a second, follow-up bid for the same program but with a longer contract.

Empirical Model

Farmer *i* will accept a tree-planting project ($a = 1$) as long as

$$v_{i,1}(m+\Delta m, s) + \varepsilon_{i,1} > v_{i,0}(m, s) + \varepsilon_{i,0}, \tag{3}$$

where Δm is the compensation or “bid” (B) offered plus annualized future timber harvest benefits minus forgone annual agricultural benefits (OC), all discounted over the contract period. Since utility is a random variable, the probability distribution of a farmer's choice to accept the bid can be written (suppressing subscript *i*) as

$$\Pr(a=1) = \Pr\{ v_1(m+\Delta m, s) + \varepsilon_1 > v_0(m, s) + \varepsilon_0\} = \Pr\{(\varepsilon_1 - \varepsilon_0) > -[v_1(m+\Delta m, s) - v_0(m, s)]\}. \tag{4}$$

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

$$\Pr(a=1) = \Pr(\varepsilon > -\Delta v) = F_\varepsilon(\Delta v), \tag{5}$$

where F_ε is the normal cumulative distribution function (cdf).[2] Its argument represents the difference in utilities of yes and no responses. 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 matures. It is assumed that annualized timber benefits will not significantly impact the decision to accept the tree-planting bid since the reversed conversion costs offset, at least to some extent, the timber returns. Stump removal and root raking put land out of production for one to two years and require, therefore, 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 farmer's long-term commitment to growing trees and learning about forestry practices, timber marketing or forestry as a whole. As Plantinga (1997) points out, other studies of large-scale tree planting programs also ignore timber benefits even though, “in theory, forestry rents will be capitalized into the value of the land and may therefore decrease the level of required compensation” (pp.270-71).

Therefore, a farmer bases her decision to accept the proposed compensation on 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.[3] Following Hanemann (1984), when the least productive acre of land is considered (i.e., the first acre to be made

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[2] Initially, discrete responses to the two different program levels were modeled using a bivariate probability density function with non-zero error correlation. The two valuation errors were consistently found to be significantly uncorrelated; therefore, the analysis proceeded with single probit estimation for the first program level.

[3] For convenience, the error terms associated with each of the utilities have been dropped.

available for tree planting), the deterministic parts of the two utility functions can be written as:

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

(6)

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

Subtracting v_1 from v_0 and dividing by σ results in

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

which can be rewritten as

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

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:

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

where X is a vector of exogenous variables, F_ε is the standard normal cumulative distribution function and ϕ is the corresponding density function (see Greene, 1997).

The log-likelihood function is given by:

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

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

Hanemann (1984) proposes a conceptual approach for deriving farmer's minimum WTA compensation, denoted by B^*. In effect, this can be accomplished by determining the amount of money needed to keep the farmer indifferent between accepting the bid and retaining her 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^*,

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

In (11), 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 yields

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

This result facilitates 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 (6) 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.[4] Hanemann (1984) ascertains that only the median and mean "are fully compatible with the notion of cardinal utility" (p.336). In the case that they differ, the choice of measure is left to the researcher's discretion.

Variable Description

The variables used in the analysis are summarized in Table 1, but the opportunity cost estimate deserves further attention. Farmers were asked to provide information for up to four of their least marginal fields. Land uses were combined into three categories: pasture, hay and grain (which includes wheat, canola, barley, rye, oats, flax, lentils, peas and summerfallow). Average contribution margins were calculated using crop revenues and variable costs of production for

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[4] The assumption of no income effect (i.e., constant marginal utility of income) is common in random utility models to facilitate welfare calculations, although this has been relaxed in recent research (Herriges and Kling 1999).

these three commodities in different soil zones and provinces; average prices for the past four to eight years were employed.[5] 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 marginal fields. These are provided in Table 2.

Not all returned surveys could be used in the probit estimation. The design of the survey did not permit those respondents unwilling to accept compensation in principle 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 the analysis. As a result of this and some missing data, only 86 observations were used to estimate willingness to accept compensation.

Results

The coefficients of the probit model were estimated using the Maximum Likelihood Module of GAUSS 3.1 (Table 3). The likelihood ratio for overall significance of the model equals 42.12, thereby rejecting, at the 0.05 level of significance (with 13 df), the hypothesis that all coefficient estimates except the constant are equal to zero. The likelihood ratio can also be used to derive a goodness of fit measure, which in this case is equal to 0.37 (Greene 1997). The model accurately predicts roughly 81.5% of observed 'yes' and 'no' answers, based on a threshold probability of a 'yes' response equal to 0.5. That is, if the computed probability of a 'yes' answer is less than 0.5, a 'no' response is predicted; likewise, a computed probability of a 'yes' response greater than or equal to 0.5 indicates a predicted 'yes' response. Compared to a naive model that always predicts a 'yes' or a 'no' response depending on which constitutes the higher sample proportion, the probit model improves predictions by almost 20 percent. A naïve model predicts

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

62% ‘no’ responses.

In Table 3, the marginal effect of a continuous variable x is also computed as (Greene 1997):

$$(13)\qquad \frac{\partial E[y\mid x]}{\partial x}=\left\{\frac{\mathrm{d}F(\beta x)}{\mathrm{d}(\beta x)}\right\}\beta = f(\beta\bar{x})\beta ,$$

where $f()$ 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.[6] The appropriate marginal effect of a dummy variable *dum* is equal to

$$(14)\qquad \frac{\partial E[y\mid dum]}{\partial dum}=\Pr[Y=1\mid \bar{X}, dum=1]-\Pr[Y=1\mid \bar{X}, dum=0],$$

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

Only two coefficient estimates are significant at the 0.05 level (Table 3). The difference between the offered compensation and the forgone agricultural return (on per acre basis) 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 average increase of almost one percent in the probability of accepting the bid. Similarly, the more trees a farmer has, the more likely she is to accept the opportunity to plant more trees. However, the effect of an additional acre of tree cover produces only a 0.1 percent increase in that the respondent accepts the bid to plant more area to trees.

The visual variable is negative and statistically significant at 0.10 level. This implies that,

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[6] Another approach is to compute a marginal effect for each observation and calculate a sample average of the individual effects (Greene 1997).

for a farmer who perceives further increase 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 14 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 56%.

Age, whether the respondent's land is located in the brown soil zone and whether the respondent feels climate change will cause them to leave agriculture have a positive effect on the probability of accepting the bid, albeit at a lower level of statistical significance. A higher net worth, on the other hand, leads to a lower likelihood of accepting the bid.

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:

$$(15) \qquad B^{*} = OC - \left(\frac{\hat{\alpha}}{\hat{\beta}} + \frac{\hat{\delta}}{\hat{\beta}} s \right).$$

Using (15), it is possible to calculate the expected compensation level for each respondent in the sample. The mean of the calculated values of the expected WTA a tree-planting program is \$40.52 per acre, with a standard deviation of 29.99. That is, the average compensation required to get farmers to plant blocks of trees is \$40.52/ac. Interestingly, some farmers in the sample appear willing to pay (as opposed to requiring compensation) as much as \$27.78/ac to engage in tree planting; that is, from (15), minimum average WTA is –\$27.78, indicating that the farmer benefits from tree planting. The maximum compensation required, on the other hand, would be $106.50 per acre. It is important to keep in mind, however, that this pertains to the least marginal acre and that compensation to plant large blocks of trees might well be much higher.

Conclusions

Assuming that a farmer chooses to plant trees on her least marginal field (likely to be in pasture or hay production), compensation would roughly equal the opportunity cost of the land. Not included in the compensation demanded by farmers is the cost of establishing, monitoring and managing a tree-planting program, and such costs would be incurred by farmers if government is unwilling to provide subsidies. Even if timber provided farmers with returns equal to forgone returns from agriculture, farmers appear unwilling to plant blocks of trees on their land without financial incentives, suggesting that there are other, perhaps non-market, costs that need to be compensated (see van Kooten, Shaikh and Suchánek 2001). The main reason for keeping land in agriculture is that forestry appears financially unattractive, but other factors can also play an important role. Research is required to examine these costs in greater detail, and to suggest incentives and mechanisms to make program implementation as effective as possible (see van Kooten, Shaikh and Suchánek 2001).

The extent to which afforestation of marginal agricultural land in the grain-belt region of Canada can contribute to domestic carbon emissions reduction remains unknown for lack of knowledge about the supply relationship. However, we can get some notion of the costs of carbon uptake. Ignore what happens to trees at harvest time. If native tree species are planted, it takes some 80 years for trees to reach maturity. Average growth amounts to about 1.0 m^3 per acre, while 0.200 tonnes of carbon (tC) are sequestered per m^3. Thus, an annual average of 0.2 tC/ac is sequestered. The corresponding figure for hybrid poplar, which has a rotation age of 15 years, is nearly 1.0 tC/ac per year. Planting costs are between $600 and $800 per acre, or, using a 4% discount rate, annualized costs are $23.00-$30.67 for native species and $15.43-$20.57 for hybrid poplar (because of the shorter rotation). This implies that, once compensation is added in, costs of carbon uptake amount to $317.60-$355.45 per tC for native species and $55.95-$61.09 per tC for hybrid poplar. Costs of carbon uptake in either case are quite high, although hybrid poplar could possibly be competitive if carbon credits become more valuable in the future (Henri 2001).

Suppose that no tree-planting projects are to be funded if costs exceed $50/tC. Does this mean that no afforestation should be done? The answer is no, because there are landowners who would accept lower levels of compensation than $40.12/ac per year. Again, the problem is one of creating the appropriate institutions and economic incentives that identify these landowners.

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Table 1: Definitions of Variables.

Name	Variable Description
Compensation	Compensation offered in the first question minus opportunity cost.
ProvAB	= 1 if respondent farms in Alberta or British Columbia; zero otherwise.
ProvMB	= 1 if respondent farms in Manitoba; zero otherwise.
Soilbr	=1 if respondent farms in brown soil-type zone; zero otherwise.
Soildb	=1 if respondent farms in dark brown soil zone; zero otherwise.
Visual	A scale variable with values 1 … 5. Value =1 if respondent strongly disagrees with the statement that increased tree cover in the region will detract from the visual appeal of the landscape, and 5 if respondent strongly agrees; zero corresponds to "no opinion" or "do not know".
Trees	Number of acres of farmland covered with trees.
Leave	=1 if respondent would leave agriculture if a warmer climate change scenario became a reality; zero otherwise.
Previous	=1 if respondent previously participated in a tree-planting program; zero otherwise.
Education	Number of years of post-secondary education.
Age	Median of age category variable (from 33 to 68 years with 5-year intervals)
Heir	=1 if respondent expects one of their children to continue farming; zero otherwise.
Networth	Normalized median of a networth category (from \$50,000 to \$1,000,000 with \$100,000 intervals)

Table 2: 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 3: Probit Estimation Results (n=86)

Variable	Coefficient estimate[b]	Marginal effect
Constant	–1.1548	–
	(–0.891)	
Compensation[a]	0.0338	0.009
	(3.288)	
Age[a]	0.0287	0.003
	(1.430)	
Trees[a]	0.0028	0.001
	(2.251)	
Soilbr	0.7056	0.271
	(1.146)	
Visual[a]	–0.3573	–0.142
	(–1.758)	
Leave	0.3792	0.086
	(1.229)	
Education[a]	–0.1074	–0.042
	(–1.059)	
Networth[a]	–0.3066	–0.122
	(–1.596)	
ProvAB	–0.4247	–0.149
	(–0.883)	
ProvMB	0.0418	0.015
	(0.067)	
Soildb	–0.1266	–0.045
	(–0.278)	
Heir	0.2332	0.083
	(0.558)	
Previous	–0.1735	–0.063
	(–0.438)	
Log likelihood ratio	42.12	
Predicted correct responses	70	
% correct responses	81.5	

[a] Indicates a continuous variable.

[b] Assymptotic t-statistics in parentheses