III. Barriers to Efficient Decisions about Carbon Farming

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Abstract

Policies to reward carbon sequestration on private land have been designed with the expectation that they will stimulate land-use change wherever carbon farming is the most profitable land use. However, the decision process to adopt carbon farming, from the landowner's perspective, has hidden uncertainties and costs that act as barriers to uptake of this land use.

I use backward mapping to understand the decision factors that landowners face in making rational, efficient decisions about adopting carbon farming. I then evaluate the uncertainties associated with key factors and the impact these have on carbon farming decisions. The results suggest that incomplete information and high risks will reduce the uptake of carbon farming below efficient levels. Instruments to provide information to landowners and limit their risk can remove many of the barriers to adoption. My analysis of these barriers suggests individual solutions to each one, which can be combined and delivered through decision support tools and contract arrangements that limit landowners' exposure to risks.

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A. Introduction

New Zealand (NZ) has adopted a policy to reward reforestation that allocates emissions allowances to landowners who establish permanent forests on their land. Under the policy, called the Permanent Forest Sink Initiative (PFSI), each unit of carbon sequestered is transferred as a "carbon credit" to the landowner. These credits are deducted from New Zealand's allocation of allowed emissions, and landowners can sell them in any market that accepts Kyoto credits.

In this paper, I examine carbon credit production through land-use practices, using New Zealand as a case study. I develop a model of landowner decisions, assuming that landowners compare alternatives on the basis of net present value. I analyze the policy using "backward mapping," an approach that focuses on the needs of actors at the point of implementation (Elmore 1980). This approach reveals a set of barriers to successful policy implementation and suggests the elements that will be needed in the potential solutions.

My goal is to investigate the barriers that could prevent a landowner's decision to adopt carbon farming over other land uses. Although many values influence landowner decisions, including cultural and social values, this analysis focuses on a landowner's evaluation of the *economic* benefits of carbon farming: New Zealand policy is designed to create economic incentives for landowners who establish permanent forest sinks. This is not an assessment of whether landowners make economically efficient decisions; it is an assessment of what capacity landowners need in order to make efficient decisions.

Limitations on information, capital, and technical capacity can lead to market failures that undermine market-based policies. These limitations are especially acute in the precise locations where carbon markets are likely to induce change: at the frontiers and margins of current production. When framing rewards for terrestrial carbon sequestration, policymakers must strike a balance between making rules too open, allowing rewards to flow to non-additional projects (Sanchez-Azofeifa et al. 2007), and making rules too restrictive, putting many worthwhile projects out of reach (Cacho, Marshall, and Milne 2005). Risks and uncertainties in the carbon credit production system will keep production below efficient levels, unless additional efforts are made to eliminate these barriers.

On marginal land, the risk of low rewards is not the main factor limiting policy uptake because, by definition, they generate little profit in any land use. In such places, transaction costs, conversion costs, and risks are important; the creation of a market is not necessarily enough to induce behavioral change. Therefore, costs and risks associated with any particular land-use practice are relatively more important in determining whether that practice is worthwhile (and where).

Policymakers would like landowners to take up carbon farming where it is economically worthwhile, but landowners need to address a series of questions about carbon farming before they can determine where it is the best use of land. For example, any carbon farming system must successfully generate a commodity that can meet the criteria of the market: in New Zealand, this means the emissions reductions they represent must be eligible, measurable, verifiable, and permanent. Landowners must construct a production system that that meets these conditions. To know if such a system is worthwhile, landowners must understand its costs, benefits, and relative value compared to other systems. Uncertainties in any of these factors make adoption of the system riskier, and therefore landowners are less likely to judge it as worthwhile.

The research questions I address in this paper are:

How can landowners determine if carbon farming is worthwhile?

How do uncertainties affect their evaluation?

What measures could reduce these uncertainties (and are the measures worthwhile)?

These questions form the basis for my analysis of the barriers landowners face. I evaluate each of the challenges in the production system in turn, focusing on how they inhibit efficient decision-making. I also suggest approaches to overcome these barriers, with the goal of answering the final question.

A native forest restoration system for carbon farming

Managing marginal land for carbon sequestration requires little more management than the cessation of periodic clearing. In some cases, seeding with native trees or even planting may be necessary, but in many cases, the process of native forest succession will begin unassisted. On the North Island – and particularly in the Gisborne District – native tree species called manuka (*Leptospermum scoparium*) and kanuka (*Kunzea ericoides*) often invade marginal pastures where grazing pressure is low (Stephens, Molan, and Clarkson 2005).

Although the management practices are not difficult, carbon farming includes more than land management. The landowner must register under the PFSI and meet the requirements of the program: measure sequestration, demonstrate that it is eligible, take steps to ensure that credits are permanent, and verify that sequestration continues to support the earned credits (Ministry of Agriculture and Forestry 2007). These conditions require specialized skills and information, not in the management of land, but in forest mensuration and other techniques. The process also requires a documented commitment to maintain sequestration for earned credits or to replace them if sequestration is reversed. Owners have flexibility in how they meet this requirement, such as using risk management tools like forest insurance, credit reserves, or cash investments to reduce or manage the impact of potential losses.

Economic rewards of carbon farming

Enrolled landowners receive credits for the net sequestration produced by reforestation of the area they dedicate to carbon farming. The economic rewards will depend upon the quantity of credits they receive. Several New Zealand researchers have also investigated the potential for reforestation to generate carbon credits through changes in management (Ford-Robertson, Robertson, and Maclaren 1999, Hall 2001, Scott et al. 2000). These studies provide guidance about the amount of sequestration possible per hectare, but landowners must also quantify how much is eligible; that is, how much of the forest is established on land that was not a forest in 1990. Therefore, the amount of credits a landowner can earn is determined by the extent of eligible land and the net sequestration it can produce.

To convert credits into income, landowners need to sell them. The revenue from the credits will depend on the price a buyer is willing to pay for credits at the time of sale (not necessarily at the time of sequestration). Several markets for credits exist, but not all of them currently accept forest credits. At the time of this research, the EBEX21 program in New Zealand was paying landowners NZ$12 per ton CO_2-e, the New South

Wales market in Australia was paying approximately NZ$15 per ton CO_2-e, and the Chicago Climate Exchange was paying between NZ$5-10 per ton CO_2-e, giving landowners a range of possibilities. Academic researchers have been calculating the economic potential for forest carbon sequestration since the 1990s, using progressively more sophisticated models (for a review, see Richards and Stokes 2004). Other models predict the globally efficient price path for carbon (e.g. Tol 2005, van Vuuren et al. 2007). These models suggest that the price of carbon should increase through the year 2100.

B. Conceptual Framework

An economic perspective on carbon farming

Economic theory presents a model of decision-making in which landowners weigh land-use decisions according to the economic benefits of each option (e.g. Rae 1994). I use this framework as a model for how landowners will determine where carbon farming is worthwhile. Landowners can place limits on their contractual commitments by selecting which areas of land to include and, to some degree, which management activities they undertake. By controlling the *land* allocated to reserves and the activities on it, landowners control the *quantity* of credits produced. Landowners with proper information can evaluate tradeoffs and limit future liabilities by choosing the extent and location of carbon farming. They can also limit their liabilities by holding some credits instead of selling them.

For this analysis, I assume that the landowner is seeking to maximize her profit from the land. Economic outcomes are usually an important factor driving decisions about land-use change (Geist and Lambin 2002), although I acknowledge that landowners may seek many different kinds of benefits or outcomes for their land. Let us assume a landowner will choose the land use that will yield the highest expected net present value for each land management unit. The profitability of each land use and the allocation of land management units to different uses reflect several factors: the biophysical capacity of the land to produce different commodities, the landowner's budget constraint, her capacity for applying inputs, the market value of the goods and services produced, and the costs of bringing those products to market. As a result, even under perfect market conditions, spatial variation in biophysical capacities and transaction costs, individual variation in capital and skills, and temporal variation in the prices of goods and services will produce a range of land uses across a landscape. Where barriers to efficient decision-making exist – e.g., lack of information, institutional barriers, and lack of infrastructure – the efficient use of land can be inhibited. This can create greater or lesser land-use diversity than might otherwise be the case.

Defining barriers and opportunities

To better understand how these factors may operate in land-use decisions, I adapt concepts and methods from policy implementation research. Recent research has focused on the tradeoffs between policy effectiveness and policy-related transaction costs (PRTCs). The Organization for Economic Cooperation and Development (OECD) framework separates PRTCs into three areas: initial and final costs of policy development (research, design, enactment, and evaluation), implementation costs, and participation costs (OECD 2007). Implementation costs include monitoring and control of implementation and the distribution costs of payments. Participation costs include farmers' direct costs and the costs of operating as an organization.

Participation costs can determine the success of market-based policies because, at a minimum, the market rewards must outweigh the participation costs before landowners will judge their participation to be economically worthwhile. In addition, under the PFSI, participating landowners are expected to bear the burden of implementation costs through their application and annual fees to the program (Ministry of Agriculture and Forestry 2007).

If these costs are structured perfectly and there are no market failures, the policy will lead to efficient levels of participation. However, real-world landowners face limited information and information asymmetry, making the timing and scale of these costs uncertain. Landowners incur costs to resolve these uncertainties, either in time or an investment of capital, but the payoff remains uncertain. The uncertainty associated with a cost makes it a *barrier*, which I define as *a factor that reduces the potential value of carbon farming by an uncertain amount at the time the landowner undertakes a decision.*

Backward mapping is a method in policy research that starts from the perspective of the agent whose behavior is affected by the policy and analyzes how the structures of hierarchy and control impact the agent's behavior, suggesting what mechanisms are most effective in achieving behavioral change (Elmore 1980). Backward mapping is useful for understanding how the characteristics of the decision situation – especially the freedom of the individual agents to choose whether and how much to participate – are an appropriate starting point for understanding the factors limiting policy uptake. The perspective of the agent in backward mapping places emphasis on the view of the participants and their needs for capacity.

I focus on a landowner's capacity for making efficient land allocation decisions in the presence of a market for carbon credits. Therefore, I utilize a model of efficient land allocation and examine the resources needed by landowners to meet the conditions of that model. Capacity, in this particular policy, refers to 1) technical knowledge of the production process for carbon credits, including the steps of decision-making, 2) technical knowledge of the factors affecting production (and hence, profit), 3) structures for supporting the stages of production, including measurement and verification, 4) structures and institutions for decision-making, allocating resources, and managing land, and 5) tools, such as contracts, needed for delivering the commodity to market and transacting sales.

<u>Analytical Framework</u>

For my evaluation of the problem, I investigate carbon farming as a production system from a landowner's perspective. To do so, it is important to first develop a general model of how landowners estimate the economic returns of carbon farming in their land-use decisions, and then to evaluate the necessary capacity for each component of the decision.

Let us assume the landowner evaluates each activity on the basis of its returns in each year and compares the returns to other land-use choices. In order to form expectations that will allow them to make an assessment of each land use, landowners need information about prices, costs, and quantities. For each possible land use and location, she will assess value of the optimal expected rents for that particular land use:

$$\max_{\{I\}} E(\pi^{l}_{jt}) = E(P^{l}_{jt} \cdot Q^{l}_{jt}(I_{jt}) - R_{jt} \cdot I_{jt}) \forall l, t, j \quad (1)$$

where *l* is a given land use, *j* is a plot of land with homogenous characteristics, *t* is the year, and

E = expected value

P = plot-level prices of possible outputs

Q = vector of all outputs produced

I = vector of inputs used in all types of production

R = plot-level prices for vector of inputs used (similar to Pfaff 1999).

For this analysis, I ignore the utility landowners receive from the land due to activities that do not yield profit, and I assume that the landowner chooses the land use for each location that yields the highest expected return.

Land uses like carbon farming have uneven cash flow, creating a dynamic series of returns, so they should be evaluated over a longer time scale. I assume that landowners choose the land use with the highest expected net present value (NPV) of the expected returns and discount the value of future cash flows. I characterize the opportunity cost as the value of the set of uses over time that yields the stream of returns with the highest net present value, *S*:

$$E(NPV)_S = \int_{t=0}^{\infty} \frac{E(P_{St} \cdot Q_{St} - C_{St})}{(1+\delta)^t} dt \tag{2}$$

Landowners can control their inputs, and therefore their costs; for existing land uses, it seems reasonable to assume they have enough experience to develop an expectation about the quantities they can produce.

Carbon farming includes not only sequestration, but other compatible land uses, *o*, that can overlap carbon farming without violating the conditions for earning and maintaining carbon credits. The expected net present value of carbon farming must account for the price and quantity of credits, the on-going costs of production, the one-time costs of conversion, and the returns from overlapping, compatible land uses:

$$E(NPV)_C = \left(\frac{\int_{t=0}^{\infty} E(P_{Ct} \cdot Q_{Ct} - C_p) + E(P_{ot} \cdot Q_{ot} - C_{ot})}{(1+\delta)^t} \right) dt - C_C \qquad (3)$$

where

E(NPV) = Expected Net Present Value of Carbon Farming

P_{Ct} = price of carbon credits at the market at time *t*

Q_{Ct} = number of credits generated in year *t* that meet the standards of the market

C_p = costs of production, including on-going enrollment and maintenance costs

C_c = costs of conversion

$P_o \cdot Q_o$ = price and quantity of other overlapping and compatible activities

C_o = costs of production from other activities

δ = discount rate

Some of the factors in this equation will be unknown to landowners when they undertake the decision about carbon farming. Landowners are likely to have some information about the value of other land uses, represented in the second term of the numerator in the integral. In the first term, however, the first unknown factor is the future price of carbon, P_{Ct}. Future prices are always uncertain, but the novelty of the carbon market and the "artificial" nature of the carbon commodity create a wide range of possible future prices.

The second unknown factor is the quantity Q_{Ct}, which is the difference between the annual increment of above-ground carbon sequestration[3], determined by the biogeochemical processes of the forest, and the fraction of this increment that is not eligible.

$$Q_{Ct} = Q_s - Q_n \qquad (4)$$

[3] In this project, I only consider the above-ground fraction of carbon sequestration. Tate et al. (2003) show that the cost of measuring other carbon fluxes is often more expensive in New Zealand than the value of accounting for the flux; Trotter et al. (2005) demonstrate that changes in land use in the study area have little impact on below-ground carbon fluxes; rules of the Kyoto Protocol and proposed rules for New Zealand policy allow landowners to ignore other stocks of carbon. However, my approach differs from Coomes et al. (2002), who attempt to account for changes in below-ground carbon, and other analyses in New Zealand (Scott et al. 2000; Richardson, Burrows, and Carswell 2004), which have used models to account for changes in other pools of carbon.

By only enrolling land that is eligible, landowners can reduce Q_n to zero, but this is not always the most cost-effective solution, because there may be a cost to isolating land for carbon farming (fencing) and non-eligible land may have little value in other uses, so it can be set aside with very little opportunity cost.

Once they have made the decision to adopt carbon farming, landowners will want to know the conditions under which they should change to another land use. In addition to the factors already listed, landowners also need information about potential costs of liabilities. Liabilities ensure the continuity of climate benefits once they have been sold, even if the activity that supports the emission reduction shifts from one forest to another, or to some other activity. If landowners choose to change land use in the future, they will have earned profits from temporary carbon farming, but will have to pay the liability costs for losing stored carbon, which is equal to the number of lost credits multiplied by the market price at that time (replacement cost). Once they have begun, landowners can continuously evaluate whether they should continue carbon farming using equation (5), which accounts for the cost of liability:

$$\begin{aligned} E(NPV)_{Ct} &= \int_{t=0}^{T} \frac{E(P_{Ct} \cdot Q_{Ct} - C_{pt}) + E(P_{ot} \cdot Q_{ot} - C_{ot})}{(1+\delta)^t} dt - C_{C_{ST}} \\ &- C_{LT} + \int_{t=T}^{\infty} \frac{E(P_{St} \cdot Q_{St} - C_{St})}{(1+\delta)^t} dt \end{aligned} \qquad (5)$$

where:

$E(NPV)_{Ct}$ = value of land use that includes carbon farming until time T

T = the time at which conversion occurs from carbon farming to land use S

C_{LT} = potential cost of liability from carbon loss at time T

$C_{C_{ST}}$ = conversion costs to land use S at time T

C_{St} = costs of production for land use S.

This is the value of continuing carbon farming until time T and then changing to an alternative land use. This option is worthwhile if the sum of the last three terms exceeds the sum of the first term, since the first term represents the value of continuing carbon farming. The cost of replacement in time T is the price of credits at the market at time T:

$$C_{LT} = P_{CT} \cdot \int_{t=0}^{T} Q_{CT} \qquad (6)$$

Landowners have an economic incentive to enter carbon farming whenever (3) exceeds (2). Once they have undertaken carbon farming, they will only have an incentive to change land use if the expected value of an alternative use exceeds the value of continuing carbon farming plus conversion costs plus liability costs.

The heterogeneity in land and landowners means this question can only be answered empirically, using site-specific information about 1) the land that is eligible, 2) the amount of sequestration possible on eligible land, 3) the expected value of carbon credits in the future, 4) conversion costs, and 5) application costs. This paper deconstructs the factors needed for landowners to form an expectation of the value of carbon farming, and then examines each of the missing pieces in turn, identifying what is needed to fill the gap.

Each of the barriers identified in the backward mapping process relates to a term in the NPV evaluation (Table 5), and these can be sorted into internal and external barriers. Internal barriers, related to decision-making costs and uncertainties landowners must overcome, include determining and controlling governance, liabilities, waiting costs, verification costs, permanence, legal approval, management conditions, and loss of option values. Gaps in information that can be remedied by external sources include eligibility, initial and subsequent assessments, transaction costs, opportunity costs, additionality assessment, and verification.

Table 1. Factors in the NPV evaluation, associated barriers, and the factor dependencies. The information upon which each factor depends is uncertain when the landowner begins the decision process, yet it can influence whether carbon farming is ultimately worthwhile. To make an efficient decision, landowners must incur costs, either to gather the information or to mitigate the risks of the uncertainties.

Term	Barrier	Dependencies
$E(C_c)$	Governance	Effectiveness of governance structure
P_{Ct}	Price of credits over time	Market for credits

$\int_{t=T}^{\infty} \frac{E(P_{St} \cdot Q_{St} - C_{ST})}{(1+\delta)^t} dt$	Opportunity cost	Market for other commodities
C_{pt}	Waiting cost	Interest rate, discount rate, duration between investment and return
C_{pt}	Transaction costs (external)	Program enrollment costs, search costs
C_{pt}	Costs of determining eligibility	Cost of 1990 land-use assessment
Q_{Ct}	Quantity of additional credits	Rate of sequestration, outcome of 1990 land-use assessment
$\frac{C_{pt}}{(1+\delta)^t}$	Verification costs	Costs of future monitoring, discount rate
C_c	Initial measurement costs	Cost of current forest assessment
$\frac{C_{pt}}{(1+\delta)^t}$	Costs of ensuring permanence	Cost of risk mitigation measures, actuarial losses, discount rate
$\frac{C_{pt}}{(1+\delta)^t}$	Costs of future measurements	Costs of future forest assessments, discount rate
$\frac{P_{CT} \cdot \int_{t=0}^{T} Q_{CT}}{(1+\delta)^t}$	Costs of liabilities	Market for credits, discount rate, rate of sequestration

C. Methods

I used a three-part methodology to investigate these barriers: qualitative research methods were used to identify barriers with key informants; quantitative spatial economic modeling was used to ascertain the impact of barriers on the value of carbon farming; and participatory case studies were used to investigate how barriers affected the decision-making process and how information tools and legal conditions could help landowners overcome these barriers. Details of the spatial economic model and the participatory case studies are presented elsewhere in this dissertation (Chapters 2 and 4, respectively); this chapter presents results that arose from triangulation through an iterative, participatory research process that progressively built up an understanding of barriers and their potential impacts.

The qualitative research involved detailed, semi-structured interviews with 54 key informants, including 22 Māori landowners, 11 non-Māori landowners, and 21 institutional informants, which included representatives of local government, national conservation agencies, private consultants, Māori Land Court judges, tribal authorities, and local forestry company executives. Landowner interviews focused on preferences for land management; ownership and governance of the land; past, present, and future management activities; economic considerations for land management; information sources for management decisions; and environmental variables affecting management decisions. Institutional interviews focused on the implementation of the PFSI, steps and costs required for landowner participation, existing capacity, and the potential for overlapping incentives. This information laid the foundation for identifying the factors to include in the spatial economic model and the institutional considerations to consider in the participatory case studies.

The spatial economic model was used as a decision support tool (DST) to assist landowner decision-making in four case studies of multiply owned Māori land blocks. Stakeholders of each land block were able to utilize the model through facilitated spatial queries of revenue flows from different areas of their property they proposed for carbon farming. Three different payment structures were presented to landowners, each financially equivalent from a buyer's perspective. For stakeholders who decided to move forward with the process, their chosen conditions were incorporated into a legal contract for approval through their land management decision process. One land block completed the process and accepted the contract; one group completed the process and rejected the contract; two groups did not complete the process during this study.

After the completion of the case study research, the concepts, DST, and legal conditions were presented in five interactive workshops with Māori stakeholders that had not been part of the case studies, to verify their applicability and completeness. Over 65 stakeholders participated in these workshops.

D. Results & Discussion

Decision-making process and barriers

To assess the decision to undertake carbon farming, I considered five sequential questions a landowner must address to determine if carbon farming is worthwhile:

1) Does the governance structure (individual or collective) have the capacity to engage in the decision process, evaluate the value of the carbon farming system, and reach a decision?

2) Is the economic outcome of carbon farming superior to other land uses?

3) What is the economic value of carbon sequestration as a component of carbon farming?

4) What is the quantity of carbon credits the landowner(s) receive?

5) What elements of the process do landowners need to complete to receive credits?

In the first step, landowners must conduct a self-assessment of the internal costs of decision-making. For Māori landowners, the costs of the process, in terms of time and resources, are not trivial. If this decision process ultimately results in the adoption of carbon farming, then the costs of the process can be considered part of the costs of conversion. The self-assessment of capabilities yields an estimate of the expected costs of this component.

The second step is an evaluation of the expected value of carbon farming compared to the expected value of other uses. Landowners must estimate both the expected value of carbon farming and the expected value of other land uses. If the value of carbon farming exceeds the value of other uses, they must assess the likelihood of whether the relative values will change in the future and whether the costs of liabilities and conversion to a different land use outweigh the NPV of carbon farming. If so, it is not worth beginning carbon farming today.

To complete the second step, landowners need to evaluate the expected value of sequestration. In the third step, they compare the expected revenues to the expected costs. Revenues come from sales of credits; costs include conversion costs, on-going production costs, and expected costs of future liabilities.

Breaking down the revenue components, in step four, landowners need to assess the quantity of credits they expect to receive. The quantity depends upon the land areas enrolled: the rate of sequestration over time on that land and its eligibility for earning credits. The quantity of credits received is subject to risks of future losses; these risks can be mitigated either with forest insurance or by holding a quantity of credits equal to the actuarial amount of expected losses.

The last step is an evaluation of the costs of carrying out the practice of carbon farming, which are subtracted from revenues to yield net profit in a given year. The costs include on-going costs of management, measurement, verification and ensuring permanence, as well as one-time costs of conversion and assessments of eligibility and additionality. For Māori, there is also a risk that the decision will not be approved by the Māori Land Court.

The steps of the decision process can be displayed in a flowchart of decision points and potential barriers (Fig. 12). Each barrier is an item that affects the assessment of NPV, but which is uncertain at the outset of the process. Landowners can use two strategies to resolve these barriers: gather more information to reduce uncertainties, or mitigate the risks created by the uncertainties. Each of these strategies incurs a cost to the landowner.

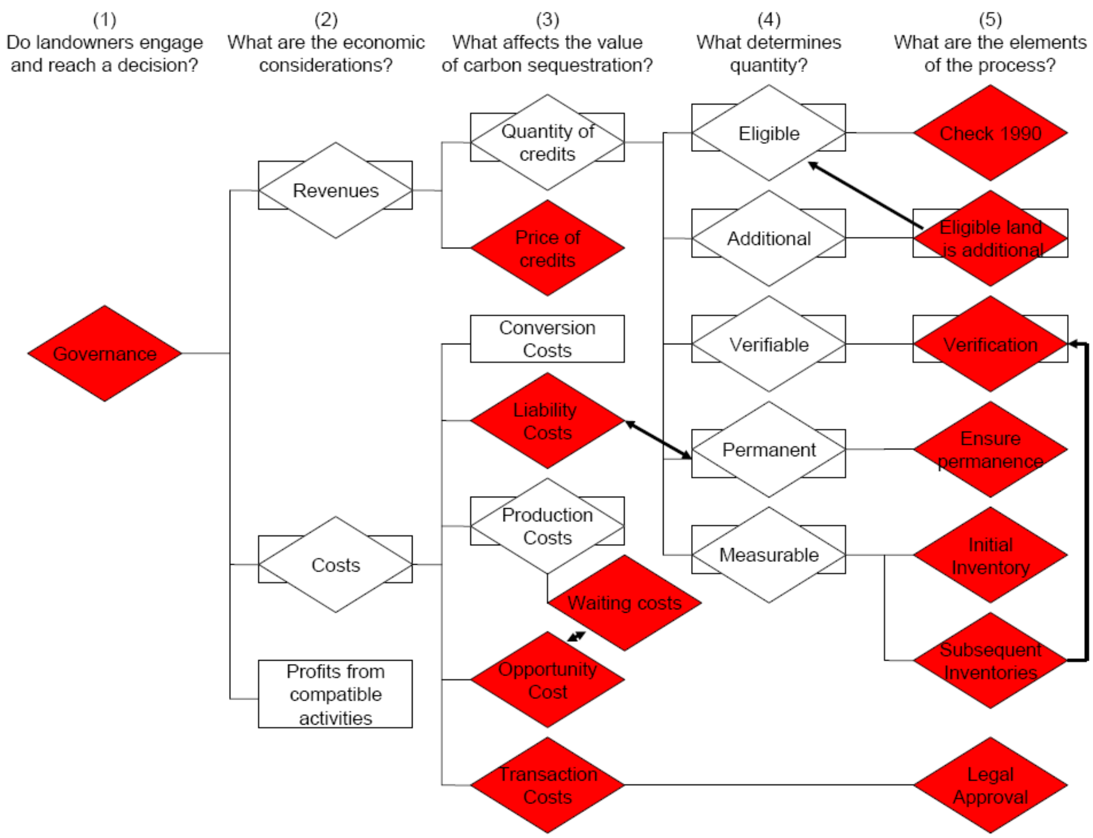

Figure 12. The decision process and barriers. Each question in the structure is uncertain for landowners prior to the decision. Elements in the column below each question determine its answer. Diamonds indicate barriers (potential costs with uncertainty that individual landowner have no way of resolving *ex ante*), rectangles indicate information the landowner can obtain *ex ante*; rectangles overlain by diamonds indicate potential barriers.

In the section below, each barrier is described in terms of the source of the uncertainty, the impact of the barrier, and potential ways to resolve it. These descriptions provide a detailed account of the impact of each barrier on decision-making.

Barriers and their impacts on decisions

1) Governance

Governance refers to the institutions and organizations responsible for decision-making on private land – in this case, to the body of individuals responsible for allocating land resources to different uses. In equation (5), this factor affects landowners' ability to form and act upon an objective based on the evaluation of the right hand side of the equation. That is, the implemented decision may not have a strong relationship to the evaluation represented in equation (5) because governance is not well-suited to making economic evaluations, or because maximizing the economic value of a land use is not the only objective to be met. On Māori land, economic goals may be part of, or even secondary to, other goals for land use, which may include particular social, cultural, and environmental outcomes.

These differences were evidenced in interviews with Māori landowners. For example, several landowners cited their goal to maintain the land, to earn merely enough rent to pay the property taxes. Some leased their land to lessees who used the land as supplemental grazing, keeping all capital mobile and doing little to maintain the capital investment (fences, buildings) on the land. Sometimes, rents were paid in kind, or grazing rights were granted as favors, which could be called in at a later time. These practices signaled a deviation from the goal of profit maximization. Interviews identified the goal of keeping land in some kind of production for the sake of retaining the land and keeping future options open. Such strategies can result in land allocation that differs from the highest and best economic use (Figure 13).

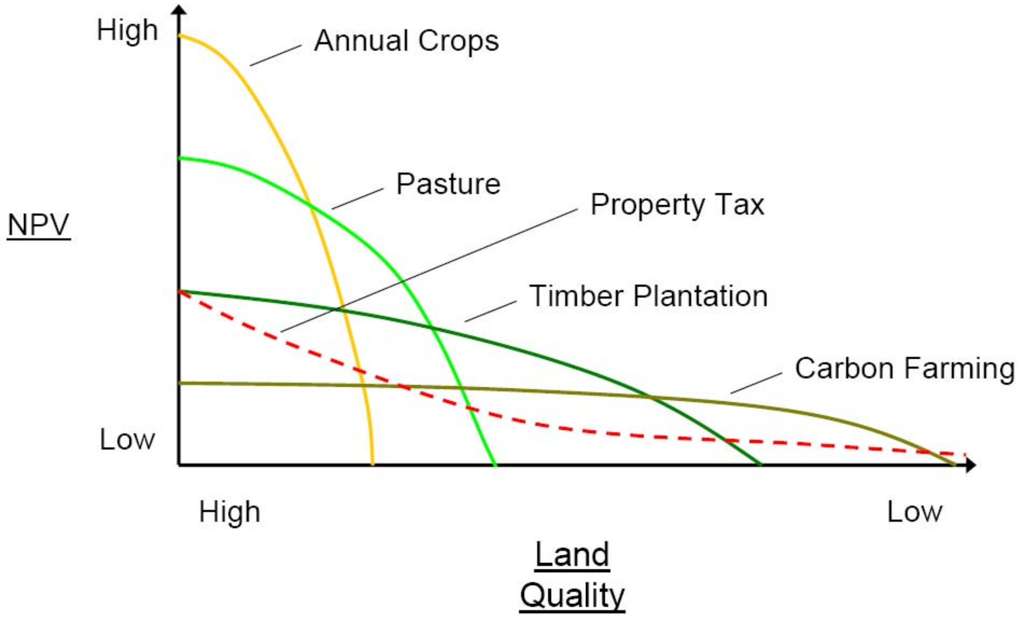

Figure 13. Different land-use outcomes from different governance strategies. The profit maximizing use of the land is the use that yields the highest NPV for a given quality. However, when land retention is the strategy, any use that exceeds the satisfactory condition (dashed line) is acceptable. In this example, revenues from carbon farming are sufficient on most of the landscape, even though it is not the most economically efficient choice.

In addition to affecting the strategy determining the objective function, governance plays a role in the costs of the decision process. For example, most Māori land blocks are owned communally, which complicates decision-making. This is a barrier internal to landowners, and affects not only their ability to adopt and implement carbon farming, but all land uses. It happens that carbon farming may be the "least effort" land use available, but landowners will not reap any economic benefits from this sequestration unless they can successfully consider the option, weigh its benefits and drawbacks, and carry through the decision, application, implementation, and contract processes. These initiatives take time and coordination.

Where land block governance has the capacity to access and utilize information, reach decisions and implement them, manage its own management practices, and carry out long-term commitments, the land block may be able to use carbon farming to meet its management objectives. In some cases, these will differ from what appears to be economically efficient management, because they will incorporate non-economic values. In other cases, management will reflect real inefficiency created by failures in governance.

2) Establishing eligibility

Eligibility is one of the four major criteria for the production system, and it determines if a land management practice will earn credits or not. To be eligible, land must have been non-forest in 1990. In equation (5), eligibility affects the quantity Q_{Ct} by changing α in equation (4).

Eligibility is a barrier because in interviews, landowners often did not know their own eligibility status, and when they did, the costs and procedures associated with establishing eligibility to the government were unknown. No other land use requires the verification of land use at another time in order to earn revenues. To establish eligibility, landowners need the services of a certified technician with access to aerial photography, satellite imagery, or other records from 1990 (Ministry of Agriculture and Forestry 2007). The technician must certify that the selected area did not meet the definition of a forest in 1990. Besides the fact that such technicians are scarce in New Zealand, not all areas have the necessary archives of photos, and analysis could take anywhere from less than an hour to several days, depending on the size, the quality of the archives, and the type of land cover in 1990.

However, identifying land-cover in 1990 is a one-time process, so it could be done once for the entire area to capture economies of scale. Dymond and others (1996) mapped the estimated land cover for the Gisborne District. This map allows landowners, consultants, and interested parties to identify whether areas are eligible, possibly eligible, or ineligible. Further work may be needed to establish eligibility for particular contract areas, but the creation of a single database that serves as a standard will be an advancement that largely removes this factor as a barrier for landowners. However, landowners must still pay for the information from the database.

3) Measuring initial conditions

Initial conditions refer to the state of the land at the time it begins earning credits. The quantity of credits produced by a project in any period is determined by the difference between the carbon stock as measured at the beginning and end of the period. This quantity is represented by Q_{Ct} in equation (5), which is equal to the difference between initial conditions and conditions at the end of the commitment period. We can expand equation (4) to define Q_{Ct} in terms of this difference:

$$Q_{Ct} = (Q_{C0} - Q_{CT}) \qquad (7)$$

where:

Q_{C0} = the quantity of carbon stored at time 0.

Q_{CT} = the quantity of carbon stored at time T.

In forestry projects, the baseline scenario measures the level of emissions which would occur under the business-as-usual land management scenario. *Ex post* adjustments to this baseline could alter the number of credits delivered to the project – a process landowners would have no control over. At the time of this writing, a report to the Ministry of Agriculture and Forestry offered four methodologies for accounting for baseline carbon stocks (PFSI Carbon Accounting Design Team 2007).

4)Assuring additionality

In international trading in markets without a cap on emissions, such as the Clean Development Mechanism (CDM), sequestered carbon must meet a standard of additionality before it can be accredited. The number of "additional" credits may be lower than the total amount of sequestration in the project. Additionality affects the quantity Q_{Ct} in equation (5).

Because much of the academic and policy discourse has dealt with this issue, I raise it here for completeness. But in New Zealand and other economies with caps on emissions, the decision is different than under the CDM. Additionality is measured at the national scale, in terms of net changes in emissions from the land-use sector relative to a national baseline. In this case, New Zealand has chosen to account for national-scale additionality by allocating credits for forests established since 1990 and registering debits for areas deforested since 1990 (Ministry for the Environment 2007). Therefore, the PFSI sets its eligibility criteria to match this additionality rule, only allocating credits to areas that were not forest in 1990. Some land may have met the definition of forest cover at that time, but in fact was being managed as something else (grazed manuka stands, for instance); the PFSI will make a case-by-case determination if such areas are eligible for credits, if they are included in an application (Ministry of Agriculture and Forestry 2007). The opportunity for landowners to opt in by providing information about their management practice in 1990 introduces some selection bias into the program, creating possible inefficiencies, but these are expected to be small. On the other hand, land that was a forest in 1990 could be managed to produce additional sequestration, but such land is dealt with under the Emissions Trading System (ETS), rather than the PFSI (Ministry for the Environment 2007). This simple policy rule, easily verified with existing remote sensing data (Dymond, Page, and Brown 1996), greatly reduces the transaction costs for landowners because they do not need to demonstrate additionality.

5) Addressing permanence

In interviews, landowners expressed concerns about the penalties for reversals. They identified the risks of pest damage, windthrow, and wildfire, but the costs of mitigating these risks were uncertain.

Under the PFSI, landowners must guarantee the permanence of the atmospheric removals represented by the credits, not necessarily the permanence of the forest, or a particular forest stand. Landowners have several options for ensuring the permanence of their removals: they could purchase insurance for the forest, they could retain a reserve of credits or money in case of reversals, or they could enroll more land than they intend to sell credits from. If insurance is actuarially fair and the landowner has perfect information about the risks of unintended reversals, the costs of these different strategies should be equivalent. Landowners can also take steps to reduce risks of reversals, such as cutting firebreaks or controlling herbivorous pests. Each strategy may appeal to different landowners or different situations. However, it is important to recognize that the forest itself need not be permanent. Despite its name, the PFSI allows landowners to exit the program if they replace the credits that have been sold. This ensures continuity of the atmospheric benefit, even if the source of that benefit changes.

Proposed rules for the PFSI require landowners to undertake all reasonable efforts to protect their forests from *force majeure* (PFSI Carbon Accounting Design Team 2007). In exchange, landowners would not be penalized for losses occuring due to *force majeure*. Only intentional reversals would require replacement of credits. Adoption of these proposed rules would remove a great deal of the uncertainty associated with ensuring permanence of forest credits.

6) Quantifying conditions in the future

Quantifying conditions in the future, for the purpose of establishing the number of credits generated by a project, can be done through a variety of techniques (Brown 2002). In reference to the decision-making rule in equation (5), this unknown quantity affects Q_{ct}, as defined in equation (7). Under rules proposed by the PFSI, landowners would not know how many credits they would receive in any commitment period until after the commitment period is over and the forest has been measured. Thus, until the measurements are made, the number of credits remains uncertain, meaning that landowners do not know if the value of their credits will outweigh the costs of the measurement effort until after the measurement is complete.

In a country like New Zealand, demand for these types of measurements might be uneven, and if all projects have to be measured at the end of each commitment period, certified forest consultants may be unable to meet the demand for their services. At such times, prices for those services may rise steeply. As a result, landowners would be unable to plan in advance for measurement costs. Furthermore, methods of measurement may change in the future, giving the landowner little certainty over these future costs at the time of decision-making.

Modeling can be used as a supplemental approach to direct measurement (Scott et al. 2000, Trotter et al. 2005, PFSI Carbon Accounting Design Team 2007), and it has certain advantages. Modeling can reduce costs to landowners for individual projects, while providing a known level of certainty about the results. Forest models can also account for changes in the rate of forest growth over time.

A modeling approach gives landowners the advantage of limiting uncertainty about the number of credits, and allows them shift their efforts into maintaining specific land management practices. Landowners can then assess their own ability to carry out the management practices necessary for carbon farming. Once management has begun to restore the forest, it is relatively simple to maintain the regenerating forest, thus assuring that credits continue to accumulate and meet quality standards. A modeling approach, however sophisticated or simple, can be used for estimating the number of credits which will be delivered at the end of the contract (PFSI Carbon Accounting Design Team 2007).

7) Knowing the price of credits

Like all commodities, the future price of carbon credits is unknown. However, production of carbon credits is different from the production of sheep, timber, or corn, in this regard, because it is a new market and there is no history of past prices to learn from. In the decision framework, the price of credits is represented by variable P_{Ct} in the equations (3) and (5).

Researchers have attempted to estimate the price of carbon at a global level since the early 1990s (see Richards and Stokes 2004). One recent model, which incorporates expectations about climate change and the supply of emissions abatement, estimates that the price of carbon credits will rise to over $180 by 2050 (van Vuuren et al. 2007). These models and estimates are largely out of the reach of landowners, because they are generally published only in the scientific literature. Currently, landowners report that what they know about carbon prices comes from the brokers and agents who approach them, sometimes with unreasonably optimistic figures. This information asymmetry is a potential source of market failure.

Over time, a price signal will emerge, but the uncertainty about future scarcity and the specific activities that will qualify for earning credits make future prices highly uncertain. In the interim, carbon price has a compound effect on decisions, because it also affects other factors in the decision, such as liability costs. Discounting of future prices means uncertainty in the future weighs less heavily on today's decision, but for landowners who weight the impact of decisions on future generations, future uncertainty is important.

8) Waiting costs: Carrying costs through to payments

Some landowners have difficulty carrying costs over long periods of time, even if the final payoff earns them a substantial return. This problem has been associated with land degradation and deforestation in developing countries (Barbier 1997), where landowners without access to capital cannot afford delays between investments and rewards. The "waiting costs" they would incur with more sustainable land uses prevent them from delaying deforestation. Waiting costs affect the outcome of the decision rule in equation (5) in several ways. The time period over which waiting costs are borne is accounted for in the discount rate, δ, in the conceptual model. (More complicated rules emerge if the decision is evaluated over multiple commitment periods, and credits are delivered at the end of each period.) Furthermore, as the landowner waits, the price of carbon may change significantly, making expectations at time *0* much different from the sale price when the credits are delivered (P_{Ct}).

This issue is not uncommon; it applies to all investments with delayed payoffs. For example, forestry projects in New Zealand may take over 30 years to pay back. For carbon farming, the waiting time is currently fixed at 5-year intervals (when the landowner will receive the credits), but a landowner may choose not to sell credits immediately. Waiting costs arise because the landowner is forced to wait until the delivery of an unknown quantity of credits before he can make decisions about sales.

Nevertheless, there are ways to overcome this barrier. Contract arrangements like forward contracts provide the mechanism to work around waiting costs. If the quantity and price of credits at the end of the period are known in advance, even with a degree of risk, the landowner can make decisions about sales in advance, applying his own risk-management strategy with regard to the uncertainty. With a known quantity of credits to offer, the landowner can engage in negotiations with a buyer about the price of those credits. The advantage, in terms of decision-making, is that the price expected in the future becomes certain at time *0*, so the landowner can make an efficient evaluation. In addition, the quantity sold also becomes certain. Once a quantity and price are agreed upon between the buyer and seller of credits, the two parties could engage in a forward contract for the sale of the credits, based on the present value of the credits. With the contract as a legal safeguard, the buyer could deliver some proportion of the payment to the landowner at the start of the contract, giving the landowner the necessary capital for starting the project.

Other payment arrangements are possible. The discounted lump sum payments just described offer up-front payments to landowners and incur no waiting costs. On the other hand, programs like EBEX21 offer pay-as-you-go (or annualized) payment contracts, which deliver revenues to landowners each year. (Payments are even each year under the EBEX21 program because that program removes the risk of quantity uncertainty, paying the landowner for a fixed amount of carbon credits each year; Carswell et al. 2003). With any of these options, the risk of project failure or under-production of credits ultimately creates financial risks for the landowner, the program, or the government. If the project should fail to produce the amount of credits already sold, the landowner would have to meet his contractual obligation by buying credits on the market. If the landowner defaulted on this obligation, the credibility of New Zealand credits would be damaged, or New Zealand would have to replace the credits. For this reason, greater certainty about the quantity of credits reduces the risk of unexpected liabilities, making forward contracts more appealing. Landowners may also choose to forward sell only the quantity of credits that will offset their costs of conversion, holding back the remaining credits until they are actually delivered.

One approach for creating the conditions to allow forward contracts is to use a carbon model, agreed upon by both the buyer and seller, which has a known level of uncertainty. A carbon model based on measurements of forests near the project area gives both parties confidence in its accuracy. In future commitment periods, the project itself can contribute information toward improving the model. Forest sampling regimes can be designed to provide outputs with quantified levels of certainty, giving landowners the ability to weigh risks (Brown 2002). Forest sampling to support the model could be based on a large area and sample sites with greater variation in conditions, leading to better precision in the model outcomes (Trotter et al. 2005). Another option would be to adjust the management conditions specified on the contract to match the conditions of the areas where the forest sampling occurred. For instance, if the model were based on sites where forests had regenerated in the absence of grazing, the contract could specify that the landowner refrain from grazing the project area. This would improve confidence that the quantity of credits delivered to the project will match the modeled predictions.

9) Liability

For forest projects, the accumulated emissions reductions from sequestration can be suddenly lost if the forest is cut, burned, or otherwise destroyed. This creates an ongoing burden to maintain the forest or replace the lost credits in the event of reversals. The liability for reversals is equal to the value of the credits lost, which may be different from their value at the time they were sold. In equation (5), these costs are reflected in the term C_L, the costs of liabilities for carbon credits.

The cost of liability is subject to the same irresolvable uncertainty as the price of carbon. Landowners often lack these pieces of information, either because they are truly unknown or because the information is out of their reach.

Steps taken to guarantee permanence will help reduce the risk of incurring a liability. Another option is to use alternative arrangements in which the landowner need never accept liability, which I called "rental agreements" or "temporary sequestration." Under these conditions, the landowner agrees to provide a temporary service of maintaining a forest for the duration of the contract. However, if a landowner sells any permanent credits, she accepts any future liabilities for those credits.

Under proposed PFSI rules, landowners will not be held liable for losses from *force majeure* (wildfires, windthrow, etc.; PFSI Carbon Accounting Design Team 2007). In fact, as long as a change in land use does not occur (i.e., deforestation, conversion to pasture or horticulture) the "human induced" behavior still exists: the landowner is still managing the land according to the conditions of the PFSI and the forests that have been sold will eventually be replaced as the forest grows. Even if sequestered carbon is temporarily re-emitted, the credits will eventually be restored as long as the land is still committed to that use. Landowners with reserves of credits could utilize these reserves until the forest restored itself.

The only payoff to landowners for not reporting intentional clearing is avoiding liability costs, and as equation (5) makes clear, the longer the has been used for carbon farming, the greater these costs will be. Several other factors reinforce the decision to stay in carbon farming. First, reversals become easier to detect as the forest becomes more mature. Second, the growth rate of the forest declines after the forest accumulates half of its carbon potential, so the cost of liabilities will always be greater than the potential value of reversing sequestration and starting over. Third, the linkage to international markets means that landowners should never have a rational expectation that prices will rise fast enough warrant a deforestation strategy, because the forest grows back slowly and other market actors are likely to assess the likelihood of future price changes at least as well as landowners, and adopt risk hedging strategies that act to dampen price variability. If the landowner changes her mind and intentionally deforests the land, she should bear the full liability for the carbon credits. Landowners should be required to signal the intention to deforest by applying for a permit to do so. (In New Zealand, this is already a legal requirement under the Resource Management Act.)

The two circumstances that may concern policymakers are 1) when the value of other land uses rise sharply, increasing the incentive to exit the program, and 2) when violations of the conditions for carbon farming are difficult to detect, such as letting livestock graze a set-aside area. In the first case, a market for carbon credits should respond to the increased scarcity of credits, and the price of carbon will rise in response until it reaches a new equilibrium. In the second case, the productivity of grazing a forest declines as the stored carbon increases, so the small increase in revenue from grazing probably would not offset the expected penalties for detected violations. As the difficulty of detection increases, the payoff to landowners for violations decreases.[4]

10) Program-specific transaction costs

Landowners face several market-related transaction costs in carbon farming: 1) costs of application to and enrollment in the PFSI or other scheme, 2) costs of verifying that they meet the criteria for the application, and 3) costs of finding markets and buyers. In equation (5), these costs are included in C_p, the costs of production. For landowners, these costs are either unknown or highly variable. Unlike production systems for most other commodities, in carbon farming the transaction costs can represent the majority of the costs of production.

The proposed PFSI application costs and administration costs were released in a consultation document in March 2007. The proposed costs for application and account administration are substantial (Table 6), especially relative to the expected returns from carbon sequestration (Table 7).

[4] One legitimate scenario is that landowners would engage in high-profit, high-risk alternative activities when the possibility of detection is low. The relevant example in New Zealand is growing cannabis in areas of young regenerating scrub. The liability cost of carbon is low, the return from cannabis is high, and detection is difficult. This is a credible possibility, but I do not deal with it here because I suspect that the government would put efforts into detecting this practice for reasons other than maintaining the integrity of the carbon market.

Table 2. Proposed costs of enrollment and account maintenance (Ministry of Agriculture and Forestry 2007).

Activity	Proposed cost to landowner
Application Processing	$8.00/ha for first 150 ha; $6.00/ha next 250 ha, $4.00/ha next 600 ha, $2.00/ha above 1000 ha
Carbon measurement audit (initial)	$232 per application plus $4.64 per ha, $100 minimum
Carbon measurement audit (subsequent)	$406 per audit plus $4.64 per ha, $100 minimum
Administration	$3.87 per ha per year
Cost recovery of establishment and account maintenance	$2.27 per ha per year
Miscellaneous charges for non-standard application processing, etc.	$115 per hour of additional processing
Risk	5% of the credits earned by each project

The proposed costs are larger than the expected value of carbon credits in the first commitment period for landowners starting from open pasture. My analysis indicates that landowners in this circumstance might not recover their PFSI costs in the first commitment period (2008-2012), although sequestration may eventually become profitable. The fact that most of the revenue from the first 5 years of the project will go back to the government for administration and application processing will undoubtedly discourage many landowners from participating.

Table 3. Estimated costs and revenues per commitment period for projects of different sizes, based on MAF Consultation Document and estimates for manuka growth in the Gisborne District (Ministry of Agriculture and Forestry 2007; Trotter et al. 2005).

Costs per commitment period for projects	Initial period	Subsequent periods	Annualized cost per ha in initial period	Expected average annual revenue per ha in first period, starting with bare ground and earning $15 per ton

150 ha	$7835	$5707	$10.45	$7.33
400 ha	$19,330	$14,542	$9.67	
1000 ha	$45,718	$35,746	$9.14	
2000 ha	$87,698	$71,086	$8.77	

Costs of verification

In addition to the application process, landowners will need to provide verification that their proposed project meets the conditions necessary to earn carbon credits, at the time of application and into the future. This is a new procedure for landowners, but is not qualitatively different from a forest assessment. The time and skills required should be similar to those routinely used by foresters. However, a notable difference is that regenerating native forests may present irregular and dense spacing of tree stems in early stages of growth, lack of published allometric relationships, and establishment on steeper terrain than is typically used for forest plantations. Proposed requirements for forest mensuration detail the procedures for verification and measurement of forests (PFSI Carbon Accounting Design Team 2007).

Ongoing verification of the status of projects in the future can be accomplished by a variety of means. First, for the highest level of certainty, site visits and repeated measurement can satisfy the need for on-going verification of forest condition and landowner compliance with prescribed management (PFSI Carbon Accounting Design Team 2007). However, this is a costly process, and monitoring of certain conditions, such as grazing, cannot occur continuously. Second, remote sensing techniques are also a possibility: Platforms such as Landsat provide periodic, high-resolution data on land cover (Dymond, Page and Brown 1996). Unfortunately, these data are not available in real-time and processed imagery can be more expensive than the carbon revenue for entire projects. Aerial photography is another remote sensing option, but is too expensive for regular monitoring, requires skilled interpretation, and must be scheduled far in advance.

A third strategy for verification is to mix approaches, combining occasional site visits with remote "observation" and periodic remote sensing (Coomes et al. 2002). The three parts of this verification process each perform a distinct function. Site visits on randomly selected occasions encourage landowner compliance, even if visits are announced in advance. (Landowners would have difficulty removing evidence of grazing, for instance, even with a few days' notice.)

The second part of the strategy, remote "observation," could be as simple as viewing the current image of the project area available on Google Earth™ (http://earth.google.com/). The purpose would be to check if a change in land cover had occurred within the project area (and potentially in areas inaccessible by site visits) at some time in the recent past, virtually at no cost. At the time of this writing, Google Earth™ images were updated infrequently, so they could only be used to find if the area had been cleared of forest; the image would not give an indication of when the clearance had occurred. Other information would be needed to establish the date of clearing. What is important is the "threat" of a monitor viewing regularly updated images from an office anywhere in the world, which is likely to encourage compliance among landowners. In addition, landowners themselves could use the technology to monitor their own land, particularly in areas they have difficulty accessing.

In the third tier of the strategy, more detailed analysis of periodic remote sensing (conducted less frequently than if verification relied on remote sensing alone) would give information on the health of the forest, its growth rate, changes to borders, and potentially the density of above-ground biomass. Since this information would not be needed for frequent checks on compliance, it could be collected once per commitment period. The resulting data, regardless of frequency, would be especially valuable for improving forest modeling. Landowners, consultants, or certifiers could enjoy substantial economies of scale by coordinating data collection events in regions where numerous projects existed. There are several advantages to a system of this type, but the primary one is low cost. Given the shortfalls of the other strategies described above, a strategy combining methods could yield nearly the same accuracy as direct project sampling and be equally effective in inducing compliance.

Costs of market search

Market searches create transaction costs for landowners by requiring their time to seek a buyer or incurring additional costs to hire a broker. One program called CarboNZero (http://www.carbonzero.co.nz/) is a low-cost way of linking buyers to brokers using a web interface and climate exchange boards. However, this approach may not work well for rural landowners, especially Māori, because they frequently lack access to communications infrastructure, such as the Internet. Furthermore, the contracts between sellers and brokers are long-term, complex, highly individualized, spatial, and require monitoring – not a contract that could be easily arranged using a web interface. As a result, costs of linking landowners to brokers may be high.

In other production systems, such as livestock, stock agents phone landowners to notify them of stock price movements. Carbon agents could also communicate with their clients about the price on offer for credits, and landowners could enter forward contracts to deliver credits at that price. Another model is in forestry, where a forest company consolidates the management of many participating land blocks, allowing a few people to monitor both prices and supply, so that they can prepare, sell, and deliver the commodity as prices and supply come together. Carbon cooperatives could work similarly.

11) Weighing opportunity cost

Opportunity cost is the value of foregone returns from alternative uses. When land is committed to carbon farming in perpetuity, profits from alternative uses are foregone, and if the contract is kept, the potential revenue from those options is infinite. However, the common method for weighing the value of a forward stream of payments is to use discounting to estimate its net present value (Rae 1994). This can be compared to the net present value of carbon farming over the same time period. In equation (5), opportunity cost is represented by the term

$$\int_{t=T}^{\infty} \frac{E(P_{St} \cdot Q_{St} - C_{ST})}{(1+\delta)^t} dt$$

That is, landowners form an expectation of the returns from other land uses, based on the expected prices and the quantities they can produce, plus the production costs associated with those uses. Landowners apply a discount rate to the stream of returns and compare the value of engaging in different land uses.

Carbon farming has a number of characteristics that make an assessment of opportunity cost problematic. The expected permanent nature of the land use, the assessment of liability for deforestation, and asymmetry of conversion costs create barriers for landowners who see carbon farming as their highest and best land use. For instance, the permanent nature of the land use forces them to consider the very long term, over which prices for other commodities might change significantly. For most landowners, their rate of time preference makes price changes in the distant future – even large ones – insignificant in today's decisions.

Landowners may have a good idea of the opportunity cost of other land uses today, but in the long term that cost may change and carbon farming may shift in value relative to other land uses. At that point, a carbon farmer who wanted to change his mind would face a set of costs unique to carbon farming. The uncertainties of both of these forces in today's decision are likely to discourage farmers from taking up the practice in the first place, except on land that is so unproductive it has virtually no value for any other use. For example, land that is already committed to a conservation easement, cultural reserve, or erosion control program (by choice or through regulation) has an opportunity cost of zero, and clearly landowners might gain from employing carbon farming there. Landowners who manage to get contracts for up-front payments and already have established scrub on eligible land may find carbon farming an attractive alternative, especially if their discount rates are high.

12) Value of lost options

The permanent nature of carbon farming, like conservation easements, requires landowners to forego future opportunities. I have already described the difficulties landowners face in accounting for the opportunity cost of their decision. A separate consideration is the *option value* of the decision. The option value of a decision is the value of flexibility in future choices for investment by the owner of an asset. Landowners who engage in carbon farming give up a great deal of flexibility in future decisions. Option value is not represented explicitly in the decision rule represented in equation (5) because it is unclear how landowners value options, when those options occur, and how much they affect decisions. Carbon farming closes off many options, but at the present time landowners have little idea which ones. In interviews, many landowners asked questions about what options are restricted:

- Can I still graze among the trees until they mature?
- If I cut trees for firewood will I lose credits?
- Can I fertilize the trees to get more credits?

- Can I harvest traditional medicines from the forest?
- Can I open tracks for bushwalks and horse trekking?

Current policy offers little guidance with regard to these issues. In many cases, the answers are nuanced, vary by location, or are subject to change in the future. For example, cutting deadfall for firewood in native forests on a limited basis is unlikely to cause a loss of credits, but cutting live trees is restricted to a certain level of canopy cover. The proposed policy under the PFSI makes no mention of grazing, partly because little is known scientifically about the effects of grazing on native forest regeneration. Used carefully in early phases of establishment, grazing may actually stimulate the recovery of forests or desirable species, but that outcome may depend on location, stocking rates, and the duration of grazing pressure. As a result, there is considerable uncertainty about the impacts of grazing on the accumulation of carbon in native forests.

The specific limitations of the PFSI will limit future options, but the Resource Management Act (RMA) will also affect options for carbon farmers. Once a forest has successfully established through carbon farming, government agencies, local authorities, or neighboring landowners can restrict a landowner's ability to change land use, through the RMA. The uncertainty about legal restrictions adds a further barrier to a landowner's decisions, by affecting the option value of the land.

13) Approval of the Māori Land Court

For owners of Māori land, the approval of the Māori Land Court is another potential barrier to carbon farming. Māori land law specifically prevents long-term or permanent alienation of land without consent of 75% of owners. Owners must document confirmation of this amount or contracts may be rejected by the Māori Land Court. Permanent carbon farming, as defined by the PFSI, would almost certainly be considered an alienation, unless Māori land law were changed to specifically exempt the program. Legal precedent from Queen Elizabeth II Trust suggests it is possible for Māori land to be committed to permanent land use obligations. However, the Nga Whenua Rahui program uses a renewable 25-year contract structure, which has had greater success on Māori land (Mohi, M., Nga Whenua Rahui, personal communication, 2006). Shorter-term leases (5-20 years) are routinely approved for Māori land, for all types of uses, and in many cases the criteria for approval is a simple majority of landowners (greater than 50%) rather than the 75% required for activities defined as "alienation." Short-term, renewable commitments or temporary sequestration options may be alternatives that will find easier approval in the Māori Land Court.

Two illustrative examples

To illustrate the impact of these barriers on efficient decisions, I use two hypothetical examples[5] drawing upon conditions found in the Gisborne District.

Anaru owns and manages a station that includes a 100 ha paddock on marginal hill country that he considers putting into carbon farming. The paddock is currently used for grazing, but it is so marginal it only supports, on average, two stock units per hectare per year. With costs of keeping up the fence and periodically clearing, he estimates that earns a margin of $30 per stock unit from this paddock, giving him a margin of $60 per hectare or an annual return of $6000 for the paddock.

Based on information available from the PFSI website, Anaru estimates that his paddock could sequester, on average, 8 tons CO_2-e per hectare per year (Trotter et al. 2005). He knows from newspaper articles that carbon credits are being sold on internet auction sites; he checks one and finds a range of prices, but estimates conservatively that he could earn $15 per ton for now. Because he has no additional fencing costs and manuka easily establishes itself in the paddock, he has no start-up costs for establishing carbon farming; he can simply remove his stock from the paddock and let manuka grow. He estimates he will earn $120 per hectare per year from carbon farming, or $12,000 for the paddock – twice his current return. Knowing that his new forest will face some risks, he plans to hold back a reserve of 20% of his credits, giving him an expected return of $9600. He also knows there will be some application costs and measurement costs, but he expects he will still do better with carbon farming than with grazing. Anaru judges both grazing and carbon farming to be somewhat risky, and he discounts future returns at a nominal rate of 8%. He also conservatively expects neither the price of carbon nor the price of livestock to rise faster than the rate of inflation, about 3%.

[5] I chose to use hypothetical, rather than real examples, for two reasons: confidentiality and complexity. Describing a particular landowner's decision-making conditions would have violated the confidentiality of my informants. Furthermore, each of the detailed case studies was affected by a complex set of factors – describing all of these factors here would confuse, rather than clarify the decision-making environment. To resolve the problem, I instead developed two simplified examples, using a composite of characteristics and features found among my informants.

Irene is a trustee of a Māori land block adjacent to Anaru's station. The Māori land block has a paddock identical to Anaru's in its characteristics and current management. However, the paddock is leased to another farmer for an annual rent of $4000. After paying property taxes, this leaves a dividend of $3000 to be distributed among shareholders. Irene is also aware of the opportunities available from carbon farming, and she plans to present the idea to the other trustees at their next meeting. She knows they will place a high value on the limitations imposed by a permanent conversion of the land – she estimates their valuation of options affecting future generations gives them an effective discount rate of 4%, or 1% above the rate of inflation. Irene also knows that the group is not well-equipped to carry out transactions in the auction market, so she speaks to a carbon broker who offers to guarantee her a price of $12 per ton for the first tranche of credits, to be delivered at the end of the first 5-year commitment period, after which a new price can be negotiated for the second commitment period. To guard against unexpected losses, she plans to purchase an insurance policy for the 5-year period at a cost of $500 and, to reassure the trustees that she is planning against future liabilities, she plans to create a reserve of credits, holding back 20% of the first tranche. Even with these extra costs, she expects to earn $7200 from the paddock (much better than the current lease contract), leaving a comfortable cushion to cover the costs of applying to the PFSI.

In both of these examples, responsible landowners have considered the information available to them, made conservative assumptions and guarded against reasonable risks, and ultimately concluded that carbon farming is a worthwhile opportunity for their land blocks. Next we examine the impact of barriers on their decisions.

Outcomes of the illustrative examples

Let us examine the hypothetical examples to understand how these barriers can impact decisions. In the first example, Anaru expected to double the revenues from his paddock, so he proceeded to adopt carbon farming. He planned to retire and sell his farm in 25 years, so he was not concerned about the impact of his decisions beyond that point. He undertook carbon farming on his paddock and enrolled in the PFSI (application costs of $1473, administration costs per year of $583; total cost over 5 years of $4388). He paid for an initial survey of the carbon stocks in the paddock ($400), an eligibility review ($200), and another assessment at the end of the first commitment period ($500). Although his paddock was cleared, the eligibility review found that there was a 5 ha patch of mature manuka present in the paddock in 1990; this area was declared ineligible for credits. Anaru watched manuka quickly establish itself on most of his paddock and some of it was higher than his head by the time the second survey was conducted at the end of year 5. However, the second survey indicated only 2.5 tons per hectare had accumulated at the end of 5 years, yielding only 238 credits. The PFSI program held 5% of these credits for risk management (12 credits), and as planned, he set aside 20% of the remaining credits (45 credits) and sold the remaining 181 credits at the price he expected (now $17.43 per ton), yielding revenues of $3154.

Anaru continued to pay the enrollment costs of the PFSI, which remained static, and the costs of surveys at the end of each commitment period, which also remained static at $500. His paddock accumulated carbon at a higher rate in subsequent periods, reaching storage of 17, 68, 130, and 192 tons per hectare in years 10, 15, 20 and 25, respectively. After removing his reserves, accounting for his 95 eligible hectares, and allocating 5% of his credits to the PFSI program (for risk management), this gave him 1047 credits, 3682 credits, 4476 credits, and 4476 credits, respectively. When he sold his land at the end of year 25, he also sold his accumulated reserve of 3648 credits at the market price.

Even though Anaru was lucky in avoiding losses and making accurate predictions about the price of carbon, his decision to put his land into carbon farming did not pay off as well as if he had kept his land in grazing. The NPV of grazing at the time of his decision was approximately $83,500. In the end, carbon farming only yielded him a NPV of about $80,000 – a small difference, but far below the doubled return he expected to earn. He made a sound economic decision in the beginning, but due to the effect of barriers, he would have been better off economically if he had continued grazing.

His neighbor Irene had a different experience. She also expected to do much better in carbon farming than with the current grazing lease. However, despite her careful consideration of the options and protections against risk, her fellow trustees found that carbon farming imposed too many constraints on future generations, and they rejected her proposal. They continued to lease the land for the next 25 years, increasing the rent to $6000 at the end of year 10 and $8000 at the end of year 20. Out of idle curiosity, Irene kept track of the value that carbon farming would have generated, based on the carbon yields her neighbor Anaru told her about.

Irene tallied her results at the end of 25 years, factoring in a doubling of the cost of her insurance policy every 5 years. Using a discount rate of 4%, she found that the NPV of grazing the farm was about $80,800. In contrast, the NPV of carbon farming, if it had been adopted, would have been over $142,200 – nearly twice the value of grazing. She wondered if the current shareholders would have valued their options this highly for the paddock, or what impact the foregone dividends could have had over 25 years.

E. Conclusion

A few studies have pointed out barriers to carbon sequestration projects (Cacho, Marshall, and Milne 2005, Henman, Hamburg, and Vega 2008), but none have undertaken a comprehensive catalog of the barriers to efficient decision-making. Taken together, these barriers suggest that creating a market for a new climate abatement commodity produced through land-use change is not sufficient to generate changes in land use. If the market for a new commodity works well, landowners will respond by producing credits cost-effectively, where production of credits is the most cost-effective land use. But like all markets, the carbon market is subject to potential failures due to imperfect information, lack of competition, and poorly defined property rights. In addition, the unique requirements for carbon credit production through forest regeneration make implementation of the system problematic.

The New Zealand policy does not rely upon government to provide technical and structural resources, nor is there a government organization situated to deliver services necessary for landowner participation. The role of the PFSI is to accept and review applications, certify that reported activities meet policy standards, and direct the NZ ETS to allocate carbon credits to private accounts. Similarly, the only role of the NZ ETS is to provide an accounting system for the transfer of credits from one entity to another. Thus, the capacity to support decision-making and implementation must come from either the participants in the new carbon market or the private sector. In this respect, the New

Zealand policy resembles the CDM, where project developers must ensure the conditions of the project and its economic viability. If New Zealand policy is to avoid the failings of the CDM, it must find cost-effective ways to ensure genuine credits without imposing high transaction costs on landowners.

Not surprisingly, as a result, landowners encounter both internal and external capacity barriers, which require different strategies for solutions. The inward, or internal, barriers obstruct decision-making. Uncertainties due to lack of prior knowledge and experience, or lack of cohesion in opinions, goals, and strategies can cause barriers to efficient decisions. When framed in terms of land management requirements and rewards, as in a contract, landowners may be able to use existing governance structures to reach a decision about selecting contract options (or rejecting them) and take action.

Landowners will also find external barriers, in the form of uncertainties about costs, revenues, and risks. These barriers are caused by lack of information. With appropriate information, including costs and benefits associated with carbon farming, external limitations to efficient decisions would be removed. However, this information would need to be specific to the landowner's own land, and therefore requires either a spatially-explicit analysis or a range of possible values with known bounds or probabilities. Such information would allow a landowner to form an expectation on the basis of his own risk preference, and make decisions to allocate land accordingly. Spatially-explicit land-use questions are often addressed by city and regional planners, using models and geographic information systems (GIS). The combination of modeling capability and geographic information processing is commonly combined in a DST, which facilitates the analysis of multiple future scenarios in the spatial context of a particular locale. Such tools are not commonly available to landowners, but existing technology makes it possible to make such a tool available for decision support for landowners.

The combination of contractual options and decision support are effective in helping landowners overcome internal uncertainties and external information barriers. However, few landowners have the legal or technical knowledge to assemble the necessary components of a contract agreement or decision support tool. Experts with such knowledge are a necessary component of the capacity needed to ensure proper policy implementation. The long-term nature of the commitment of resources and the need for on-going verification requires trust between the landowner and the information provider. For this reason, given Māori history and attitudes toward the Crown, a government agent may not be the best messenger for delivering this information. A neutral third party with no financial interest in the sale of credits would be the ideal agent to provide such capacity.

In contrast to the deliverer of information, however, the *source* of the information delivered to landowners should be the same, or as close as possible, as the information used by government to assess, evaluate, and allocate credits. The information should meet the same (or better) standards of quality and accuracy. Without information that meets these standards, the person providing the capacity has the potential to mislead landowners into poor decisions.

Permanence, and the liabilities associated with reversals, is perhaps the most difficult barrier for Māori landowners. Sales of credits require a permanent commitment of resources and eliminate future opportunities. By restricting land use in perpetuity, current landowners take away the rights of future generations. For individual owners of general land, this problem is more tractable because their decision period is limited to the expected length of their tenure on the land – no individual owner actually owns land in perpetuity. However, for Māori land, perpetual easements are a difficult issue because of two factors: 1) legal restrictions on commitments beyond one generation, 2) cultural values of self-determination and intergenerational equity. With time horizons longer than an individual's tenure or lifetime, the value of options long into the future weigh more heavily than when an individual expects a limited tenure on a piece of land.

The precedent in international policy, from CDM projects, requires guarantees of permanence and protection for buyers against future liabilities if the forest is lost. However, some researchers have suggested that temporary storage also has value (Schlamadinger and Marland 2000, Chomitz 2000; for a counter example, however, see Kirschbaum 2003). As Chomitz (2006) points out, carbon credits are a commodity that can be used as an asset, and the value of temporary use of an asset is related to the overall value of the asset. Furthermore, he notes that temporary offsets may well become permanent, even without the protections of an easement.

Chomitz (2006) suggested a starting point for the value of temporary carbon sequestration equal to the current rate of interest times the market price of a carbon allowance. This is similar to Kerr's (2004) analysis of the value of efficient rental contracts for carbon sequestration, in which the maximum value of renting a temporary credit was equal to the net present value of the return on an investment, which was equal to the price of a carbon credit carried until the time when compliance must be met, minus the market price at the time of compliance. Under the assumption that emitters are held accountable on a periodic basis (annually or for each commitment period) and must show offsetting activities, there is a positive value for buyers in acquiring temporary offsets of emissions. Indeed, in theory an emitter could "rent" offsets for a particular year's emissions in perpetuity, demonstrating that a stock of credits had been protected continuously, even if different stocks were offsetting those emissions at different times. Under this arrangement, the buyer, rather than the seller, continues to have responsibility, or liability, for the emissions.

This concept could be advantageous to landowners, too. While the value of each temporary credit is much lower than the value of a permanent credit, the landowner can rent credits each year, rather than sell them only once. This allows an annual income stream as long as the landowner continues to protect the forest. However, if the landowner decides to change land use, she will not bear responsibility for replacing the credits. In addition, the stock of offset emissions continues to increase as the forest grows, and if the forest remains intact, this stock is not reduced unless the landowner decides to sell some or all of the credits as permanent offsets. The rental arrangement preserves the possibility for landowners to convert temporary credits into permanent credits, but introduces flexibility in the timing of the conversion, so landowners can weigh the value of carbon sequestration and alternative land uses, gain experience with management and carbon markets, and have time to reach a consensus on land use. These benefits are important to Māori landowners in particular, but apply to all landowners. Furthermore, the documentation of a rental agreement provides a record of the starting date for reversion and forest protection, which will be valuable if landowners eventually decide to convert temporary credits into permanent credits. Even if temporary credits are later reversed, they have still provided temporary benefits for mitigating climate change and providing other ecological services.

Without *a priori* knowledge about management requirements and the expected value of carbon farming, landowners are less likely to perceive the benefits of carbon farming and make efficient decisions about it, resulting in lower levels of participation. A market-based policy like the PFSI will have limited impact on land use and rural livelihoods if barriers to uptake are not removed. However, addressing these barriers with existing legal options and existing scientific information could largely restore the capacity for landowners to utilize carbon markets efficiently, providing substantial benefits to climate change mitigation.

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