Mitigating Climate Change by Planting Trees: The Transaction Costs Trap

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ABSTRACT. *Land-use change and forestry projects are considered a low-cost option for addressing climate change mitigation. In Canada, afforestation is targeted to sequester enough carbon to meet one-fifth of its international obligations, and at lower cost than emissions reduction. We examine economic aspects of the institutions and incentives needed to encourage landowners in Canada to adopt tree planting on a large scale. Based on data from a survey of landowners, the transaction costs of getting landowners to convert their land from agriculture to plantation forests appear to be a significant obstacle, possibly increasing the costs of afforestation projects beyond what conventional economic analysis suggests.* (JEL Q25)

I. BACKGROUND

Land-use change and forestry (LUCF) projects that result in greater carbon storage in terrestrial ecosystems are widely seen as a low-cost alternative to CO_2-emissions reduction for mitigating climate change (Obersteiner, Rametsteiner, and Nilsson 2001; Sohngen and Alig 2000; Chomitz 2000; Frumhoff, Goetze, and Hardner 1998). While terrestrial carbon storage was given an expanded role as a result of COP6-II in Bonn, in July 2001, it remains unclear what role such sinks will play under Kyoto's Clean Development Mechanism (CDM)—where rich countries sponsor carbon-offset projects in developing countries—and under Joint Implementation (JI), which involves shared projects in industrial countries (Moura-Costa 2001). Nonetheless, industrialized countries can now pursue a wide range of domestic LUCF projects. These favor countries with a large land base and low population density. Thus, Canada envisions meeting 22% of its Kyoto commitment through terrestrial sinks (Canadian Pulp & Paper Assoc. 1999).

In principle, a country should get credit only for sequestration above and beyond what occurs in the absence of carbon-uptake incentives, a principle referred to as "additionality" (Chomitz 2000). Thus, carbon (C) sequestered as a result of incremental forest management activities (e.g., juvenile spacing, fire control, fertilization) would be eligible for C credits, but only if the activities would not otherwise have been undertaken (say, to provide higher returns or maintain market share). Similarly, afforestation projects are additional if they provide environmental benefits (e.g., regulation of water flow and quality, wildlife habitat) not captured by the landowner and would not be undertaken in the absence of economic incentives, such as subsidy payments. The case for additionality is easier to make for tree planting on agricultural land than for enhanced management of extant forestland (Caspersen et al. 2000).

Estimated costs of LUCF options depend on where they are located, and whether they occur in developing or developed countries. Frumhoff et al. (1998) identify potential LUCF projects in a number of developing countries, with costs ranging from negative values to about $10 per tonne C (tC). LUCF projects that result in negative costs of C uptake are generally high-yielding plantation forests that do not meet the test of addition-

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ality, because they should be undertaken even in the absence of C-offset incentives. There are other LUCF projects in developing countries that do meet the additionality test and can be pursued at costs of less than $25 per tC. Afforestation projects in industrial countries, including those in transition, can be pursued at costs of $5–$136 per tC (Sohngen and Alig 2000; Henri 2001). While some energy (emissions reduction) projects that result in reductions in CO_2 emissions can be pursued at very low cost, their extent is limited in terms of global CO_2 targets. The consensus opinion is that most energy projects are more costly to undertake than LUCF projects (Obersteiner, Rametsteiner, and Nilsson 2001; Henri 2001).

Traditional economic techniques are used to estimate the costs of carbon sequestration related to LUCF projects, but they generally assume transactions are costless. In the case of afforestation in industrialized countries, for example, it is assumed that land can be transferred from agriculture into forest plantations (or back to agriculture) seamlessly—that there is no resistance from farmers and no unaccounted for costs related to the mechanism used to encourage landowners to plant trees. However, the costs of capturing and protecting property rights and transferring them from one agent to another—the transaction costs—are not zero. The transaction costs include ''the costs of discovering exchange opportunities, negotiating contracts, monitoring and enforcing implementation, and maintaining and protecting the institutional structure'' (Pejovich 1995, 84). They consist of the costs of arranging a contract *ex ante* and monitoring and enforcing it *ex post*, as opposed to production costs, which are the costs of executing a contract.

One purpose of this paper is to argue that there are indeed transaction costs associated with plantation forests in developed countries that could make them more costly than originally anticipated. Unanticipated transaction costs could also thwart attempts by governments to implement afforestation on a large scale. To examine this issue, we employ results from a survey of agricultural landowners in western Canada.

We begin in the next section by demonstrating that LUCF projects in Canada generally meet the test of additionality. However, the success of any program to induce landowners to change their land use will depend on how it is packaged. What role do transaction costs play, and what influences them? What incentives and institutions are needed to get landowners to adopt large-scale tree planting programs, and keep the costs of such programs to a minimum? These issues are addressed from a theoretical perspective in Sections 3 and 4, where we apply ideas from the new institutional economics (NIE) to the problem of contracting to plant trees. In Section 5, we employ the results of a survey of landowners in western Canada to provide insights concerning transaction costs and the design of appropriate institutions and economic incentives for creating additional terrestrial carbon sinks at least cost. Our conclusions follow.

II. ECONOMICS OF TREE PLANTING ON AGRICULTURAL LAND IN CANADA

One can determine whether or not afforestation meets the ''additionality'' test by making a few simple calculations. Consider first planting native white spruce and aspen on marginal agricultural land in Canada's forest-grain belt transition zone located at the northern extent of the Great Plains (see van Kooten et al. 2000). Current marginal agricultural activities in the region (generally grazing and hay production) can be replaced with plantations of native spruce and aspen or plantations of rapid-growing hybrid poplar. Rough calculations of the costs and benefits of switching from marginal agricultural activities to one of these tree crops are provided in Table 1. These indicate that, while there may be external benefits from planting spruce and aspen (reduced soil erosion, biodiversity, carbon uptake), planting will not occur without subsidies, since landowners would lose at least $500 per ha. Switching land use from the marginal agricultural activity to hybrid poplar, on the other hand, appears to result in a net gain of $450 per ha or more.

If hybrid poplar does indeed yield higher

TABLE 1
APPROXIMATE ECONOMICS OF TREE PLANTING ON MARGINAL AGRICULTURAL LAND IN CANADA[a]

Item	Spruce/Aspen	Hybrid Poplar
Harvest age	80 years	15 years
Yield at harvest age	180 m^3 per ha	190 m^3 per ha
Assumed stumpage price	\$40 per m^3	\$25 per m^3
Discounted return	\$320 per ha	\$2600 per ha
Opportunity cost of land[b]	\$330 per ha	\$156 per ha
Planting costs	\$500–1500 per ha	\$1500–2000 per ha
Approx. net returns per rotation	−(\$510–1510) per ha	\$450–950 per ha
Net discounted returns in perpetuity	−(\$530–\$1575) per ha	\$1000–2100 per ha

[a] Future costs and benefits are discounted at 4%.
[b] Assumes current use of land is native pasture that permits two animal unit months of grazing per ha per year, valued at \$7 each.
Source: Derived from data in van Kooten et al. (2000)

long-run net returns than extant agricultural activities, why have landowners not adopted this land use? There are some possible reasons. First, there remains uncertainty about the costs of tree planting, yields and stumpage values. Costs and benefits will vary by geographical location, including nearness to saw mills, pulp mills or biomass burning facilities. Second, returns to current investments accrue in the distant future, so the landowner's income stream is not regular. This could explain van Kooten's (2000) conclusion that it might take 25 to 40 years (or longer) for Canada to reach its C-uptake potential through an afforestation program. Third, landowners may perceive the financial risks of planting hybrid poplar to be too great. Fourth, by planting trees, farmers may feel that their ability to participate in future government agricultural programs is threatened, since eligibility for programs is generally based on land use and historic yields (and forestry is excluded). Finally, the despite positive benefits of forests (e.g., reduced soil erosion), relative to native species the negative environmental effects of hybrid poplar plantations, such as reduced biodiversity and susceptibility to disease (Callan 1998), limit their viability as an alternative land use.

Afforestation projects in Canada appear to meet the additionality condition: To get landowners to plant trees, it will be necessary to provide subsidies or other incentives. To be effective and competitive with other methods of reducing CO_2 in the atmosphere, it will be necessary to implement the "right" policies. What are the prospects?

III. TREE PLANTING ON AGRICULTURAL LAND: COORDINATION MECHANISMS

Neoclassical economics assumes that decision-makers are rational economizers who have perfect knowledge; markets are perfectly competitive, homogeneous goods are traded and prices embody all of the needed information; transaction costs are ignored as is market failure more generally. The new institutional economics (NIE) differs from neoclassical economics in some fundamental ways (Acheson 1994).

- The NIE takes the position that economic agents are rationally bounded, while information is costly to obtain. Agents do not have perfect information but are often opportunistic, acting in their own self-interest with guile. People are only weakly rational and weakly moral, often withholding information when it is in their interests to do so (Acheson 1994, 8). Bounded rationality and opportunism *cause* transaction costs (CPB 1997, 46). Yet, transactions take place even though information is incomplete or distorted. Further, people do not always have exclusive rights to what is traded (e.g., to carbon credits), which then becomes a source of uncertainty and leads to incomplete contracting.

- There are costs to using markets because of market imperfections and outright market failure.
- In many transactions (including ones that deal with provision of tree planting services), price is not the sole consideration. There exists a range of social and legal ties among people, and extra-market benefits are common. For example, in the Peace River region of northwestern Alberta and northeastern British Columbia, tree planting is probably looked upon negatively because farmers are adverse to planting trees that took their fathers great pain to remove, while those traveling through the region benefit from a visually appealing, diverse landscape that came about as a result of land clearing.
- Finally, a key assumption of the NIE is that institutions have a strong impact on the economic system and that institutions are often the result of political processes.

Four economic coordination mechanisms are available for addressing below socially optimal tree planting in agriculture: competition, command and control (C&C), cooperative exchange (contracts), and common values and norms (CPB 1997). C&C refers to state ownership or outright regulation, while competition relies on market-type incentives that are created with or without state intervention.[1] Cooperative exchange, and common values and norms, are intermediary between the extremes of competition and C&C, although there is overlap among all of the coordination mechanisms. Competition may be more appropriate in a heterogeneous society, while common values and norms develop more easily in a homogeneous society (CPB 1997, 42–44). In Sweden, for example, moral suasion and education (values and norms) are used in lieu of regulation to get many small forestland owners to supply nature (greater biodiversity) despite reduced commercial timber benefits; in other jurisdictions, onerous regulations are required (see Wilson et al. 1998).

Each of the coordination mechanisms has its potential strengths and weaknesses. Regulation appears to be the path of least resistance for governments, because it is used more frequently than other means. Perhaps governments perceive that regulation will lead to the desired amount of C-uptake at least cost to the public treasury; for example, policymakers may consider it a simple and inexpensive matter to mandate that landowners plant trees on some proportion of their land.[2] The state could also purchase land and plant trees itself, but then incentives are lacking to minimize costs (Shleifer 1998) and the costs to the treasury could be substantial.

State intervention through regulation or outright land purchase can be justified on efficiency grounds if there are savings in transaction costs that exceed the gains from using other means for achieving the C sink objective, or if there are economies of scale and scope that would not be realized otherwise. For example, Graham (2001) shows that, if wood waste in northern British Columbia is to be used in a biomass burning facility, economies of scale may not be realized unless a certain minimum area of agricultural land near the facility is converted to trees.[3] Economies of scope occur because it may be more efficient to provide two amenities, say commercial timber benefits and extra-market amenities (C uptake and storage), together rather than separately. The state can guarantee that such economies are realized. Thus, society is more certain that the desired good or service is supplied. However, lessons from the NIE indicate that the heavy hand of government intervention could just as well lead

[1] Forest certification is an example of a competitive structure that arose without any government intervention (see Cashore, Auld, and Newsom 2001). However, state intervention is required for C offset markets to develop, as noted below.

[2] It may be required for the landowner to remain eligible for agricultural programs, say, but a stronger regulatory fist can also be used. In Denmark, for example, landowners are prohibited by law from converting forestland back to agriculture, which has discouraged participation in EU tree planting programs.

[3] In this case, waste wood comes from timber of too high a quality to be burned to produce energy, so lower-quality fibre from plantations on marginal agricultural land is needed to realize economies of scale in biomass burning.

to policy failure and not to correction of externality; C&C can result in inefficiency due to rigidity, inadequate experimentation and lack of incentives (CPB 1997).

Competition is made possible if states use broad-based incentives to obtain afforestation services, and these could be implemented in the context of private trading. But even if society relies solely on competition and markets, there is still a role for government. Before a landowner can sell C offsets (say to a private demander, such as a utility company), the state needs to establish the market for offsets (e.g., by separating the right to carbon from the right to the trees) and its bounds (e.g., establishing a cap on terrestrial C credits). The government can also use a carbon tax/subsidy scheme to provide the correct incentives to landowners (van Kooten, Binkley, and Delcourt 1995), letting the market decide how much terrestrial C is supplied. In addition, futures and insurance markets could be used to provide some protection against political whims and the vagaries associated with the production of carbon uptake that are inevitable due to future uncertainty about tree growth, fires and disease, and carbon and fiber prices.

One advantage of relying on competition to provide terrestrial C-sink services is that society may get greater diversity in the types (qualities) of sinks provided, particularly if wood product sinks are permitted and/or biomass burning becomes increasingly attractive. Competition encourages cost minimization, making domestic terrestrial carbon sinks more competitive with LUCF projects in other countries or energy projects. On the negative side, competition may inhibit economies of size and scope. Further, uncertainty and lack of commitment may characterize competition, with land use apt to return to the original agricultural use if appropriate market institutions (e.g., markets for C offsets, future and/or insurance markets) are not in place.[4] A country cannot know with any degree of certainty at the time it implements this coordination mechanism how much carbon offsets are available at some future commitment period.

For reasons of political acceptability, common values and norms, and contracting, are likely the most important coordination mechanisms in practice. Commitment is an obvious strength in the case of common values and norms, while enforcement is a problem, particularly with contracting. We discuss contracting in more detail in the next section.

Provision of C-uptake services (carbon offsets) is not costless, but it could be made costlier by inappropriate choice of a coordination mechanism. The ability to implement a coordination mechanism (if at all) depends crucially on existing institutional arrangements, or governance structure, within the jurisdiction. It is not possible to implement a system of transferable carbon credits if governments do not establish ownership rights to carbon and if private property rights are not enforceable and upheld by the courts. Further, attitudes or culture affect the type of coordination method to be employed. Given the history of agricultural programs, it is unlikely that a carbon tax/subsidy scheme will be politically acceptable.[5] Likewise, if forestland ownership and forest exploitation have been in public hands (as in much of Canada), government agencies and ENGOs will oppose their privatization. There will then be a preference for public afforestation programs, particularly if the purpose is both to supply nature (enhance biodiversity) and sequester carbon, as opposed to private programs where landowners can sell C offsets (tree-planting services) in a competitive market.

IV. CONTRACTING TO PLANT TREES

Contracts will vary by the quality of nature desired (say, native species versus hybrid poplar), local institutions and the costs of providing different forms of nature, and the ability to reallocate funds from demanders of nature to suppliers. Contracts refer to

[4] Feng, Zhao, and Kling (2001) discuss the problem of ephemeral carbon uptake related to changes in agronomic practices meant to enhance carbon soil sinks and propose three schemes for addressing this problem—a pay-as-you-go scheme that is similar to a carbon tax/subsidy, variable length contracts and a carbon annuity account.

[5] Similarly, under the pay-as-you-go scheme, it may be difficult or impossible to collect payments for C released, as noted by Feng, Zhao, and Kling (2001).

the ''arrangements'' between the ''principal'' who demands the nature and the ''agent'' who supplies it. The typical principal-agent model assumes the principal maximizes some objective function subject to the agent's utility constraint (Hart and Holmström 1987). In the case of tree planting on agricultural land, the principal will generally be the government, but it could be a private agency (e.g., an ENGO, a utility company or forestry firm), while the agent is the landowner. The principal has several options for obtaining carbon credits:

(1) purchase the land and provide all of the associated forestry services (planting, tending, harvesting and hauling);[6]
(2) contract with the landowner over a relevant period to convert land to trees, with one of the parties responsible for the associated forestry services; and/or
(3) contract to purchase annually certified carbon offsets from the landowner at agreed upon prices, with the landowner responsible for the production of C credits.

Clearly, option (1) is identical to public ownership (discussed above) or some other situation where the externality is internalized. As with the market option, under (3) the landowner encounters no incentive problem, because the agent alone decides how many C offsets to sell each year. The landowner bears most of the risks, but the principal cannot be totally certain as to how much carbon will be supplied by the agent each year.

Option (2) is some middle ground between (1) and (3), and contracts are involved explicitly. By ''hiring'' the landowner, the principal may suffer from possible shirking on the part of the agent. Shirking consists of activities that are difficult to monitor but reduce potential carbon uptake. It includes selective harvesting of trees for personal use, not policing against selective logging by outsiders, lack of vigilance in preventing fire, and permitting cattle onto lands planted to trees (thus slowing tree growth). Depending on the terms of the contract, under option (2) the landowner no longer bears the full risk of the undertaking, and may not bear any risks if she is compensated only for providing the services of the land. Clearly, in order to maximize the payoff, the principal must adopt appropriate contractual forms with built-in incentive schemes that induce behavior on the part of landowners that ''best'' coincides with the objectives of the principal. Therefore, a typical principal-agent model generates a trade-off between risk avoidance and incentive implications.

Transaction Costs and Contracting

The principal desires to choose one or more contractual forms that economize on transaction costs (e.g., a lease agreement with the principal performing forestry activities, or an agreement to purchase a certain amount of C-uptake services each year). Three sources of transaction costs can be identified (Pejovich 1995, 84-87). First, there are search costs related to finding potential suppliers of land (and buyers of carbon offsets, if necessary), obtaining information about their behavior and circumstances, and getting information about expected growth rates of trees on land to be converted to forest.

Second, bargaining is an essential element of the contracting process, so there are negotiation costs (Kostritsky 1993). Negotiation can be thought of as a process for achieving common understanding of the main attributes of the contract and reaching agreement about the obligations of the respective parties to the contract. Naturally, there are benefits of repeated contracting, because economic agents gain experience (and information) over an extended period of time, modifying their behavior not only in their own interest but also out of consideration of the relationship that evolves over time. This is why ''relational'' contracts have gained popularity, because they contain provisions that allow for readjustment in the allocation of risks as circumstances change.

Opportunities for repetitive contracting

[6] Of course, the principal could sub-contract with silvicultural and logging contractors to have these associated services provided, but this is beyond the current discussion (see Wang and van Kooten 1999).

are limited for Canadian terrestrial carbon sinks because it takes 15 or more years for trees to reach maturity. In lieu of repeated contracts and explicit markets for carbon offsets, landowners may decide to cooperate in the sale of tree-planting services. This may be important because many farmers have experience with cooperatives (e.g., grain coops are common across the Canadian prairies) and there may be only one or a few buyers of C-uptake services (generally a large utility or the state). If landowners cooperate in the sale of carbon offsets, they are in a better position to undertake planting, harvesting, fire protection, monitoring and other forestry activities, with cooperatives likely investing in specialized assets to do so.

Finally, contracts need to be prepared and monitored to ensure that the parties to a contract abide by its terms. There is the need to enforce a contract and collect damages when partners fail to observe their obligations, and property rights must be protected against third-party encroachment. In order to guarantee that the agreed amount of carbon credits is produced, and that the agent is not shirking, certification of carbon offsets is required. At this time, however, there is no ready mechanism in place for certifying carbon credits, which will add to the costs of producing C offsets compared to programs to reduce CO_2 emissions, for example.

Incomplete Contracting

A traditional view is that no contract can be formed until clear and complete agreement is reached, but such a contract would need to provide for all contingencies and specify comprehensively the time, price, quantity and quality of performance (Kostritsky 1993). The perfectly contingent contract assumes highly rational actors capable of bargaining, at reasonable costs, to allocate explicitly all future risks associated with the undertaking. In the real world, contracts are incomplete because some terms are unspecified due to the costs of negotiation and information gathering (or certifying C credits). With informational barriers and uncertainty about the future, comprehensive contracting is not realistic since humans are boundedly rational and act in their self-interest with guile. Contracting agents may intend to behave rationally, but are limited as to what is possible—they have a finite (unknown) capacity for knowledge, understanding and reasoning, and they cannot foresee all possible future contingencies. Incomplete contracting raises transaction costs and the price of the contract.

Transaction costs related to incomplete contracting can be a major barrier to contracting, particularly in the case of tree planting where there is a great deal of uncertainty. Catastrophic fires, wind blow downs, large changes in the value of C offsets (since knowledge about and markets for C-uptake are still emerging), lack of certification, and other unforeseen circumstances contribute to uncertainty. Once an uncertain event is realized, one or other party to the contract may be able to take advantage of the other, particularly if there are no opportunities for repetitive contracting. Recognizing limits on rationality helps explain why parties may initially fail to agree (e.g., landowners demand outlandish compensation). Nonetheless, incomplete contracts are common in the real world, mainly because the parties to the contract recognize the existence of uncertainty and are flexible enough to leave some items (contingencies) to be resolved at some future date. In some cases, the courts may intervene to resolve incompleteness, while in others incompleteness is resolved through negotiation. It is worth noting that the owner of assets often has greater bargaining power in situations where contracts are vague, not specifying what needs to be done in all circumstances (Hart and Moore 1990). This explains why landowners may wish to form cooperatives that sell tree-planting services to the state or some other entity.

Finally, while factors such as bounded rationality and the problem of information constitute barriers to fully contingent contracts, resulting in incomplete contracts, opportunism tends to result in shirking (noted above), making policing more difficult. Appropriate incentives help ensure that the actions of the agent are in the principal's interest, and contracts must be enforced so that gross violations do not occur. Features such as contract length and contract detail address these potential problems. Repeated contracting can help in this regard because violators will lose future contracts, but this is unlikely for terrestrial carbon sinks as already noted, while it is an empirical matter whether landowners will enter into long-term contracts (exceeding 15 years, say). The familiar hypothesis that the principal and agent maximize the expected value of the contract only holds *ex ante*, as *ex post* each party will focus on their individual interest and try to expropriate as much of the individual gain as possible on each occasion. Thus, it may be understood that incentive enhancing is possible through *ex ante* alignment, whereas hazard mitigation is mainly achieved through *ex post* governance of incomplete contracts (Williamson 1998).

Framework for Reducing Transaction Costs

Within the general framework of contractual relations, a number of schemes hold promise for lowering transaction costs (Kostrisky 1993). First, contracts can contain a generalized ''default'' rule that permits implicit bargaining. The advantage of such a rule lies in reducing the costs of negotiating every detail (obligation) at the outset, allowing for the determination in the future of some specific terms and duties. Where uncertainty about what will constitute optimal behavior at the time of performance may be significant, it is a good idea to leave aspects of that performance open to negotiation rather than constrain parties to specific but potentially inappropriate actions. For instance, long-term contracts often contain provisions for periodic adjustments of prices; removing carbon from the atmosphere may become more or less urgent as more information becomes available or as countries reach a carbon agreement that is binding, so renegotiations become an important component of the contract. Contracts with built-in renegotiation clauses are considerably simpler than contingent claims contracts. It is then that principals and agents gain trust. Indeed it is ideal to have agreements that remain flexible in the face of changing circumstances, relying on trust to smooth out differences.

Second, it may be necessary to include in a contract a reasonable level of detail to minimize opportunistic behavior, although some scope for opportunism inevitably remains and, therefore, only limited success may be expected from planning in advance.

Finally, with an understanding of the role of transaction costs, it becomes a legitimate concern to inquire about the level of transaction costs in a given institutional environment. Transaction costs can be reduced by choice of an appropriate governance mode. For example, a market transaction usually prevails when nonspecific investments are involved, but, as asset specificity increases, market arrangements tend to give way to bilateral contracts (Williamson 1985).

One of the important reasons for writing C-sink contracts is to guard against the hazards inherent to changes in land use that span 15 years or more. Contracts protect landowners who invest in specialized assets that are related directly to tree planting (viz., equipment used in forestry) or indirectly because remaining farmland is used differently as a result of converting some proportion of the farm to forest (e.g., investment in intensive livestock rearing). If adequate performance guarantees or incentives are included, it gives some assurance to the principal that the tree-planting contract will generate the expected amount of carbon sequestration.

As noted in the introduction, Canada intends to rely on afforestation of marginal agricultural land for a significant component of its international commitment to mitigate climate change. Therefore, in the next section, we investigate the reaction of landowners to potential institutions and incentives to get them to contribute land for this purpose. Our objective is to determine whether there are obstacles that increase the transaction costs of LUCF projects.

V. SOME EMPIRICAL EVIDENCE

Data for the analysis were obtained from a mail-out survey of farmers in Canada's grain belt region using addresses compiled by Watts List Brokerage, a firm that maintains mailing lists related to agriculture. According to the firm, its ''Canadian Farmers'' database—the largest and most comprehensive database of farmers in Canada—is updated quarterly exclusively from survey and research sources, so the most current and accurate information are assured. After omitting farmers with less than 160 acres of land, the database consists of 34,618 farmers in western Canada, out of which a random sample of 5,000 names was purchased. Due to cost considerations, a random sub-sample of 2,000 farmers was employed. The survey was sent out in July 2000, with postcard reminders following after approximately three weeks. Unfortunately, the Watts List Brokerage database was less reliable than the company claimed, with a large number of surveys returned as undeliverable because farmers were deceased or had left farming. A total of 208 surveys were returned for a response rate of 13%, but only 182 surveys were usable. This response rate compares favorably with the 12% response rate reported by the Environics Research Group (2000) and Bell et al. (1994) in surveys of Canadian and American farmers, respectively. The survey instrument was quite extensive, with numerous questions about the farm enterprise, agricultural production on marginal fields (landowners were asked to provide details about production on their least productive fields), potential strategies for coping with global warming, and so on. Only responses to a subset of questions are employed here. Further details of the survey methodology, the survey questions and responses are found in Suchánek (2001).

Survey respondents were given the following information:

Carbon credits are earned by increasing removal of CO_2 from the air and storing it in plant material. Farmers create carbon credits by planting trees on their land, converting cropland to grassland, and/or reducing tillage operations. The size of credits is determined by the increases in tree biomass (i.e., faster growing trees remove more CO_2 from the atmosphere, thereby generating larger carbon credits), crop residues and soil organic matter brought about by the action, with monitoring done by an environmental non-governmental or governmental agency. Farmers could sell carbon credits on carbon markets that are now being developed. Alternatively, farmers could exchange their carbon credits for subsidies (from government, industry, etc.) to engage in the activities that provide the carbon credits—ownership of the carbon credit is effectively transferred to another party.

TABLE 2

STRATEGIES FOR PRODUCTION OF CARBON FOR SALE: PERCENTAGE RESPONDING ''YES''[a]

Strategy	%
Reduce tillage operations	60.7
Replace tillage summer fallow with chemical fallow	47.4
Reduce summer fallow by increasing cropping intensity	54.1
Plant fast-growing trees in large blocks[b]	23.7
Plant native trees in large blocks[b]	20.7
Plant shelterbelts and/or individual trees	57.8

[a] The actual survey question was: ''Which of the following strategies would you be likely to pursue in order to produce carbon for sale? Remember, you pay the cost for implementing any of the strategies you identify, but are compensated from sale of the carbon produced by the strategy.'' More than one alternative could be checked.

[b] Based on survey pre-test results, and given the order in which questions were posed in the survey, the nature of farm activities in the region and that respondents were asked to consider their marginal lands, planting would generally be a minimum 40 acres of marginal land.

Nearly 75% of survey respondents indicated a willingness to create carbon offsets if they could somehow sell carbon credits or if they were adequately compensated. However, they expressed substantially different preferences for the types of land use changes they were willing to implement in order to create carbon offsets. As indicated in Table 2, less than one-quarter of farmers indicated they were willing to plant large blocks of trees, even if they could sell the carbon so that they were fully compensated for lost revenues. The majority of respondents considered planting trees only in the limited case where they could earn C offsets for planting shelterbelts or individual trees. (While 110 respondents had experience with tree planting, 104 had planted shelterbelts and 52 had planted individual trees, but only 6 had planted large blocks of trees.) More than 60% of respondents indicated that they would reduce tillage operations, and about 55% would reduce summer fallow intensity (increase years that the land is in crops), if they could recoup the added costs by selling carbon credits. Each of these activities increases soil organic matter, as does chemical fallow, an option considered by only a minority of respondents.

Overall, these responses indicate that farmers prefer carbon sink options that they are most familiar with and that have long been recommended by soil scientists as means for reducing soil erosion (Lerohl and van Kooten 1995).[7] It is not going to be easy to get farmers to adopt tree-planting programs on a scale needed to meet a significant component of Canada's Kyoto target. Farmers' preferences for other carbon sinks (only recently agreed to at the Bonn meeting) are probably conditioned by their experience, by the recent emphasis on agricultural soil sinks, and by the fact that some (albeit limited) areas of the prairie region are unlikely to be suited for growing trees without irrigation.[8] It remains our contention that the major obstacle will be to convince farmers to plant trees, with the success of so doing dependent on the institutions and incentives to be used.

Survey respondents appear to be quite familiar with contracts, as indicated in Table 3. Indeed, 62% indicated that they have had crop share or lease agreements, as a renter, landowner or both. However, fewer have experience with land-use restrictions that prevent crop production (5.5%), such as leases to keep wetlands out of crop production, or that restrict crop practices (9.3%), such as agreements that prevent haying before a certain date. Contracts restricting land use ranged in length from 1 to 10, 25, and even 30 years (Figure 1), some within the range required for tree planting.

TABLE 3
SURVEY RESPONDENTS' EXPERIENCE WITH VARIOUS CONTRACTS

Type of Contract	Respondents	Percent
Land-use restriction that prevents crop production	10	5.5%
Restriction on cropping practices	17	9.3%
Crop share or lease agreement	113	62.1%
—as renter	104	57.1%
—as landowner	68	37.4%
Other	6	3.3%

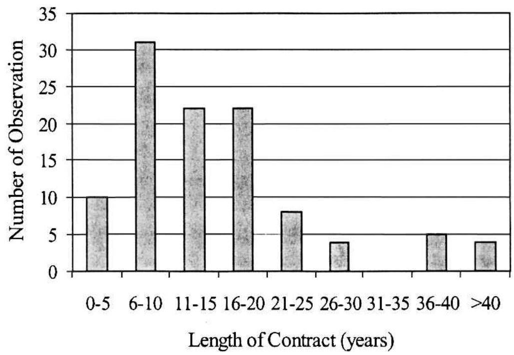

FIGURE 1
RESPONDENTS' STATED PREFERENCES FOR LENGTH OF TREE-PLANTING CONTRACTS

Respondents were asked to compare four governance structures for establishing carbon sinks (Table 4). In choosing the mechanisms, we ruled out regulation and outright government purchase of land as politically infeasible. Surprisingly, landowners expressed a preference for tree-planting contracts over a pure market mechanism that would enable them to sell offsets without interference. However, landowners appear reluctant to enter into contracts with environmental NGOs (Greenpeace and the World Wildlife Fund were specifically identified not because of any experience in contracting with them but only as examples of potential ENGOs); rather, respondents prefer to work with governments or even large companies that need to purchase carbon offsets.[9] This might be the

[7] Nine respondents indicated that they already had reduced tillage operations and/or employed chemical rather than tillage summer fallow, while six had employed continuous cropping for a long time (10+ years). Two of the operators felt they should be able to claim retroactive carbon credits, while three additional respondents asked specifically about getting C credits as a result of zero or minimum tillage operations.

[8] Seven respondents indicated that their land was not suitable for growing trees, while two suggested that trees were not native to the prairies (although certain species can survive, even in the driest areas).

[9] Four respondents specifically noted that they did not trust the government to honor its contracts, indicating that states can change the terms of a contract as they please.

TABLE 4
RESPONDENTS' RANKING OF GOVERNANCE STRUCTURES FOR ESTABLISHING C SINKS

Governance Structure	Normalized Rank
Tree-planting contracts with government/state agency	1.00
Tree-planting contracts with private firms (large CO_2 emitters)	0.87
Sell C credits in markets established to allow trade	0.71
Tree-planting contracts with ENGOs	0.44

case because farmers have experience dealing with government through a plethora of agricultural programs, although this does not explain the proclivity towards contracting with large private companies.

Using survey data summarized in Table 4, a market preference variable was constructed to investigate the role of asset specificity and experience with contracts as possible explanations of a preferred governance structure. This variable takes on a maximum value of 1.0 for an individual who would rank markets as the most preferred option followed, in order, by contracts with private firms, with ENGOs and, last, with government; it takes on a value of zero for precisely the opposite ranking.[10] The value of the market preference variable ranged from 0 to 0.91, and averaged 0.42; it was regressed on various explanatory variables. The log-odds OLS regression results are provided in column 1 of Table 5. They indicate that previous experiences with contracts that require farmers to restrict land use or cropping practices are insignificant explanatory variables. Such contracts were probably with a state agency, and not a private firm.

The survey did not ask respondents to identify assets that might be specific to certain types of land uses. Since landowners were not involved in forestry operations at the time of the survey, they were assumed to have no assets specific to forest planting or harvesting. Further, since dairy farms had been eliminated from consideration, survey respondents were engaged in crop production or livestock raising, or both. Therefore, we assume numbers of cattle are an indicator of "commitment to cattle," and that this variable serves as a surrogate measure for cattle loading ramps, specific investment in cattle transportation, specialized veterinary equipment, barns, and other specific assets that would be used by farmers committed to cattle rearing. Likewise, net worth is assumed to serve as an indicator for assets specific to grain enterprises—greater net worth is generally indicative of higher land value (with cropland worth more than pasture) and presence of more assets specific to crop production (investments in crop production are greater than those needed for cattle). Only net worth is statistically significant in the market preference regression, with those with higher net worth more likely to prefer market-type instruments over other governance forms. This provides some support to suggest that assets specific to crop production prevent farmers from planting blocks of trees.

Respondents were asked whether they would even consider large-scale tree planting if they were adequately compensated.[11] Out of 177 respondents who answered this question, 45 indicated they would not consider planting trees. In an attempt to determine factors that might explain responses, a logit regression model was employed, with results provided in column 2 of Table 5. The only statistically significant variable that explains why farmers would agree to plant trees if adequately compensated is whether or not they are located in the black soil zone. Surprisingly, those in the black soil zone where conditions for tree growth are likely best, while agricultural prospects are lower (as it borders the boreal forest, thus experiencing wetter

[10] Respondents ranked the four items in order. A value of 3 was assigned to the highest ranked item and 0 to the lowest; in the case of ties, the average of the two rankings was used.

[11] The actual dichotomous choice question is: "Suppose you were to enter a contract that permits someone to plant trees on (some proportion of) your land. All direct costs of tree planting (e.g., establishment, monitoring, management, maintenance costs) are covered, and you are provided annual compensation. You do not have any right to harvest the trees before the contract expires, but when the contract ends, trees become your property. Would you consider a tree-planting program if you were adequately compensated?"

TABLE 5

REGRESSION RESULTS[a]

Explanatory Variable	(1) Log-odds[b]	(2) Logit: Yes to Planting	(3) Length of Contract
Constant	−1.8086	1.3490	12.1470
	(−3.030)	(5.216)	(1.648)
Net worth	0.0017		
	(2.015)		
Land base			−0.0004
			(−0.576)
Number of cattle	0.0005		0.0016
	(0.712)		(0.634)
Age of operator			0.169
			(1.497)
Preference for markets if selling carbon credits			−6.268
			(−1.69)
Farm located in black soil zone		−0.6436	−3.999
		(−1.835)	(−2.020)
Experience with contracts that:			
Restrict land use	−0.5811	1.1454	0.573
	(−0.539)	(1.083)	(0.158)
Restrict crop practices	−0.8676		
	(−0.989)		
R^2	0.0691	0.0410[c]	0.1577
No. of observations	92[d]	177	83[d]

[a] t-statistics or asymptotic t-statistics are provided in parentheses. Number of observations varies due to missing information. Only the ''best'' regression results are provided as determined by the highest value of $\bar{R}^2$.

[b] Dependent variable is $\ln(y/1 - y)$, where y is the market preference variable, and OLS regression is used.

[c] Cragg-Uhler R^2; likelihood ratio = 5.000 with 2 df.

[d] Includes only those who indicated a willingness to consider large-scale tree planting.

conditions and earlier frosts), would be less likely to agree to large-block tree planting even if they were adequately compensated. These are also the individuals most likely to be near sawmills or pulp mills and to have had recent experience with land clearing (not asked in the questionnaire).[12] Clearly, improving land by removing trees is considered a costly proposition from both a financial and perhaps utility point of view. As a result, farmers are not keen to reverse this process.

When asked about preferences concerning the length of a potential tree-planting contract, survey respondents overwhelmingly chose contracts that did not exceed 20 years (Figure 1). Upon regressing stated contract length on available explanatory variables (see column 3, Table 5), only two variables turned out to be statistically significant. Farmers located in the black soil zone preferred shorter contracts (probably so that trees did not get ''too established'' and thus difficult to remove), as did those who expressed a greater proclivity for relying on markets to sell carbon credits (as measured by the market preference variable). Asset specificity, as measured by numbers of cattle and area farmed (in lieu of net worth) were not statistically significant in explaining preferred contract length; nor was experience with other contracts that resulted in land use changes.

Finally, nearly 82% of respondents answered ''yes'' to whether they would join a

[12] Landowners in the black soil zone do not appear to have more trees on their land than those in other regions, with the correlation between proportion of land covered by forest and the black soil zone dummy variable being 0.0288.

cooperative to sell carbon-offset services. This high proportion of yes responses is because farmers in western Canada have a great deal of experience with cooperatives. They market their grain (and often livestock) through cooperatives (actually pooling agents), such as the Saskatchewan Wheat Pool, Alberta Wheat Pool and Canadian Wheat Board, while they purchase many inputs (including groceries) at a coop. This might explain why a logit regression model failed to identify any variables that might explain preference for cooperating to sell carbon credits.

VI. DISCUSSION

While landowners in Canada are in a position to help the country achieve carbon emissions reduction through large-block tree plantations, the results of this study suggest that getting farmers to do so may be a hard sell. Even if they are fully compensated for lost agricultural revenues and tree planting costs, more than one-quarter of survey respondents (45 of 177) indicated that they would be unwilling to enter into an afforestation program voluntarily. Rather, landowners appear content to change cropping practices in ways that provide some, albeit much smaller, carbon benefits, whether that consists of planting shelterbelts and individual trees or changing cropping practices so that more organic matter (and thus carbon) is stored in soils. Less than 1/4 of survey respondents consider large-block tree planting even to be an effective means for producing carbon credits for sale, compared to much higher proportions citing other agricultural activities (Table 2). Importantly, these other activities provide benefits, such as reduced wind erosion or greater soil fertility, in addition to those associated with carbon uptake. Even then landowners demand or expect to be compensated.

There may be unaccounted for transaction costs that prevent large-scale tree planting on marginal agricultural lands in Canada. While usual economic analyses of tree planting indicate that it is a cost-effective means for achieving carbon offsets, our results indicate that there may be unknown transaction costs that could raise costs considerably. As indicated, farmers are reluctant to make dramatic changes to the way they use their land; they prefer to continue with what they know best, and current agricultural policies, programs and research (e.g., with respect to soil carbon sinks) entrench such behavior. Further, there is some (albeit limited) evidence that asset specificity, in the form of developed land and investments in tractors, combines and other assets specific to crop production, may be an obstacle to afforestation, at least in the minds of farmers. Finally, the great majority of farmers would not be willing to enter into tree-planting agreements that exceeded about 15 years, the rotation age for hybrid-poplar (see Figure 1). This militates against programs to plant native tree species for biodiversity reasons, since such trees have a rotation age of some 40 years or more.[13]

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[13] The Canadian government is likely to implement a tree-planting program for marginal agricultural land that employs native tree species (pers. comm., T. Lempriere, Canadian Forest Service, July, 2000).

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