Abatement and Transaction Costs of Carbon-Sink Projects Involving Smallholders

Oscar Cacho and Leslie Lipper

NOTA DI LAVORO 27.2007

MARCH 2007

CCMP – Climate Change Modelling and Policy

Oscar Cacho, *School of Economics, University of New England, Australia*
Leslie Lipper, *Agricultural and Development Economics Division, Food and Agriculture Organization, Rome, Italy*

Abatement and Transaction Costs of Carbon-Sink Projects Involving Smallholders

Summary

Agroforestry projects have the potential to help mitigate global warming by acting as sinks for greenhouse gasses. However, participation in carbon-sink projects may be constrained by high costs. This problem may be particularly severe for projects involving smallholders in developing countries. Of particular concern are the transaction costs incurred in developing projects, measuring, certifying and selling the carbon-sequestration services generated by such projects. This paper addresses these issues by analysing the implications of transaction and abatement costs in carbon-sequestration projects. A model of project participation is developed, which accounts for the conditions under which both buyers and sellers would be willing to engage in a carbon transaction that involves a long-term commitment. The model is used to identify critical project-design variables (minimum project size, farm price of carbon, minimum area of participating farms). A project feasibility frontier (PFF) is derived, which shows the minimum project size that is feasible for any given market price of carbon. The PFF is used to analyse how the transaction costs imposed by the Clean Development Mechanism of the Kyoto Protocol affect project feasibility.

Keywords: Agroforestry, Climate Policy, Carbon Sequestration Costs

JEL Classification: Q23, Q57, O1, O13

This research was funded by the Australian Centre for International Agricultural Research (ACIAR) and by the Food and Agriculture Organization of the United Nations (FAO).

This paper was presented at the Workshop on "Climate Mitigation Measures in the Agro-Forestry Sector and Biodiversity Futures", Trieste, 16-17 October 2006 and jointly organised by The Ecological and Environmental Economics - EEE Programme, The Abdus Salam International Centre for Theoretical Physics - ICTP, UNESCO Man and the Biosphere Programme - MAB, and The International Institute for Applied Systems Analysis - IIASA.

Address for correspondence:

Oscar Cacho
University of New England
School of Economics
Armidale NSW 2351
Australia
E-mail: ocacho@une.edu.au

1. Introduction

Concerns over global warming have led to the establishment of markets for greenhouse gas emissions. The most common greenhouse gas, and the main gas emitted by burning fossil fuels, is carbon dioxide (CO_2). Carbon trading has grown significantly since the Kyoto Protocol was ratified, reaching a value of US$10 billion in 2005 (Capoor and Ambrosi, 2006). Most transactions have occurred within the European Union Emission Trading Scheme. However, the focus of this study is Article 12 of the Kyoto Protocol, the Clean Development Mechanism (CDM), which has the purpose of assisting developing countries to achieve sustainable development while contributing to meet the emission-reduction commitments agreed upon by Annex I countries[1]. The medium of exchange under this Article is the CER (Certified Emission Reduction), measured in tonnes of CO_2 equivalents (CO_2e).

The demand for CERs will be met mostly by the energy sector, through clean technologies. However, tree-based systems also have a role to play, as they are a convenient way of reducing net emissions by sequestering CO_2 from the atmosphere through the process of photosynthesis. Under the current rules of the CDM afforestation and reforestation (AR) are the only allowable means of sequestering carbon. CERS are awarded for AR activities that generate sequestration additional to a baseline (or business as usual) estimate. AR projects in tropical countries may involve participation of smallholders and communities or they may be based on industrial plantations. Smallholder projects consist of activities undertaken by farmers who manage small land areas and whose production system may be a mix of subsistence and marketable crops. Industrial plantations generally consist of monoculture of commercial trees for timber, pulp or fruit production.

There is much interest in the development and environmental communities in the potential for small-scale carbon projects to simultaneously contribute to rural development and climate change mitigation. However high transactions costs associated with smallholder participation is a major barrier to be overcome. In this paper we present an economic model of the decision to participate in carbon sequestration projects from both a buyer and seller perspective, including the impact of transactions costs. In the following section we lay out basic economic issues in carbon sequestration supply and transactions costs, followed by a model of project participation for buyers and sellers. Section 4 includes a discussion of how key model parameters are constructed, including sequestration rates and payments, abatement costs and transactions costs. In section 5 the simulation model is presented with the results shown in section 6. Section 7 presents the concept of the project feasibility frontier and sensitivity analysis. The paper concludes with a discussion of means to facilitate the feasibility of smallholder carbon projects based on model results, and a discussion of future possible extensions of the model.

2. Carbon Sequestration Supply and Transactions Costs

Carbon sequestration projects differ in terms of cost per unit of carbon emissions avoided or carbon sequestered, determined by the opportunity costs of switching land uses.They also differ in terms of other environmental and social benefits provided. For example, a complex

[1] Annex I countries include the OECD countries (except Mexico and Turkey) and transition economies in eastern Europe. The US and Australia did not ratify the Protocol and the bulk of demand for carbon credits comes from Europe and Japan.

agroforest may represent an efficient use of family labour, provide sustenance and contain higher biodiversity than a monoculture of a fast-growing tree species. A large-scale monoculture plantation, on the other hand, may accumulate more carbon and provide employment, but it may provide little biodiversity and social benefits besides employment. These issues need to be considered by host countries when designing policies to encourage the adoption of carbon-sequestration projects that also provide environmental and social benefits.

The supply of CERs depends on availability and costs of different technologies and resource endowments, and these will be partly determined by location. In Figure 1 the potential supply function in the absence of transaction costs (S_A) represents the marginal abatement costs of providing different cumulative levels of emission reductions.

For a given supply function, as determined by current technology and land availability, the equilibrium levels of price and quantity (Q_A, P_A) depend on the demand function (D). The curve S_A shows the prices that would be required to motivate different levels of abatement, or mitigation, in a world of zero transaction costs, where supply decisions depend simply on abatement costs.

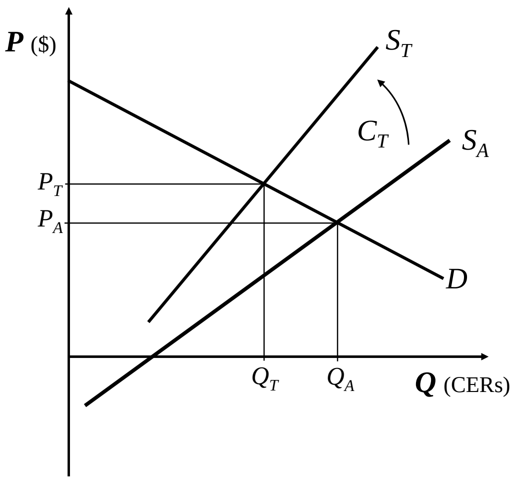

Figure 1. The market for CERs and the role of transaction costs

In order to receive certification and enter the CER market, a project will have to incur various transaction costs in showing that it is reducing net emissions (e.g. increasing net sequestration). Carbon sequestered and stored in agroforestry projects needs to be accounted for in a way that ensures the carbon changes are real, directly attributable to the project, and additional to any changes that would have occurred in the absence of the project. Transaction costs (C_T) make the supply function shift up and to the left (from S_A to S_T in Figure 1), hence reducing the size of the market. The new equilibrium point (Q_T, P_T) represents a lower quantity of CERs at a higher price compared to the original equilibrium (Q_A, P_A). If the transaction costs are too high, the market will not develop at all. This study focuses on the supply side of the market and concentrates on agroforestry projects involving smallholders.

3. A Model of Project Participation Including Transactions Costs

Consider a project composed of one buyer and many sellers. The Buyer is an NGO (the project proponent) and the Sellers are smallholders. The Sellers are paid for adopting agroforestry land uses that sequester carbon above a baseline. The Buyer purchases these carbon offsets and sells them in the CER market. So the Buyer acts as an intermediary between the smallholders and the international carbon market.

For simplicity, define a representative farmer with a given farm area *a* and current land use, call this the 'average' seller and assume there are *n* identical sellers. The representative seller will participate in the project if the reward received for carbon sequestration (v_C) is larger than the opportunity cost of switching land uses (the abatement cost, v_A) plus the transaction cost of participating in the project (v_T), The condition for seller participation is:

$$v_C > v_A + v_T \tag{1}$$

with the three variables measured in terms of present value. The present value of carbon payments received by the seller is:

$$v_C = a\sum_t C_t \, p_F \left(1+\delta_s\right)^{-t} \tag{2}$$

where C_t represents the expected stock of carbon above the baseline per hectare of land in year *t*, p_F is the farm price of carbon and δ_S is the Seller's discount rate. The abatement cost to the Seller is:

$$v_A = a\sum_t R_t \left(1+\delta_s\right)^{-t} \tag{3}$$

Where R_t represents the opportunity cost experienced in year *t* as a result of having switched land use to a tree-based system in year zero. The transaction cost experienced by the seller is the discounted sum of a stream of annual transaction costs (q_t):

$$v_T = \sum_t q_t \left(1+\delta_s\right)^{-t} \tag{4}$$

Now consider the Buyer. The Buyer will implement a project if the present value of carbon payments received in the CER market (V_C) is at least equal to the present value of payments to smallholders (the abatement cost to the buyer, V_A) plus the transaction costs of designing and implementing the project (V_T). The condition for Buyer participation is:

$$V_C \geq V_A + V_T \tag{5}$$

V_C is the discounted sum of payments obtained by accumulating the carbon offsets produced by all landholders in the project, certifying them and selling them in the CER market:

$$V_C = n \cdot a \sum_t p_C C_t \left(1+\delta_B\right)^{-t} \tag{6}$$

where p_C is the rental price per tonne of carbon and δ_B is the Buyer's discount rate. The abatement and transaction costs for the Buyer are, respectively:

$$V_A = n \cdot a \sum_t p_F C_t \left(1+\delta_B\right)^{-t} \qquad (7)$$

$$V_T = \sum_t Q_t \left(1+\delta_B\right)^{-t} \qquad (8)$$

where Q_t represent the annual transaction costs. The Buyer must set the farm price of carbon (p_F) at a level that satisfies conditions (1) and (5). This decision is influenced by the size of the project and the number of participants, as explained later.

4. Constructing key parameters in the model

A. Projecting carbon sequestration rates and payments

The carbon emission reduction available for credits in a given year (C_t) is only the amount of carbon sequestered under the project that is above the baselineThat is, only the 'additional' emissions reductions relative to the business-as-usual scenario are eligible. In any given year:

$$C_t = C_{P,t} - C_{C,t} \qquad (9)$$

Where $C_{P,t}$ and $C_{C,t}$ are the expected carbon stocks in the proposed land use and the current land use, respectively, in year *t*. If time series data on diameter and height of trees are available for the site, the amount of carbon sequestered by aboveground biomass can be estimated based on allometric equations (Brown, 2002). Alternatively, projections of carbon stocks can be based on models (i.e. Wise and Cacho 2005a, 2005b).

Regarding carbon payments, to avoid the problem of permanence[2] Marland et al. (2001) propose the use of a rental price. The difference between the purchase and the rental system is that the former represents a purchase of carbon flows with redemption of payments upon project termination or failure (Cacho, Hean and Wise 2003), whereas the later involves a rental of carbon stocks with no redemption of credits required. Both systems are compatible with temporary CERs for AR projects under the CDM[3], but the rental system is more convenient for modelling purposes.

The range of farm prices (p_F) that the buyer can pay is influenced by the market price of carbon (p_C). Here we express p_F and p_C as annual rental prices per unit of biomass carbon stored in trees. To understand the relationship between rental prices and purchase prices consider the present value (*PV*) of an asset that yields a perpetual stream of annual payments *Y* discounted at rate *i*:

$$PV = \frac{Y}{1-\mathrm{e}^{-i}} \qquad (10)$$

[2] The permanence problem arises in afforestation and reforestation projects because carbon captured in trees can be released upon harvest, in contrast with energy projects where an avoided emission is permanent.
[3] A temporary CER or "tCER" is a CER issued for an AR project activity which expires at the end of the commitment period following the one during which it was issued (UNFCCC document FCCC/CP/2003/6/Add.2).

In a perfect market the ratio *Y*/*PV* is equivalent to the rental price of the asset expressed as a proportion of the asset's value. If we let the asset be a CER (expressed as a tonne of CO_2) valued at price p_{CER}, and consider that the process of photosynthesis converts 3.67 units of CO_2 into one unit of biomass carbon, then the rental price of biomass carbon is:

$$p_C = 3.67\left(1 - e^{-i}\right) p_{CER} \tag{11}$$

The value of the discount rate in the rental carbon market (*i*) depends on the rate of return expected by investors. For simplicity we assume the carbon market discount rate is the same as the Buyer's. Therefore the value of *i* in (10) and (11) is calculated by converting the rate for discrete discounting δ_B into a continuous rate $i = \ln(1+\delta_B)$.

The CER price places an upper limit on the feasible farm price, because the Buyer would set $p_F \leq p_C$ even in the absence of transaction costs. The relationship between the purchase price and the rental price is affected not only by the discount rate but also by expected price trends. If the price of carbon is expected to increase in the future then the rental price will be lower than indicated by equation (11), because those renting will require a discount to forego the option of purchasing today. Conversely, if the price of carbon is expected to decrease in the future the rental price will be higher than indicated by equation (11).

B. Abatement Costs

Abatement costs for the Seller are defined as the costs of producing one unit of (uncertified) carbon sequestration services, or the cost of producing one unit of biomass carbon. In any given location, abatement costs can be estimated as the opportunity cost of undertaking a carbon-sequestration activity rather than the most profitable alternative activity, or the cost of switching from the previous land use to the new land use, as represented in equation (3). This cost includes the present value of the stream of revenues foregone as a result of participating in the project. It may also include additional risk exposure or loss of food security arising from this participation (Cacho, Marshall and Milne 2003). If we ignore risk perceptions and other barriers to adoption that could be overcome by participating in the project, the opportunity cost from equation (3) is:

$$R_t = R_{C,t} - R_{P,t} \tag{12}$$

where $R_{C,t}$ and $R_{P,t}$ are the annual net revenues of the current land use and the proposed land use respectively. In agroforestry systems with multiple outputs (eg. fruit, timber and spices) the annual revenue is the sum of the revenues obtained from the different products. In a system with *J* land uses and *I* inputs we have:

$$R_{P,t} = \sum_j y_{j,t}\, p_j - \sum_i x_{i,t}\, c_i\,, \qquad j \in (1,...,J),\ i \in (1,...,i) \tag{13}$$

Where, $y_{j,t}$ is the yield of output *j* in year *t*, p_j is the price per unit of output, $x_{j,t}$ is the amount of input *i* used in year *t* and c_i is the cost of input *i*.

C. Transaction Costs

Williamson (1985) distinguished the costs of contracting as *ex ante* and *ex post* transaction costs. These correspond with activities undertaken in the processes of achieving an agreement and then continuing to coordinate implementation of the agreement, respectively. Stavins (1995, p. 134) stated: "transaction costs are ubiquitous in market economies and can arise from the transfer of any property right because parties to an exchange must find one another, communicate, and exchange information". In the case of carbon markets transaction costs tend to be high, because the property right to be exchanged is difficult to measure and its exact size is subject to uncertainty.

Cacho, Marshall and Milne (2003, 2005) present a typology of transaction costs applicable to carbon-sink projects, largely based on Dudek and Wiener (1996). Here we aggregate their seven categories into five and distinguish between the costs borne by buyers and sellers (Table 1).

Table 1. Classification of transaction costs in AR projects for carbon sequestration

Cost type		Buyer (Q)	Seller (q)
Search and negotiation	*ex ante*	W_S	w_S
		• find sites, establish contact, organize information sessions, draft contracts, provide training, promotion • establish baseline for region • estimate potential C stocks and flows of project • design individual farm plans • produce PDD	• attend information sessions • undertake training • design farm plan
Approval	*ex ante*	W_A	w_A
		• approval by host country (DNA) • validate the project proposal (DOE) • Submit to CER Board	• obtain permit
Project management	*ex ante*	W_P	w_P
		• buy computers and software, establish office • establish permanent sampling plots	• purchase tape and equipment for measuring trees and sampling soil
	ex post	• maintain database and administer payments • coordinate field crews, pay salaries • distribute payments to landholders • interest costs	• attend regular project meetings
Monitoring	*ex post*	W_M	w_M
		• enter data from farmer sheets calculate C payments • process soil C samples • measure random sample of plots to check farmer estimates • verification and certification of carbon (DOE)	• measure trees, fill in form and deliver to project office • sample soil C
Enforcement and insurance	*ex post*	W_E	w_E
		• maintain buffer of C • purchase liability insurance • settle disputes	• protect plot from poachers and fire • participate in dispute settlement

The transaction costs experienced by buyers and sellers in time period *t* are respectively:

$$Q_t = W_{S,t} + W_{A,t} + W_{P,t} + W_{M,t} + W_{E,t} \quad (14)$$

$$q_t = w_{S,t} + w_{A,t} + w_{P,t} + w_{M,t} + w_{E,t} \quad (15)$$

where the subscripts represent search and negotiation (*S*), approval (*A*), project management (*P*), monitoring (*M*), and enforcement and insurance (*E*). Using the CDM project cycle as a basis (Figure 2) we can relate these costs to the design and implementation of projects.

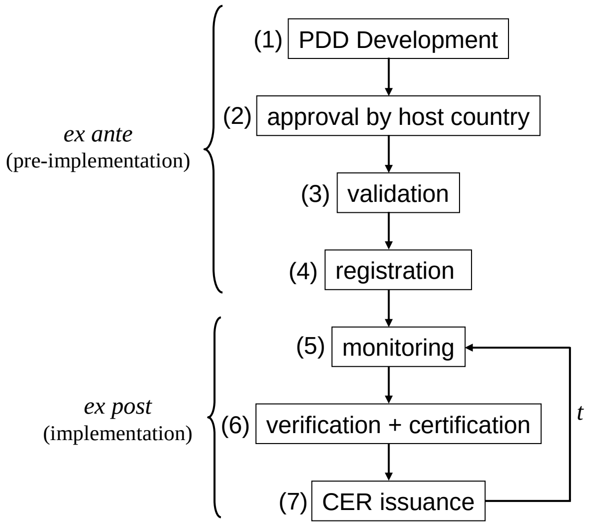

Figure 2. The CDM project cycle

Search and negotiation costs. The CDM project cycle starts with the preparation of a Project Design Document (PDD). This requires the project developer to identify a suitable region; gather agricultural, social and economic information about the region to develop the baseline; identify suitable land uses and estimate their carbon sequestration potential; contact and establish relationships with the local people; negotiate the terms of the project and the schedule of payments for carbon-sequestration services; and possibly undertake environmental and social impact studies. These activities are included within *Search and negotiation* costs in Table 1. Estimates of these costs in the literature vary widely depending on the nature of the activities within the project, the scale of the project, assumptions regarding the presence of local NGOs and farmer groups that may facilitate the process of contacting local people, and the availability of local experts to design the monitoring strategy and prepare the PDD.

Approval costs. Steps 2, 3 and 4 of the CDM cycle in Figure 2 fall within the *Approval costs* category. They include approval by the Designated National Authority (DNA) of the host country; validation of the PDD by a Designated Operational Entity (DOE) accredited by the CDM Executive Board; and registration of the project when submitted to the Executive Board. The costs of these activities depend on several factors, including the institutional infrastructure of the host country and the availability of a local DOE that can validate the PDD as a cheaper alternative to an international consultant.

Monitoring costs. Steps 5, 6 and 7 of the CDM cycle in Figure 2 fall within the *Monitoring costs* category of Table 1. These are the costs of measuring the CO_2 abatement actually achieved by the project, including certification and verification by a DOE. Once the CDM Executive Board issues the appropriate number of CERs the project developer (the Buyer) becomes a seller in the international carbon market. Any additional transaction costs that may be associated with selling CERs in the international market are not accounted for below. It is assumed that the project developer can access the full price per CER, although it is a simple matter to reduce the price by a brokerage fee if applicable. Monitoring costs are recurrent, as they are incurred every time a new batch of carbon is submitted for CER crediting.

Two types of transaction costs listed in Table 1 do not fit neatly within the CDM project cycle; nonetheless they are necessary for the approval and operation of the project.

Project management costs include the cost of keeping records of project participants and administration of payments to sellers, as well as salaries and transportation costs of project employees. *Ex ante* project management activities include the establishment of a local project office and the training of staff. Project management costs are not normally recognized explicitly in the literature on transaction costs of Kyoto mechanisms, but they are expenses incurred in buying and selling carbon-sequestration services, so they should be considered.

Enforcement and insurance costs arise from the risk of project failure or underperformance, which might be caused by fire, slow tree growth, or leakage[4]. Enforcement costs may be incurred in the form of litigation and dispute-resolution expenses. Insurance options may include purchase of an insurance policy, deduction of a risk premium from the price of carbon, and maintenance of buffer carbon stocks that are not sold. These activities form part of the risk-management strategy required within the PDD.

D. Empirical Estimates of Transaction Costs

A review of published CDM transaction-cost estimates for small projects (Michelowa et al 2003; de Gouvello and Coto 2003; Krey 2004; EcoSecurities 2003) indicates that search and negotiation costs (W_S) range between \$22,000 and \$160,000; approval costs (W_A) range between \$12,000 and \$120,000; and monitoring costs (W_M) range between \$5,000 and \$270,000. Only one source (EcoSecurities) presents risk-mitigation costs (1% to 3% of CERs), which fall under enforcement and insurance (W_E). The wide range of values in all categories illustrates the fact that transaction costs are highly sensitive to the type and size of project assumed. In addition, since the market is very recently established, there is still considerable variation and discussion about the rules of exchange which affect transactions costs.

Useful information regarding transaction costs of projects involving smallholders is provided by the Scolel Te project in Southern Mexico, which has developed a management system called ‘Plan Vivo’. De Jong et al. (2004) outline the transaction costs associated with designing the Plan Vivo Management System. Under the Search and negotiation category we could include the costs of undertaking the feasibility study, the carbon inventories, the land-use analysis, and the development of the regional baseline. The total cost of these activities was approximately \$830,000. Trained technicians develop Plan Vivos in their community

[4] Leakage occurs when the emissions reductions achieved in the project area are offset by an increase in emissions outside the project boundary, leading to no net reduction in emissions (or even a net increase).

either with individual farmers or with the community as a whole. Designing a Plan Vivo requires about 3 days of training by a professional technician. Salary, transport and lodging, are the main expenditures for training sessions, which typically cost between $400 and $500 each (de Jong et al. 2004).

Arifin (2005) presents estimates of the transaction costs incurred by community-based forestry management groups in Sumber Jaya, Indonesia. Activities identified by Arifin include obtaining information and joining farmer groups (search and negotiation); the cost of obtaining a permit to participate (approval); the cost of attending meetings (project management); and the costs of guarding crops and participating in dispute settlement (enforcement and insurance). Arifin calculated these costs as the time required to perform these activities multiplied by the wage rate.

5. Implementation of a Numerical Model for Empirical Analysis

In this section we extend our model to enable us to undertake empirical analysis of situations in which both buyers and sellers conditions for participating in the carbon market are met, including the effects of transactions costs as laid out above. The model, which is implemented in the Matlab environment (The Mathworks 2000), can be solved numerically for any set of exogenous variables. Essentially, the model consists of a set of nonlinear equations that are solved iteratively to find combinations of variables that satisfy project-participation constraints.

In Table 2 a list of variables and their units as defined for the model is presented, covering various dimensions of abatement and transactions costs, returns to carbon sequestration and other key factors that influence project feasibility.

The foregoing analysis, based on a hypothetical 25-year project, is used to identify critical project-design variables. Prices are expressed in terms of US dollars. The baseline is assumed to be a cassava crop with an NPV of $4,376/ha and the project activity is a damar agroforestry system with an NPV of $4,372/ha. The damar system is a complex agroforest developed by the Krui people of Lampung, south Sumatra. The system consists of a sequence of crops building up to a “climax that mimics mature natural forest” (ASB 2001). The main tree species is damar (*Shorea javanica*), a source of resin that provides a flow of income. Other outputs include fruits, pepper and firewood.

The carbon stock of the baseline was assumed to be zero because cassava biomass is harvested every year and soil carbon is not accounted for. The carbon accumulation pattern of the damar system (Figure 3) was represented by a Gompertz equation:

$$C_{P,t} = \beta \left(\frac{\alpha}{\beta} \right)^{\exp(-\gamma \cdot t)} \qquad (16)$$

Table 2. Variable definitions for project-participation model

Variable	Description	Units
V_C, v_C	Carbon payments received by Buyer, Seller	$ (present value)
V_A, v_A	Abatement costs experienced by Buyer, Seller	$ (present value)
V_T, v_A	Transaction costs experienced by Buyer, Seller	$ (present value)
C_t	Carbon stock above the baseline in year *t*	tC/ha
$C_{P,t}$	Carbon stock of project activity in year *t*	tC/ha
$C_{C,t}$	Carbon stock of current activity (baseline) in year *t*	tC/ha
R_t	Opportunity cost of land use change in year *t*	$/ha
$R_{P,t}$	Net revenue of project activity in year *t*	$/ha
$R_{C,t}$	Net revenue of baseline in year *t*	$/ha
A	Average farm area	Ha
p_F	Farm price of carbon	$/Tc
p_C	Rental price of carbon	$/tC
p_{CER}	Purchase price of CER	$/tCO_2e$
P_L	Price of labour	$/pd
N	Number of participating farms	Farms
δ_B	Buyer discount rate	(%)
δ_S	Seller discount rate	(%)
$y_{j,t}$	Yield of product *j* in year *t*	units/ha [a]
p_j	Price of product *j*	$/unit [a]
$x_{i,t}$	quantity of input *i* in year *t*	units/ha [b]
c_j	cost of input *i*	$/unit [b]
Q_t	Total Buyer's transaction costs in year *t*	$
q_t	Total Seller's transaction costs in year *t*	$

[a] output units vary (eg kg, t, m^3) depending on the type of product

[b] input units vary (eg pd, kg, bag) depending on the type of input

with parameter values α=0.5, β=471.6 and γ=0.0958. These parameter values result in an average carbon stock of 89.3 tC/ha over the 25-year period of the project. This agroforestry system will continue to capture carbon after the project ends (Figure 3).

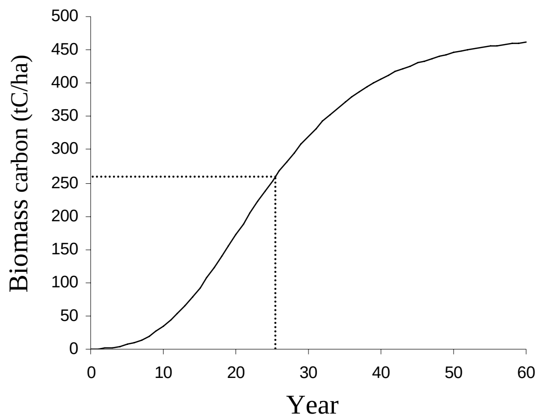

Figure 3. Simulated biomass carbon trajectory for damar in Sumatra; the hypothetical project duration is indicated by a dotted line

Transaction cost assumptions are presented in Table 3. Note that the units of measurement of these costs vary. In the case of the Buyer, costs can be *ex-ante* fixed costs ($), annual fixed costs ($/y), or variable costs dependent on the number of participating farms ($/farm) or on the size of the project ($/ha/y). In the case of the Seller, costs are expressed in terms of labour. The original five transaction-cost categories are disaggregated to account for variation in the units of measurement. The expanded classification is presented under 'Cost type' (column 1, Table 3), where number subscripts denote the different cost types. For example, there are three types of monitoring costs; W_{M1} ($/ha/y), W_{M2} ($/y), and W_{M3} (CER/y).

Table 3 . Transaction cost assumptions in base case

Cost type	Activity	Cost	Units
	Buyer (project manager)		
W_{S1}	consultation and negotiation	20,000	$
W_{S1}	establish baseline and C flows of project for region	20,000	$
W_{S1}	design monitoring plan	5,000	$
W_{S1}	prepare project design document	6,500	$
W_{S2}	design individual farm plans	200	$/farm
W_A	approval by host government	1,000	$
W_A	validate the project proposal (DOE)[a]	6,000	$
W_A	submit to CER Board (Registration fee)	*	$
W_{P1}	purchase IT infrastructure, establish local office	20,000	$
W_{P2}	maintain database/software and administer payments	10,000	$/y
W_{P2}	coordinate field crews, pay salaries	40,000	$/y
W_{M1}	measure C stocks in sample of farmers' plots	8	$/ha/y
W_{M2}	verification and certification of carbon by DOE	10,000	$/y
W_{M3}	adaptation fee	0.02	CERs/y
W_{E1}	maintain buffer of C	0.10	CERs/y
W_{E2}	settle disputes	100	$/farm/y
	Sellers (farmers)		
w_S	attend information sessions	6	d
w_S	undertake training	10	d
w_S	design farm plan	4	d
w_A	obtain permission to participate in project	4	d
w_P	attend regular project meetings	5	d/y
w_M	measure trees and report results to project office	3	d/ha/y
w_E	protect plot from poachers and fire	10	d/y
w_E	participate in dispute resolution	2	d/y

* Registration fees vary with project size <15,000 CERs=$5,000; 15,000 to <50,000 CERs=$10,000; 50,000 to <100,000 CERs=$15,000; 100,000 to < 200,000=$20,000; >200,000 CERs = $30,000

[a] Designated Operational Entity

Monitoring costs of AR projects can be high, and designing the right monitoring strategy is important (Cacho, Wise and MacDicken 2004). Monitoring also involves verification and certification of carbon stocks by a designated operational entity (DOE). This is assumed to cost $10,000 per year (Table 3), but the cost could be higher if international experts are required or the project sites are scattered over a large area.

Designing individual farm plans (W_{S2}) involves a technician visiting each farm and drawing a land-use change plan in consultation with the farmer. This is assumed to cost $200 per farm to the Buyer, which would include one or two days of a local technician's time plus travel expenses. This activity would also take four days of the Seller's time.

Enforcement and insurance is assumed to involve maintaining a buffer of 10% of biomass carbon not sold as CERs, plus an average cost of $100 per farm per year to settle disputes; this expense would include any legal fees involved. The buffer is also a risk-mitigation strategy to account for leakage or the possible loss of trees.

Using the expanded notation introduced in Table 3, transaction costs can now be calculated as:

$$V_T = W_{S1} + W_A + W_{P1} + nW_{S2} + \sum_t \begin{bmatrix} W_{P2} + W_{M2} + n(W_{E2} + aW_{M1}) + \\ (W_{M3} + W_{E1})(C_{jt} - C_{0t})p_C \end{bmatrix} (1+\delta_B)^{-t} \tag{17}$$

$$v_T = \left[w_S + w_A + \sum_t [w_P + w_E + a\, w_M](1+\delta_S)^{-t} \right] p_L \tag{18}$$

Assumptions regarding prices and discount rates are presented in Table 4. The price of CERs is set initially at a high value ($20/t CO_2) to ensure the project is feasible.

Table 4. Other assumptions for base case

Variable	Value	Description
p_{CER}	20	price of CERs ($/t CO2e)
p_C	4.28	farm price of carbon ($/t C)
p_L	1.72	price of labour ($/d)
n	500	number of farms in project
a	2	average area of farm (ha)
δ_B	0.06	Buyer discount rate
δ_S	0.15	Seller discount rate
i	$\ln(1+\delta_B)$	discount rate in carbon rental market
	89.3	mean carbon stock (tC/ha) for Damar
	0	mean carbon stock (tC/ha) for Cassava (baseline)
	4,372	net present value ($/ha) of Damar
	4,375	net present value ($/ha) of Cassava (baseline)

Replacing equations (4) and (8) with (17) and (18) respectively, and inserting parameter values in the appropriate equations, we can now solve the model and determine under what conditions both buyers and sellers will participate in the market; based on conditions for project participation (1) and (5). Experiments consist of solving the model for different values of p_{CER}, p_F, a and n and determining when both conditions (1) and (5) are satisfied.

A series of computer experiments were performed on the hypothetical project. The model is built upon the assumption that the project consists of *n* identical farms each consisting of *a* hectares. The project developer establishes individual contracts whereby farmers agree to change their land use from cropping to agroforestry and receive payments for the carbon captured in their trees. In designing the project the Buyer decides on the number of participants (n), the carbon price paid to farmers (p_F) and other features such as monitoring and risk-mitigation strategies.

6. Model Results

A. Determining the Feasible Range for Farm prices

The first step in the numerical analysis is to determine bounds for the farm price. This involves finding the minimum price acceptable to the Seller (p_S) and the maximum price the Buyer is willing to pay (p_B). First, p_F is set such that $v_C - v_A = v_T$ and the resulting value is called p_S; then p_F is set such that $V_C - V_A = V_T$ and the resulting value is called p_B. The project is feasible only if $p_B \geq p_S$, and the farm price falls within the range $p_S \leq p_F \leq p_B$. The actual value of p_F depends on the market power of the participants, the objectives of the Buyer and the outcome of negotiations.

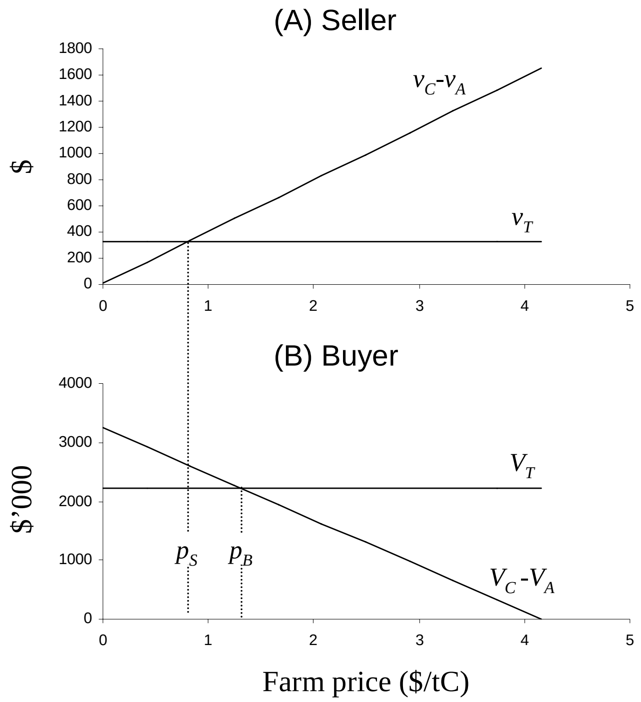

Figure 4. The feasible range of farm prices within which the project will be feasible is derived by finding the minimum price acceptable to the Seller in (A) and the maximum price acceptable to the Buyer in (B)

The carbon margin for the Seller (v_C-v_A in Figure 4A) increases linearly with p_F, whereas the carbon margin for the Buyer (V_C-V_A in Figure 4B) decreases linearly with p_F. The intersections of the carbon margin curves with their respective transaction cost curves indicate the price bounds (p_S, p_B). Given the assumptions in Tables 3 and 4 the feasible farm price ranges between $0.83/tC and $1.31/tC. For simplicity we now set $p_F = (p_S + p_B)/2$ as the base price to determine the effects of other project design variables; therefore p_F = \$1.07/tC in the base case.

B. Determining Minimum farm size

In the base case we assume and average farm area of two hectares, this size is consistent with the average area of land granted to transmigrants in Sumatra (Grist and Menz, 1997). The assumptions in Table 4 imply that the project covers 1,000 ha (500 farms of 2 ha each) and increases the biomass carbon stock by 89,300 tC above the baseline. This corresponds to a total of 327,731 CERs produced by the project (89,300 tC × 3.67 tCO_2/tC). Given that we are dealing with smallholders it is important to determine to what extent the size of participating farms affects the feasibility of the project. To answer this question we solve the model for a range of values of a, while simultaneously adjusting n to keep project size constant at 1,000 ha (or 327,731 CERs). This operation does not affect the carbon margin but it has a significant effect on transaction costs for the Buyer (Figure 5).

As farm size increases the Buyer's transaction costs decrease at a decreasing rate and become relatively flat at farm sizes beyond 5 ha or so. Reducing farm size below 1 ha causes transaction costs to increase exponentially. The minimum farm size for the given parameters is 1.6 ha, which would require 625 participating farms to maintain total project area at 1,000 ha. At this point the Buyer's transaction costs would be approximately \$2.42 million, which translates into \$7.39/CER. By comparison, for a project with 5-ha farms (requiring 200 farms to maintain the project area at 1,000ha), the Buyer's transaction costs would be \$1.75M, or \$5.34/CER.

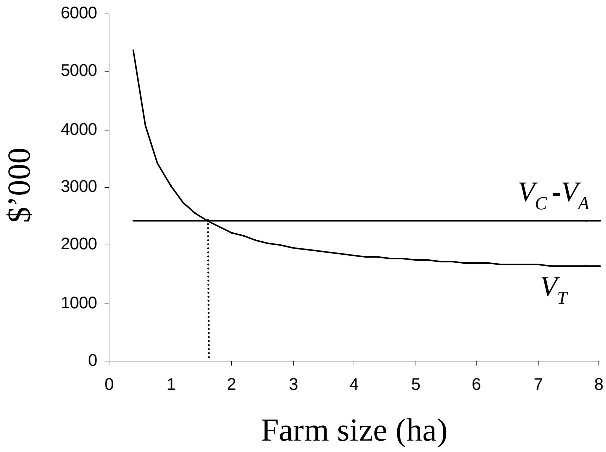

Figure 5. Minimum feasible farm size is indicated by the dotted line at the intersection of the carbon margin (V_C-V_A) and the transaction costs (V_T) for the Buyer (note: the number of farms decreases as farm size increases to keep the project size constant at 1000 ha, farm price is \$1.07/tC)

C. Determining Minimum number of farms

Now assume that farm size remains constant at 2 ha and the total project area can increase by increasing the number of contracts with farmers. In this case, as the total project area increases the farm price the Buyer is prepared to pay (p_B) also increases (Figure 6). This is because, although both the carbon margin (V_C-V_A) and transaction costs (V_T) increase with the increasing number of participants, the latter increases slower because the fixed cost are spread among a larger number of participants. The Buyer's price increases at a decreasing rate, from \$0.81 to \$1.91/tC as the number of farms under contract increases from 355 to 1,000; and total project area increases from 700 ha to 2,000 ha. In Figure 6, the minimum number of farms (355) is that at which the Buyer's maximum farm price is the same as the minimum price acceptable to the Seller ($p_B = p_S$).

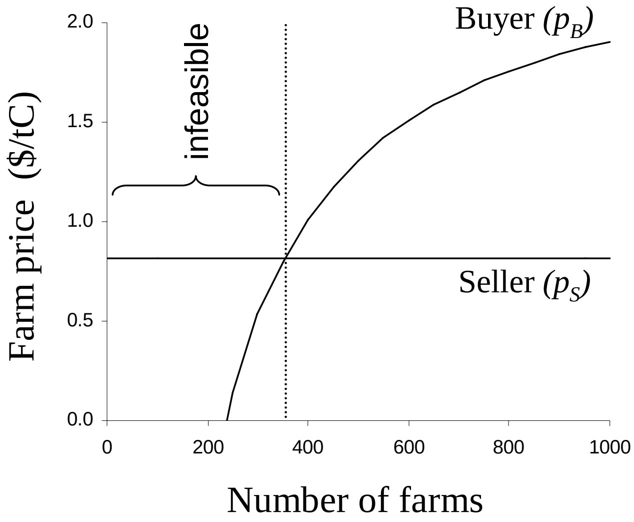

Figure 6. The breakeven number of farms, indicated by the dotted line, is calculated as the point at which the maximum price the Buyer is willing to pay (p_B) equals the minimum price the Seller is willing to accept (p_S)

D. Effects of CER price

The CER price used above (\$20/tCO_2e) is rather high given current market conditions, so it is important to determine how a lower price will affect project feasibility. In particular, it is of interest to evaluate how the CER price affects the critical values of p_S, p_B, n and a identified above. Essentially, this involves changing p_{CER} and repeating the above analysis to identify the points at which the Buyer's carbon margin (V_C-V_A) equals the transaction cost (V_T). Results are presented in Table 5. The middle column of results shows the base case already discussed, the other two columns are the results with p_{CER} values of \$25 and \$15. Given the transaction costs assumed and the default number of farms (500) and farm size (2 ha), a p_{CER} of \$15 is not feasible. At this CER price the Buyer's price (p_B=0.39) is below the Seller price (p_S=0.83). Setting the farm price p_F at its lowest feasible value of \$0.82/tC, we find that the minimum farm area with constant project size (1,000 ha) is 3.43 ha. This result (Block A in Table 5) is represented by downward shift of the V_C-V_A line in Figure 5 as the CER price decreases, causing the new intersection with V_T to occur at a larger farm size.

The last three rows of Table 5 (the Block labelled B) are the most interesting, because they show the absolute minimum possible project size (when $p_F = p_S$), or the breakeven project size, rather than the minimum project size with p_F arbitrarily set at the mean between Buyer's and Seller's prices. The breakeven number of farms increases from 355 at a p_{CER} of \$20 to 772 at a p_{CER} of \$15. This shift represents a doubling in project area from 710 ha to 1,544 ha and is equivalent to an increase in project size (in terms of CERs) from 233 kt CO_2e to 506 kt CO_2e.

Table 5. Effect of CER price on critical values of project-design variables

	Price of CERs ($/$tCO_2$e)		
	25	20	15
Seller minimum carbon price ($/tC), p_S	0.83	0.83	0.83
Buyer maximum farm price ($/tC), p_B	2.22	1.31	0.39
Farm price ($/tC), p_F	1.52	1.07	0.82
A) *With project area constant (1000ha):*			
Minimum farm area (ha)	1.18	1.61	3.43
Corresponding number of farms	846	622	291
Project CERs (tCO_2e)	327,891	327,891	327,891
B) *With farm size constant (2ha) and* p_F=p_S*:*			
Breakeven number of farms	230	355	772
Corresponding project area (ha)	460	709	1,544
Project CERs (tCO_2e)	150,875	232,552	506,250

To put our results in perspective consider that, in May 2006, there were 176 CDM projects registered[5], claiming to reduce emissions by an average of 301,633 tCO_2e/y. Classified by size, there were 71 large-scale projects with average emission reductions of 638,133 tCO_2e/y and 78 small-scale projects claiming an average of 29,554 tCO_2e/y. To convert our results from stocks of carbon to flows of CO_2 and compare them to existing projects, note that the aboveground biomass carbon stock of the damar system is assumed to increase from 0 to 252 tC/ha in 25 years (Figure 3); this represents an annual CO_2 reduction of 37 tonnes (3.67×252/25); multiplying this value by the breakeven project areas in Table 5 we obtain 17,020 tCO_2/y, 26,233 tCO_2/y and 57,128 tCO_2/y for CER prices of $25, $20 and $15 respectively. So our hypothetical project may fit within the small-scale category at a CER price of $20 or above.

7. The Project Feasibility Frontier and Sensitivity Analysis

We have seen above that smaller projects become feasible as the CER price increases. Often, it is convenient to express project size in terms of total CERs rather than number of farms, as this allows comparison with other projects, including those in the energy sector. Figure 7 shows how the minimum project size (in terms of CERs) decreases as the CER price increases. This curve forms a frontier, because projects falling below or to the left of this curve are not feasible under the given transaction costs, whereas projects that fall above or to the right of the frontier are feasible. We will call this curve the project feasibility frontier (PFF).

[5] http://cdm.unfccc.int/Projects/registered.html

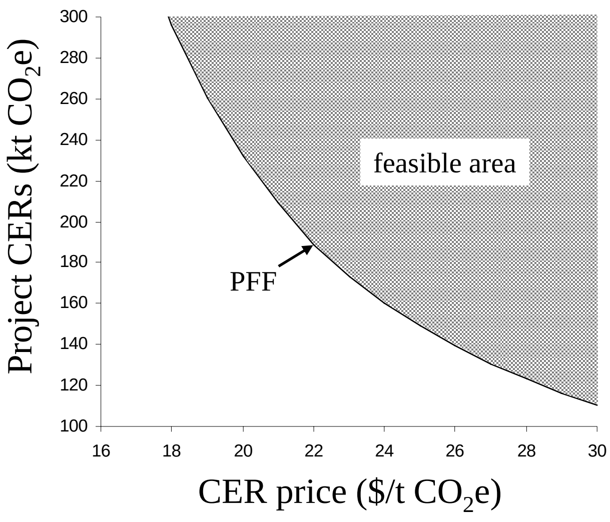

Figure 7. The project feasibility frontier (PFF)

In essence the PFF is the set of points at which the carbon margins just cover the transaction costs for both parties. The breakeven value of *n* is then converted to CER units with the formula:

Project CERs = $n \times a$ (ha) × 89.3 (tC/ha) × 3.67 (tCO_2/tC).

The PFF is a convenient way of exploring the influence of land productivity, individual transaction costs, or any other exogenous variable on the viability of a project. A new PFF can be derived by changing any exogenous variable and repeating the process; thus providing a useful tool for sensitivity analysis.

A. Effect of carbon sequestration potential

The damar system in our project is assumed to increase average carbon stock by 89.3 tonnes per hectare over the life of the project (25 years). But there can be considerable variability in the productivity of farms within the same region. Therefore it is important to determine the influence of carbon-sequestration potential on project viability. Figure 8 presents PFFs for three levels of carbon sequestration potential: the base case, a low potential (0.75 $C(t)$), and a high potential (1.25 $C(t)$).

A change in carbon sequestration potential causes the PFF to shift in the opposite direction. When $C(t)$ increases by 25% the PFF shifts left, so that, compared to the base case, smaller projects are viable at a given CER price; or lower CER prices are required to make a given project size viable. A decrease in $C(t)$ has the opposite effect, and the effect is more pronounced. These results indicate that a reduction in actual carbon sequestered relative to expectations can have a major influence on the success of the project.

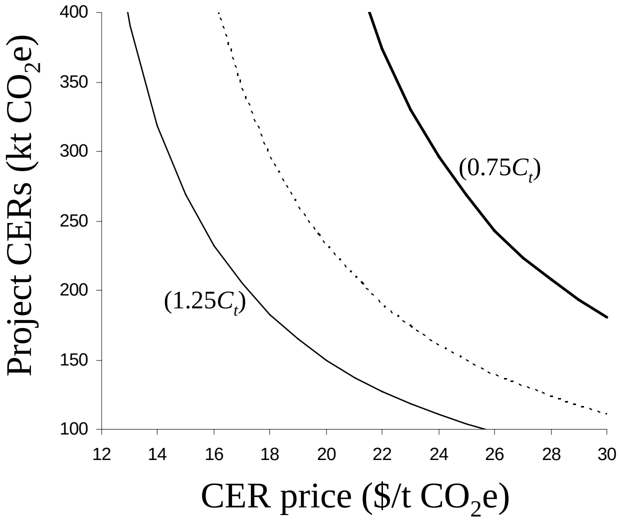

Figure 8. The effect of carbon sequestration potential on the position of the project feasibility frontier; the dotted line represents the base case, solid lines represent an increase (to 1.25×base) or a decrease (to 0.75×base) in the carbon-stock trajectory

B. Effect of Transaction costs

The transaction costs assumed for this analysis were presented in Table 3. These values are arbitrary but plausible. There is high uncertainty regarding some of these costs and thus it is important to evaluate their effect on project viability. This can be done by modifying the Seller's transaction costs, $q(t)$, and/or the Buyer's transaction costs, $Q(t)$, and solving the model. Figure 9 presents PFFs for three transaction-cost scenarios: the base case, low Buyer cost (0.75 $Q(t)$), and a low Seller cost (0.75 $q(t)$).

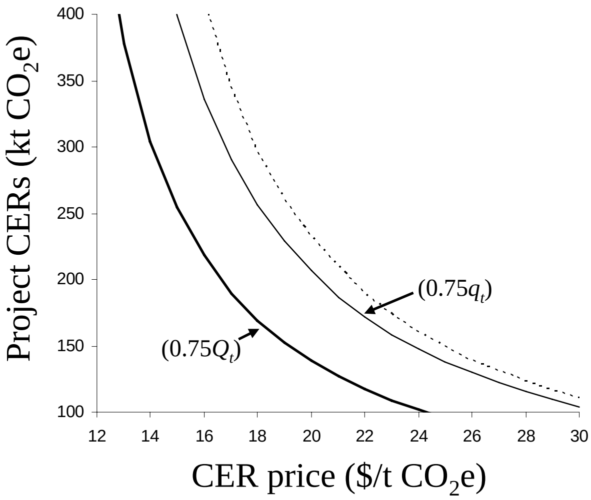

Figure 9. The effect of transaction costs on the position of the project feasibility frontier; the dotted line represents the base case, the solid lines represent a 25% decrease in the transaction costs of the Buyer (Q_t) or Seller (q_t)

Decreases in transaction costs cause the PFF to shift left, making smaller projects viable at a given CER price; or lowering the CER price required to make a given project size viable. Buyer's transaction costs have a more pronounced influence than Seller's transaction costs.

So reducing the transaction costs experienced by buyers should be a priority when designing projects, which is the subject we turn to in the following section.

8. Discussion: potential for improving the feasibility of smallholder carbon projects and future research

A. Potential for Reducing Transactions Costs

The model results indicate that reducing transactions costs is an important means to increase the feasibility of smallholder participation in carbon markets. In this section we outline some strategies by which these costs can be reduced, and the role of the public sector in facilitating them.

The biggest gains in improving the feasibility of smallholder carbon sequestration projects may be realized by reducing the *ex-ante* transactions costs the buyers face. Reducing fixed costs may be expected to have greater benefits for smallholder participation, since these are shared over the total number of hectares in the project. Strategies to reduce these types of transactions costs fall into three broad categories: 1) Increasing project size by fostering/building upon collective action amongst suppliers; 2) reducing contracting costs by utilizing existing management structures; and 3) reducing information costs through public provision of data, templates and guidelines. The categories are not mutually exclusive and in fact in many cases are complementary.

Foster collective action. Coordinating and consolidating sequestration supply among groups of poor landholders is an important way to reduce transaction costs associated with smallholder projects and one which has received considerable attention in the literature. (Lipper and Cavatassi 2004; Cacho et. al. 2003; Smith and Scherr 2002; Landell-Mills and Porras 2002) Examples of projects involving smallholder coordination in the supply of carbon services are described in Cacho et. 2003, Smith and Scherr 2002 and Orlando et. al. 2002. In these projects the costs to buyers of identifying, contracting, and enforcing viable carbon sequestration opportunities among smallholders are reduced through the presence of an intermediary representing the suppliers, which can be an NGO, community group or government agency. It is important to note however, that the transactions cost facing the sellers can increase by participating in such group schemes, and this cost must be lower than the benefits that sellers derive from participation. Several of the existing carbon smallholder projects were built upon some type of existing community projects, such as ongoing community-based natural resource management projects, particularly community forestry projects or farmer's groups. For example, the Scolel Te project was initiated with a stakeholder group of interested farmers drawn mainly from one farmers union operating in the Chiapas region. (http://www.eccm.uk.com/scolelte/involved.html). Communities that already have experience in working cooperatively are likely to have lower costs of participation as well as dispute resolution – another important transaction cost.

One potentially important area for collective action to reduce transactions costs is through peer-monitoring schemes. There is anecdotal evidence that, when farmers learn the value of carbon biomass, they could monitor their plots at low cost. For example, farmers in Sumatra are able to assess the volume of wood in their trees by sight; they are accurate within the 0.25 m^3 increments used in the timber market (Hairia *et al.* 2001). In field tests undertaken by Delaney and Roshetko (1999), two days were required for a crew to learn inventory methods for measuring carbon in agroforestry gardens in Java. This evidence suggests that training smallholders to identify and measure their own trees or participate in a peer monitoring scheme may be a good investment, since monitoring costs are a fairly significant recurring transaction cost. In addition self or peer monitoring systems have the potential to yield more accurate carbon assessments, because the accuracy of carbon measurements depends on the number of sampling sites (e.g. see Cacho *et al*., 2004). Therefore involving smallholders in self-monitoring could not only reduce monitoring and enforcement costs, but also achieve high measurement accuracy by allowing high sampling intensity at a fairly low cost.

Utilize existing infrastructure/management capacity. Transactions costs associated with establishing local offices, purchasing IT infrastructure, maintain database/software and administer payments could be greatly reduced where carbon projects are implemented by existing public or private entities that already have some or all of the infrastructure and management capacity in place. Another potentially important management structure to build upon is conditional cash transfer mechanisms that various countries and local governments are involved in implementing. (See de la Briere and Rawlings 2006 for a summary) These programs have been implemented in a wide range of middle and low income developing countries and they involve linking cash payments to behaviour modification – usually in the area of education and health. Important management lessons as well as the potential to use existing payment infrastructure can be obtained from these programs and make a significant reduction in fixed transactions costs facing small-scale sequestration projects.

Reducing information costs. Generating and disseminating information is one of the largest source of transactions costs in carbon projects: including the establishment of baselines, methodologies for implementation and monitoring, as well information on buyers and sellers to reduce search costs. At this point the carbon market is still quite young, so information costs are high as a set of rules, methodologies and baseline datasets are currently under development. For example, the establishment of carbon baselines is one of the most expensive ex ante transactions costs, and the generation and dissemination of information by development agencies can have a considerable effect in reducing transaction costs. The Good Practice Guides of the IPCC and associated tools have reduced the cost of developing project documents, in particular those for small scale projects, which allow generic parameters to be used to estimate carbon stocks of project activities. Another important aspect of reducing information costs is the development of a set of rules and methodologies specific to small scale projects. Under the CDM small-scale projects are allowed to adapt a simplified set of procedures including a simplified PDD. Haites (2004) states:

"The simplified methodologies adopted by the Executive Board for small-scale CDM projects appear to reduce the transaction costs for those projects enough to make such projects economically viable. Evidence as to whether the transaction cost per CER is higher or lower than for a regular CDM project is mixed. But indications of a supply of potential small-scale CDM projects suggest that the transaction costs for the simplified methodologies are sufficiently low to make some small projects economically viable at the current market price for Kyoto units".

This statement refers to projects in the energy sector which tend to be easier to monitor. It is not clear whether the same applies to AR projects. To test whether this is true the model can be solved using values representing the simplified modalities and procedures for small-scale CDM projects. Therefore it is important to obtain cost estimates for such projects for future analyses.

Several efforts are underway to reduce buyer and seller search and negotiation costs – including the establishment of websites such as the Ecosystem marketplace (www.ecosystemmarketplace.com) as well as websites, workshops, publications, technical projects, research activities and capacity building work on the part of several UN agencies and NGOS including FAO, GEF, UNEP, WWF, IUCN, TNC and others.

B. Future Extensions to the Model

The analytical tools developed in this study can be applied to address a rich variety of questions with relevance to policy makers and project developers. Some interesting questions that are not answered here, but that could be tackled by applying the model, are discussed in this section.

We assumed that carbon stocks are measured, verified and certified, and the new batch of CERs is submitted every year, thus supplying the project with an annual income stream. Similarly, participating farmers receive annual payments in proportion to the stock of carbon they maintained during the year. Variations on these schedules are possible. For example, the project may certify and sell temporary CERs every five years, thus reducing monitoring and certification costs, but also delaying the receipt of payments and therefore increasing the need for credit.

Variations on the schedule of payments to farmers are also possible. For example, the project could provide a larger initial payment, to help farmers cover the expense of establishing agroforestry in their land, followed by smaller future payments. The payment schedule would be designed so that the present value of the total payment is the same as it would have been with annual payments. The Fondo Bioclimatico carbon project in Mexico offers an example of this approach. In their first year of participation, farmers receive an upfront payment equivalent to 20% of the total amount to be accrued over 20 to 30 years. Three more payments of 20% are made in years 2, 3 and 5, and the final payment is made in year 10 (Corbera 2005). This strategy requires the project developer to take on more risk because initial payments exceed the value of the carbon already sequestered, and this money would be lost should farmers abandon the project. However, the strategy also raises interesting possibilities. Since the Seller's discount rate is higher than the Buyer's, the project developer can increase the present value of payments to farmers, while keeping the present value of the project cost constant; thus providing higher incentives to farmers with no additional cost (although with some additional risk).

In our analysis we assume that all participating farmers join the project in its first year, and that the number of participants remains constant throughout the project. In reality, the project may start with a few farmers and, if it is successful, grow as other farmers apply to join once they observe the advantages of participation. The Fondo Bioclimatico provides an example of this evolution (Corbera 2005). The project started in 1997 with 6 communities, 43 contracts and covering 77.5 ha. By 2004 the project had 33 communities, 650 contracts and covered 845 ha. As the project has grown and fixed costs have been absorbed it has become feasible to allow smaller farms to participate.

Our analysis assumes that smallholders are price-takers in a homogenous carbon market, however there is the potential to develop a "premium" product in the form of CERs that are certified for not only carbon but also sustainable development and poverty reduction. This is the concept behind the "gold standard certification for CERS that has been developed by an NGO " http://www.cdmgoldstandard.org/. Gold standard claims that their certification often leads to projects obtaining premium prices for CERs. One important question in the development of these types of niche markets is the relative size of the additional transactions costs associated with obtaining certification as compared with the price premium obtained, and the overall effects on project feasibility taking into account all other relevant parameters.

We have assumed that farms participating in a project are homogeneous. This simplifies the analysis by allowing us to calculate transaction costs, abatements costs and carbon payments for the average farm, and then multiply the results by the number of farms to obtain project-level results. This simplification also makes it computationally feasible to derive the project-feasibility frontier (PFF) for a large number of scenarios, thus helping us understand the influence of different types of transaction costs and other assumptions on the feasibility of a project. In deriving the PFF we implicitly assume that there are as many farms of a given area as needed by the project to cover transaction costs. In reality, a limited number of farms is available in a region and, furthermore, there can be considerable variability between farms in terms of size and productive capacity. Antle and Valdivia (2006) observed this variability in US agriculture and pointed out that it may have important implications for policy analysis of payments for environmental services.

Finally, the baseline is another factor that can have significant influence on project viability, in terms of both opportunity cost and expected carbon stocks in the absence of the project. Our evidence suggests that the best strategy for achieving success is to concentrate on degraded lands that have low opportunity cost and low carbon stocks.

References

Antle, J.M. and Valdivia, R.O. 2006. Modelling the supply of ecosystem services from agriculture: a minimum-data approach. Australian Journal of Agricultural and Resource Economics. 50:1-15.

Arifin, B. 2005. Institutional Perspectives of Lifescape Co-Management: lessons learned from RUPES sites in Sumatra, Indonesia. In Murdiyarso, D and Herawati, H. (eds.). Carbon Forestry: who will benefit? Workshop on Carbon Sequestration and Sustainable Livelihoods, Bogor, Indonesia, CIFOR. 156-176.

ASB. 2001. The Krui agroforests: a model of sustainable community-based management. *Policy Briefs, Alternatives to Slash and Burn, July 2001*. (http://www.asb.cgiar.org).

Brown, S. 2002. Measuring carbon in forests: current status and future challenges. *Environmental Pollution*. 116:363-372.

Cacho, O.J., Hean, R.L. and Wise, R. 2003. Carbon-accounting methods and reforestation incentives. *Australian Journal of Agricultural and Resource Economics.* 47: 153-179.

Cacho, O.J., Marshall, G.R. and Milne, M. 2003. Smallholder agroforestry projects: potential for carbon sequestration and poverty alleviation. The Food and Agriculture Organization of the United Nations (FAO). ESA Working Paper 03-06.

Cacho, O.J. Marshall, G.R. and Milne, M. 2005. Transaction and abatement costs of carbon-sink projects in developing countrie, *Environment and Development Economics.* 10(5): 1-18.

Cacho, O.J., Wise, R. and MacDicken, K. 2004 Carbon monitoring costs and their effect on incentives to sequester carbon through forestry. *Mitigation and Adaptation Strategies for Global Change*. 9 (3): 273 – 293.

Capoor, K. and Ambrosi, P. 2006. State and trends of the carbon market 2006. The World Bank, Washington D.C.

Corbera, E. 2005. Bringing development into carbon forestry markets: challenges and outcomes of small-scale carbon forestry activities in Mexico. In Murdiyarso, D and Herawati, H. (eds.). Carbon Forestry: who will benefit? Workshop on Carbon Sequestration and Sustainable Livelihoods, Bogor, Indonesia, CIFOR. Pp. 42-56.

de Gouvello, C. and Coto, O. 2003. Transaction costs and carbon finance impact on small-scale CDM projects. PCF Plus, Washington DC.

de Jong, B.H.J., Gaona, S.O., Montalvo, S.Q., Bazan, E.E., and Hernandez, N.P. 2004. Economics of Agroforestry carbon sequestration, In J.R.R. Alavalapati and D.E. Mercer (eds.), Valuing Agroforestry Systems: Methods and Applications, Dordrecht, Kluwer Academic Publishers, pp. 123-138.

de la Briere, B. and Rawlings, L. 2006. Examining Condicional Cash Transfer Programs: A Role for Increased Social Inclusión? Social Protection Discussion Paper Number 0603, World Bank Institute Washington DC.

Delaney, M. and Roshetko, J. 1999. Field tests of carbon monitoring methods for home gardens in Indonesia. In: Field tests of carbon monitoring methods in forestry projects. Forest Carbon Monitoring Program, Winrock International, Arlington, VA, USA. pp 45-51.

Dudek, D.J. and Wienar, J.B. 1996. Joint implementation, transaction costs, and climate change, Organisation for Economic Co-operation and Development, Paris.

EcoSecurities. 2003. Chapter 5: Transaction Costs, Efficiency and Supportive Governance, The Clean Development Mechanism: A User's Guide, New York, United Nations Development Programme, pp. 55-68.

Grist, P. and Menz. K. 1997. On-site effects of *Imperata* burning by Indonesian smallholders: a bioeconomic model. *Bulletin of Indonesian Economic Studies*. 33(3):79-96.

Hairiah, K., Sitompul, S.M., van Noordwijk, M. and Palm, C. 2001. Carbon stocks of tropical land use systems as part of the global C balance: effects of forest conversion and options for 'clean development' activities. ASB Lecture Note 4A, ICRAF, Bogor. (http://www.icraf.cgiar.org/sea)

Haites, E. 2004. Estimating the Market Potential for the Clean Development Mechanism: Review of Models and Lessons Learned. PCFplus Report 19, Washington DC.

Krey, M. 2004. Transaction costs of CDM project sin India – an empirical survey. HWWA Report 238. Hamburg Institute of International Economics.

Landell-Mills and Porras, I. T. 2002. Silver bullet or fools' gold? A global review of markets for forest environmental services and their impact on the poor. International Institute for Environment and Development (IIED). March 2002. London.

Lipper, L. and Cavatassi, R. 2004. Land-use change, carbon sequestration and poverty alleviation. *Environmental Management*. 33(1): S374-S387

Marland, G., Fruit, K. and Sedjo, R. 2001. Accounting for sequestered carbon: the question of permanence. *Environmental Science and Policy*, 4: 259-268.

Michelowa, A., Stronzik, M., Eckermann, F. and Hunt, A. 2003. Transaction costs of the Kyoto mechanisms. *Climate Policy*. 3:261-278.

Orlando, B. D. Baldock, S. Canger, J. Mackensen, S. Maginnis, M. Manguiat, S. Rietbergen, Robledo, C. and Schneider, N. 2002. Carbon, Forests and People: Towards the integrated management of carbon sequestration, the environment and sustainable livelihoods; IUCN The World Conservation Union Gland, Switzerland and Cambrindge, UK.

Otsuka, K. and Place, F. 2001a. Issues and theoretical framework. In: Otsuka, K. and Place, F. (eds), *Land Tenure and Natural Resource Management: A Comparative Study of Agrarian Communities in Asia and Africa*. The John Hopkins University Press, Baltimore and London, pp. 3-33.

Smith, J. and Scherr, S.J. 2002. Forest Carbon and Local Livelihoods: Assessment of Opportunities and Policy Recommendations CIFOR Occasional Paper No. 37.Stavins, J. (1995), 'Transaction costs and tradeable permits'. *Journal of Environmental Economics and Management*. 29: 133-148.

The Mathworks. 2002. Using Matlab. The Matworks Inc. Natick, Massachusetts.

Williamson, O.E. 1985. *The Economic Institutions of Capitalism*. Free Press, New York.

Wise, R.M. and Cacho, O.J. 2005a. Bioeconomic analysis of carbon sequestration in farm forestry: a simulation study of *Gliricidia sepium*. *Agroforestry Systems*. 64: 237-250.

Wise, R.M. and Cacho, O.J. 2005b Tree-crop interactions and their environmental and economic implications in the presence of carbon-sequestration payments. *Environmental Modelling and Software*. 20 (9): 1139-1148.

NOTE DI LAVORO DELLA FONDAZIONE ENI ENRICO MATTEI

Fondazione Eni Enrico Mattei Working Paper Series

Our Note di Lavoro are available on the Internet at the following addresses:

http://www.feem.it/Feem/Pub/Publications/WPapers/default.htm
http://www.ssrn.com/link/feem.html
http://www.repec.org
http://agecon.lib.umn.edu
http://www.bepress.com/feem/

NOTE DI LAVORO PUBLISHED IN 2007

NRM	1.2007	*Rinaldo Brau, Alessandro Lanza, and Francesco Pigliaru*: How Fast are Small Tourist Countries Growing? The 1980-2003 Evidence
PRCG	2.2007	*C.V. Fiorio, M. Florio, S. Salini and P. Ferrari:* Consumers' Attitudes on Services of General Interest in the EU: Accessibility, Price and Quality 2000-2004
PRCG	3.2007	*Cesare Dosi and Michele Moretto*: Concession Bidding Rules and Investment Time Flexibility
IEM	4.2007	*Chiara Longo, Matteo Manera, Anil Markandya and Elisa Scarpa*: Evaluating the Empirical Performance of Alternative Econometric Models for Oil Price Forecasting
PRCG	5.2007	*Bernardo Bortolotti, William Megginson and Scott B.* Smart: The Rise of Accelerated Seasoned Equity Underwritings
CCMP	6.2007	*Valentina Bosetti and Massimo Tavoni*: Uncertain R&D, Backstop Technology and GHGs Stabilization
CCMP	7.2007	*Robert Küster, Ingo Ellersdorfer, Ulrich Fahl* (lxxxi): A CGE-Analysis of Energy Policies Considering Labor Market Imperfections and Technology Specifications
CCMP	8.2007	*Mònica Serrano* (lxxxi): The Production and Consumption Accounting Principles as a Guideline for Designing Environmental Tax Policy
CCMP	9.2007	*Erwin L. Corong* (lxxxi): Economic and Poverty Impacts of a Voluntary Carbon Reduction for a Small Liberalized Developing Economy: The Case of the Philippines
CCMP	10.2007	*Valentina Bosetti, Emanuele Massetti, and Massimo Tavoni*: The WITCH Model. Structure, Baseline, Solutions
SIEV	11.2007	*Margherita Turvani, Aline Chiabai, Anna Alberini and Stefania Tonin*: Public Policies for Contaminated Site Cleanup: The Opinions of the Italian Public
CCMP	12.2007	*M. Berrittella, A. Certa, M. Enea and P. Zito*: An Analytic Hierarchy Process for The Evaluation of Transport Policies to Reduce Climate Change Impacts
NRM	13.2007	*Francesco Bosello, Barbara Buchner, Jacopo Crimi, Carlo Giupponi and Andrea Povellato*: The Kyoto Protocol and the Effect of Existing and Planned Measures in the Agricultural and Forestry Sector in the EU25
NRM	14.2007	*Francesco Bosello, Carlo Giupponi and Andrea Povellato*: A Review of Recent Studies on Cost Effectiveness of GHG Mitigation Measures in the European Agro-Forestry Sector
CCMP	15.2007	*Massimo Tavoni, Brent Sohngen, and Valentina Bosetti*: Forestry and the Carbon Market Response to Stabilize Climate
ETA	16.2007	*Erik Ansink and Arjan Ruijs*: Climate Change and the Stability of Water Allocation Agreements
ETA	17.2007	*François Gusdorf and Stéphane Hallegatte*: Compact or Spread-Out Cities: Urban Planning, Taxation, and the Vulnerability to Transportation Shocks
NRM	18.2007	*Giovanni Bella*: A Bug's Life: Competition Among Species Towards the Environment
IEM	19.2007	*Valeria Termini and Laura Cavallo*: "Spot, Bilateral and Futures Trading in Electricity Markets. Implications for Stability"
ETA	20.2007	*Stéphane Hallegatte and Michael Ghil*: Endogenous Business Cycles and the Economic Response to Exogenous Shocks
CTN	21.2007	*Thierry Bréchet, François Gerard and Henry Tulkens*: Climate Coalitions: A Theoretical and Computational Appraisal
CCMP	22.2007	*Claudia Kettner, Angela Köppl, Stefan P. Schleicher and Gregor Thenius*: Stringency and Distribution in the EU Emissions Trading Scheme –The 2005 Evidence
NRM	23.2007	*Hongyu Ding, Arjan Ruijs and Ekko C. van Ierland*: Designing a Decision Support System for Marine Reserves Management: An Economic Analysis for the Dutch North Sea
CCMP	24.2007	*Massimiliano Mazzanti, Anna Montini and Roberto Zoboli*: Economic Dynamics, Emission Trends and the EKC Hypothesis New Evidence Using NAMEA and Provincial Panel Data for Italy
ETA	25.2007	*Joan Canton*: Redealing the Cards: How the Presence of an Eco-Industry Modifies the Political Economy of Environmental Policies
ETA	26.2007	*Joan Canton*: Environmental Taxation and International Eco-Industries
CCMP	27.2007	*Oscar Cacho and Leslie Lipper* (lxxxii): Abatement and Transaction Costs of Carbon-Sink Projects Involving Smallholders

(lxxxi) This paper was presented at the EAERE-FEEM-VIU Summer School on "Computable General Equilibrium Modeling in Environmental and Resource Economics", held in Venice from June 25th to July 1st, 2006 and supported by the Marie Curie Series of Conferences "European Summer School in Resource and Environmental Economics".
(lxxxii) This paper was presented at the Workshop on “Climate Mitigation Measures in the Agro-Forestry Sector and Biodiversity Futures”, Trieste, 16-17 October 2006 and jointly organised by The Ecological and Environmental Economics - EEE Programme, The Abdus Salam International Centre for Theoretical Physics - ICTP, UNESCO Man and the Biosphere Programme - MAB, and The International Institute for Applied Systems Analysis - IIASA.

2007 SERIES	
CCMP	*Climate Change Modelling and Policy* (Editor: Marzio Galeotti)
SIEV	*Sustainability Indicators and Environmental Valuation* (Editor: Anil Markandya)
NRM	*Natural Resources Management* (Editor: Carlo Giupponi)
KTHC	*Knowledge, Technology, Human Capital* (Editor: Gianmarco Ottaviano)
IEM	*International Energy Markets* (Editor: Matteo Manera)
CSRM	*Corporate Social Responsibility and Sustainable Management* (Editor: Giulio Sapelli)
PRCG	*Privatisation Regulation Corporate Governance* (Editor: Bernardo Bortolotti)
ETA	*Economic Theory and Applications* (Editor: Carlo Carraro)
CTN	*Coalition Theory Network*