

6. Analysis of project design

Assumptions

In this chapter we apply the model developed in Chapter 5 to a complex agroforestry system in Sumatra, based on information presented in Appendix 1. A hypothetical 25-year project is simulated and used to identify critical project-design variables. The baseline is assumed to be a cassava crop with an NPV of \$4,376/ha and the project activity is a damar tree (*Shorea javanica*) agroforestry system (see Appendix 1) with an NPV of \$4,372/ha. The carbon stock of the baseline is 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 10) is represented by a Gompertz equation with parameter values $\alpha = 0.5$, $\beta = 471.6$ and $\gamma = 0.0958$ (see equation (4.6) for the functional form). These parameter values result in an average carbon stock of 89.3 tC/ha over the 25-year period of the project. Note that this system will continue to capture carbon after the project ends.

A series of computer experiments was performed for this hypothetical project. 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.

Transaction-cost assumptions are presented in Table 11. 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 (\$/year), or variable costs dependent on the number of participating farms (\$/farm) or the size of the project (\$/ha/year). 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' (Table 11, column 1), where

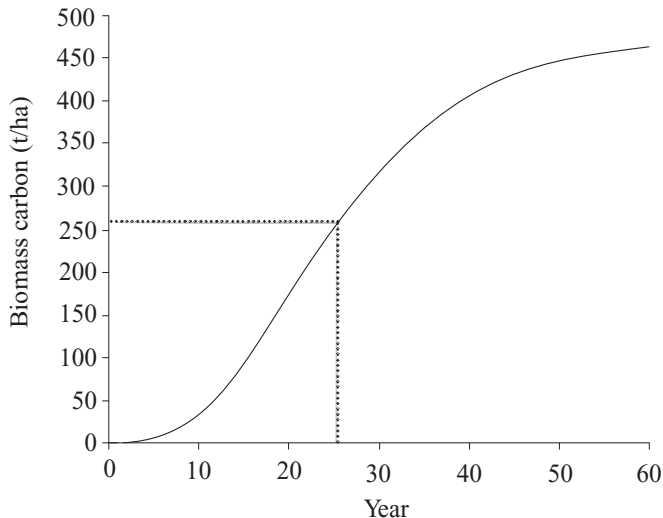


Figure 10. Simulated biomass carbon trajectory for damar (*Shorea javanica*) in Sumatra; the hypothetical project duration is indicated by a dotted line

number subscripts denote the different cost types. For example, there are three types of monitoring costs: W_{M1} (\$/ha/year), W_{M2} (\$/year), and W_{M3} (CER/year).

Monitoring costs for AR projects can be high, and designing the right monitoring strategy is important. 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 11), but the cost could be higher if international experts were required or the project sites were scattered over a large area.

Designing individual farm plans (W_{S2}) involves a technician visiting each farm and designing a land-use change plan in consultation with the farmer. This is assumed to cost \$200 per farm to the buyer, which would cover 1–2 days of a local technician’s time plus travel expenses. This activity would also take 4 days of the seller’s time (Table 11).

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 (Table 11); this expense would include any legal fees involved. The buffer is a risk-mitigation strategy to account for leakage or the possible loss of trees.

Using the expanded notation introduced in Table 11, transaction costs can now be calculated using equations (6.1) and (6.2) (see next page).

Assumptions about prices and discount rates are presented in Table 12. The price of CERs is set initially at a high value ($\$20/tCO_2$) to ensure the project is feasible.

Replacing equations (5.4) and (5.8) with (6.1) and (6.2), respectively, and inserting parameter values in the appropriate equations, we can now solve the model developed in Chapter 5 and determine under what conditions the project is feasible. Based on conditions for project participation [equations (5.1) and (5.5)], the project is feasible if conditions (6.3) and (6.4) are satisfied. The expressions on the left of these inequalities

Table 11. 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 carbon (C) flows of project for region	20,000	\$
W_{S1}	Design monitoring plan, establish permanent sampling plots	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 (designated operational entity, DOE)	6,000	\$
W_A	Submit to CDM Executive Board (registration fee)	See table footnote ^a	\$
W_{P1}	Purchase IT infrastructure, establish local office	20,000	\$
W_{P2}	Maintain database/software and administer payments	10,000	\$/year
W_{P2}	Coordinate field crews, pay salaries	40,000	\$/year
W_{M1}	Randomly check C stocks reported by farmers	8	\$/ha/year
W_{M2}	Verification and certification of carbon by DOE	10,000	\$/y
W_{M3}	Adaptation fee	0.02	CER/year
W_{E1}	Maintain buffer of C	0.10	CER/year
W_{E2}	Settle disputes	100	\$/farm/year
Sellers (farmers)			
w_S	Attend information sessions	6	days
w_S	Undertake training	10	days
w_S	Design farm plan	4	days
w_A	Obtain permission to participate in project	4	days
w_P	Attend regular project meetings	5	days/year
w_M	Measure trees, fill in form and deliver to project office	3	days/ha/year
w_E	Protect plot from poachers and fire	10	days/year
w_E	Participate in dispute resolution	2	days/year

^a Registration fees vary with project size: <15,000 CER = \$5,000; 15,000 to <50,000 CER = \$10,000; 50,000 to <100,000 CER = \$15,000; 100,000 to <200,000 = \$20,000; >200,000 CER = \$30,000.

$$V_T = W_{S1} + W_A + W_{P1} + nW_{S2} + \sum_t \left[\frac{W_{P2} + W_{M2} + n(W_{E2} + aW_{M1})}{(W_{M3} + W_{E1})(C_{jt} - C_{0t})} p_C \right] (1 + \delta_B)^t \quad (6.1)$$

$$v_T = \left[w_S + w_A + \sum_t [w_P + w_E + a w_M] (1 + \delta_S)^t \right] p_L \quad (6.2)$$

$$v_C(a, p_F, C(t), \delta_S) - v_A(a, p_L, R(t), \delta_S) \geq v_T(p_L, q(t), \delta_S) \quad (6.3)$$

$$V_C(a, n, p_{CER}, C(t), \delta_B) - V_A(a, n, p_F, C(t), \delta_B) \geq V_T(a, n, p_{CER}, C(t), Q(t), \delta_B) \quad (6.4)$$

are the carbon margins; the expressions on the right are transaction costs (in present-value terms). Experiments consist of solving the model for different values of the arguments (in particular p_{CER} , p_F , a and n) and determining when both (6.3) and (6.4) are satisfied.

Farm price

The first step in the numerical analysis is to determine bounds for the farm price (Figure 11). This involves finding the minimum price acceptable to the seller and the maximum price the buyer is willing to pay. 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 between the buyer and seller.

The carbon margin for the seller ($v_C - v_A$ in Figure 11a) increases linearly with p_F , whereas the carbon margin for the buyer ($V_C - V_A$ in Figure 11b)

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 11 and 12, the feasible farm price ranges between \$0.83/tC and \$1.31/tC (Figure 11). For simplicity we now set the base price as $p_F = (p_S + p_B) / 2$ to determine the effects of other project design variables; therefore $p_F = \$1.07/tC$ in the base case.

Minimum farm size

The assumptions in Table 12 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 CER produced by the project (89,300 tC \times 3.67 tCO₂/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

Table 12. Other assumptions for base case

Variable	Value	Description
p_{CER}	20	Price of Certified Emission Reductions (\$/tCO ₂ e)
p_C	4.28	Farm price of carbon (\$/tC)
p_L	1.72	Price of labour (\$/day)
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 ^a
	0	Mean carbon stock (tC/ha) for cassava (baseline) ^a
	4,372	Net present value (\$/ha) of damar ^a
	4,375	Net present value (\$/ha) of cassava (baseline) ^a

^a Source: Ginoga et al. (2002)

1,000 ha (or 327,731 CER). While this operation does not affect the carbon margin, it has a significant effect on transaction costs for the buyer (Figure 12).

As farm size increases, the buyer's transaction costs fall at a decreasing rate and become relatively flat at farm sizes beyond 5 ha or so. Reducing farm

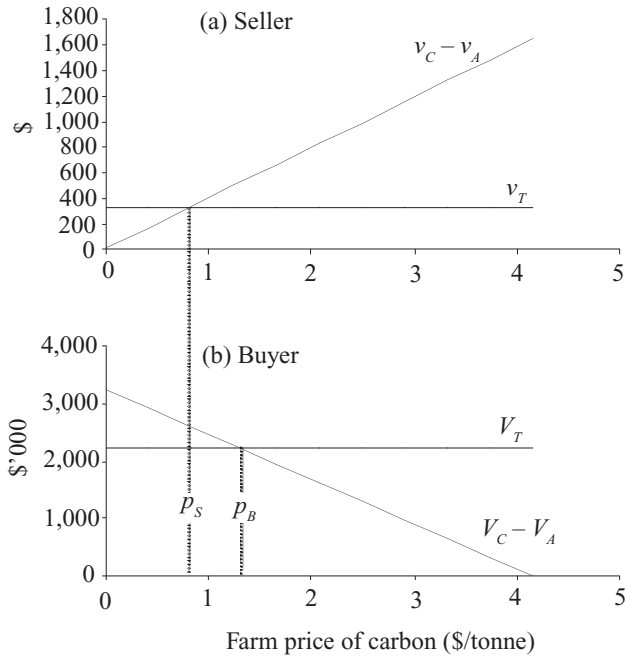


Figure 11. The range of farm prices within which the project will be feasible is derived by finding the minimum price acceptable to the seller in (a) and the maximum price acceptable to the seller in (a) and the maximum price acceptable to the buyer in (b).

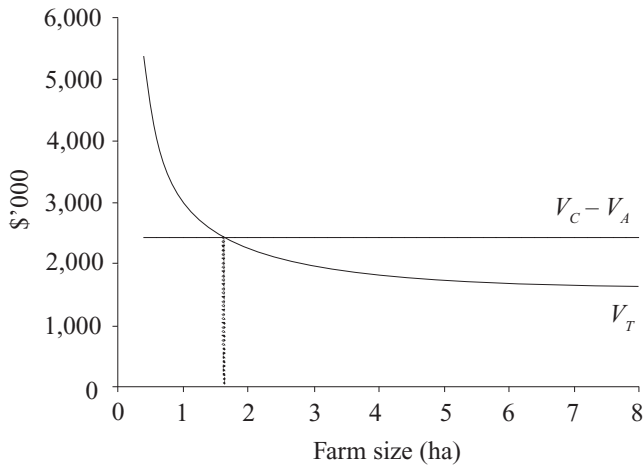


Figure 12. Minimum feasible farm size is indicated by the dotted line at the intersection of the carbon margin ($V_C - V_A$) and the transaction costs (V_T) for the buyer

size below 1 ha causes transaction costs to increase exponentially. The minimum farm size for the parameters given is 1.6 ha (Figure 12), 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 1,000 ha), the buyer's transaction costs would be \$1.75 million, or \$5.34/CER. Many farmers in Indonesia work areas of 1 ha or less and they would be excluded from this hypothetical project unless they could contract with the project as a group offering a larger area of land.

De Jong et al. (2004) report that families participating in the *Scolec Te* project in Mexico are able to initiate reforestation activities on 0.5–1.5 ha without a significant drain in their labour resource. According to our results, these farms would not be acceptable in the hypothetical project unless their carbon-sequestration potential could be increased, their transaction costs reduced, or both. These questions are considered later, through sensitivity analysis.

Corbera (2005) reports that Fondo Bioclimatico, the organisation that runs the *Scolec Te* project, increased the number of contracts between 1997 and 2004, from 43 farmers in 6 communities to 650 farmers in 33 communities. During the same period the reforestation area increased from 78 ha to 845 ha. This implies that the average farm area has fallen from 1.8 ha to 1.3 ha and may indicate that it has been feasible to accept smaller farms into the project as the initial infrastructure has been established and learning costs have been covered.

Minimum number of farms

Now assume that farm size remains constant at 2 ha, but it is possible to change the total project area by regulating the number of contracts with farmers (Figure 13). As the number of participating farms increases, both the carbon margin ($V_C - V_A$) and transaction costs (V_T) for the buyer increase linearly, but the former increases faster. Under this scenario, a minimum of 415 farms is required for a feasible project (with p_F fixed at \$1.07/tC). This will result in transaction costs of approximately \$2 million for a total project area of 830 ha capturing 272,017 tCO₂, and translates into transaction costs of about \$7.37/CER, which totally offsets the carbon margin. By comparison, with 1,000 farms transaction costs represent 73% of the carbon margin.

Now consider the possibility that, as the total project area increases, the maximum farm price the buyer would be prepared to pay may also increase. To confirm this, we solve the model for different values of n , while holding farm size constant at 2 ha and adjusting p_F until all carbon profits are dissipated; that is, for any given value of n we solve for the buyer's break-even value of p_F that makes $V_C - V_A = V_T$. Results of this analysis are presented in Figure 14. The buyer's farm 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 the total project area increases from 700 ha to 2,000 ha.

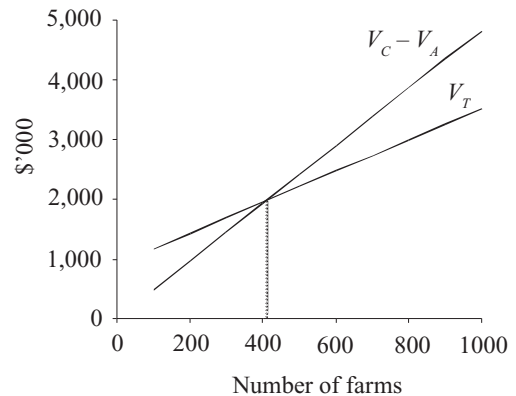


Figure 13. The minimum number of farms required for a feasible project is indicated by the dotted line. Note that the total project area increases as the number of farms increases because the farm size is fixed at 2 ha; farm price of carbon is \$1.07/tonne.

In Figure 14, 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 ($p_B = p_S$). Note that this number of farms differs from that associated with Figure 13 (415). Here p_F is endogenously determined as a break-even price for any given value of n , whereas in Figure 13 p_F was exogenously set at \$1.07 as the average between p_B and p_S .

Effects of CER price

The CER price used above (\$20/tCO₂e) is rather high, 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 . 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 13.

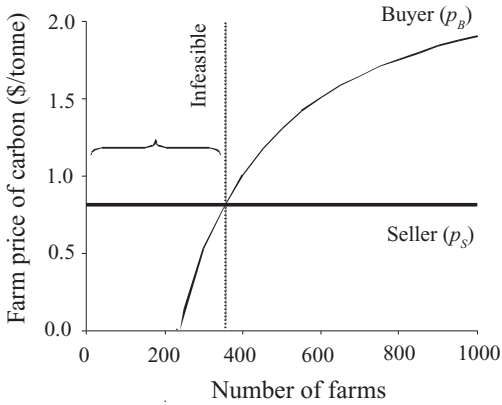


Figure 14. The break-even number of farms, indicated by the dotted line, is calculated as the point at which the maximum price the buyer is willing to pay (p_B) equals the minimum price the seller is willing to accept (p_S).

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's 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, and the minimum number of farms at constant farm area (2 ha) is 771. The former result (the block labelled (a) in Table 13) is represented by downward shift of the $V_C - V_A$ line in Figure 12 as the CER price decreases, causing the new intersection with V_T to occur at a larger farm size. The latter result (block (b) in Table 13) is represented by a downward shift of the $V_C - V_A$ line in Figure 13, causing the new intersection with V_T to occur at a larger number of farms.

The last three rows of Table 13 (block (c)) are the most interesting because they show the absolute minimum possible project size (when $p_F = p_S$), or the break-even project size, rather than the minimum project size with p_F arbitrarily set at the mean between buyer's and seller's prices. The break-even 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 CER) from 233 ktCO₂e to 506 ktCO₂e.

To put our results in perspective, consider that in May 2006 there were 176 CDM projects registered, claiming to reduce emissions by an average of 301,633 tCO₂e/year. Classified by size, there were 71

Table 13. Effect of Certified Emission Reduction (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 (1000 ha):			
Minimum farm area (ha)	1.18	1.61	3.43
Corresponding number of farms	846	622	291
Project CERs (tCO ₂ e)	327,891	327,891	327,891
(b) With farm size constant (2 ha):			
Minimum number of farms	312	415	771
Corresponding project area (ha)	624	829	1542
Project CERs (tCO ₂ e)	204,549	271,874	505,731
(c) With minimum farm price ($p_F = p_S$):			
Break-even number of farms	230	355	772
Corresponding project area (ha)	460	709	1,544
Project CERs (tCO ₂ e)	150,875	232,552	506,250

large-scale projects with average emission reductions of 638,133 tCO₂e/year and 78 small-scale projects claiming an average of 29,554 tCO₂e/year. To convert our results from stocks of carbon to flows of CO₂ and compare them with existing projects, note that the above-ground biomass carbon stock of the damar system is assumed to increase from 0 to 252 tC/ha in 25 years (Figure 10); this represents an annual CO₂ reduction of 37 tonnes (3.67 × 252/25); multiplying this value by the break-even project areas in Table 13, we obtain 17,020 tCO₂/year, 26,233 tCO₂/year and 57,128 tCO₂/year 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.

The effect of CER price (p_{CER}) on minimum project size is nonlinear (Figure 15). The minimum number of farms required for the project to break even decreases rapidly as p_{CER} increases and the rate of decrease diminishes as p_{CER} increases. This curve will be used to derive a project feasibility frontier.

The project feasibility frontier

We have seen above that smaller projects become feasible as the CER price increases. So far, project feasibility has been expressed in terms of the number of

participating farms of a given size. 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 16 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 call this curve the project feasibility frontier (PFF).

In essence, the PFF is derived by converting the inequalities in the expressions (6.3) and (6.4) into equalities and solving for the farm price (p_F) and number of farms (n) that satisfy both equations (6.5).

For any set of values in the argument list (the variables in brackets in equation (6.5)), these equations indicate the point at which the project becomes viable. Solving this system with respect to (p_F, n), we obtain the break-even point for both buyer and seller. This is the point at which the carbon margins just cover the transaction costs for both parties. The break-even value of n is then converted to CER units with the formula:

$$\text{project CERs} = n \times a \text{ (ha)} \times 89.3 \text{ (tC/ha)} \\ \times 3.67 \text{ (tCO}_2\text{/tC)}.$$

$$\begin{aligned} v_C(a, p_F, C(t), \delta_S) - v_A(a, p_L, R(t), \delta_S) &= v_T(p_L, q(t), \delta_S) \\ V_C(a, n, p_{CER}, C(t), \delta_B) - V_A(a, n, p_F, C(t), \delta_B) &= V_T(a, n, p_{CER}, C(t), Q(t), \delta_B) \end{aligned} \quad (6.5)$$

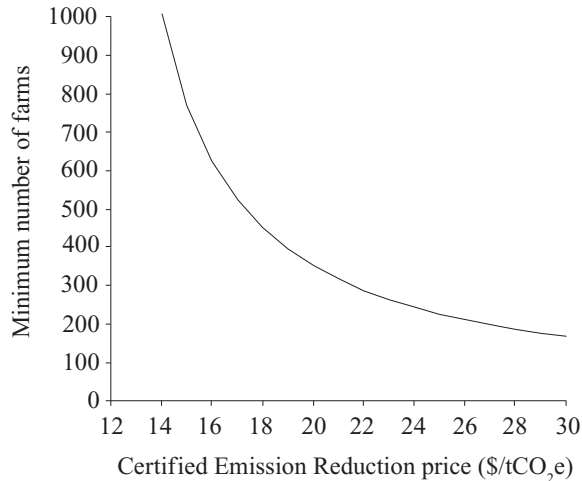


Figure 15. The break-even number of farms as a function of Certified Emission Reduction price for the base case

The PFF is plotted by solving equations (6.5) for different values of p_{CER} . The PFF is a convenient way to explore 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.

Effect of carbon-sequestration potential

The damar system in our project is assumed to increase average carbon stock by 89.3 t/ha over the life of the project (25 years) but, as shown in Appendix 1, there can be considerable variability in the productivity of farms within the same region. It is therefore important to determine the influence of carbon-sequestration potential on project viability. This can be done by modifying the carbon trajectory $C(t)$ and solving equations (6.5). Figure 17 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. For an increase in carbon-sequestration potential, the elasticity of project size with respect to sequestration potential (Figure 18) ranges from -3.7 at a CER price of \$11 to -1.1 at a CER price of \$30. For a price decrease, the elasticity ranges from -5.4 at a CER price of \$19 to -2.6 at a CER price of \$30. These results indicate that a reduction in actual carbon sequestered relative to expectations can have a major influence on the success of the project.

Effect of transaction costs

The transaction costs assumed for this analysis were presented in Table 11. These values are arbitrary but plausible. They are based on our review of existing projects in Appendix 2 and cost estimates from the literature reviewed in Chapter 5. There is high uncertainty about 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 equations (6.5). Figure 19 presents PFFs for three transaction-cost scenarios: the base case, low buyer cost ($0.75 Q(t)$) and low seller cost ($0.75 q(t)$).

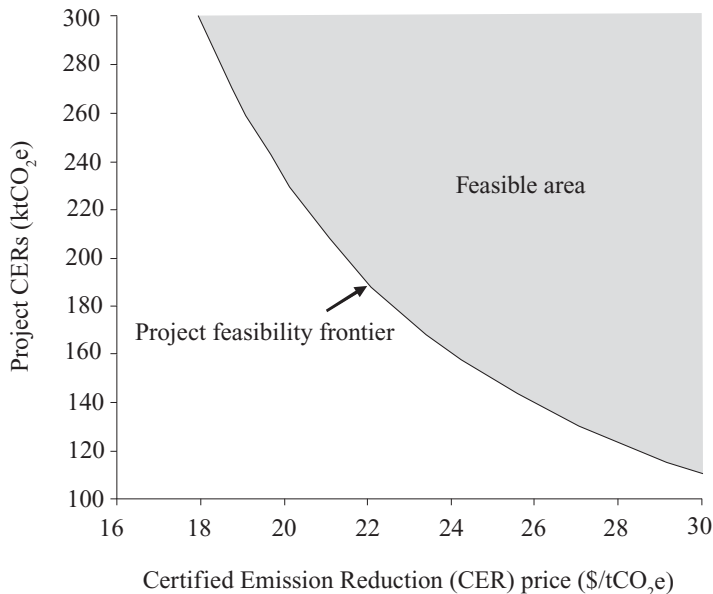


Figure 16. The project feasibility frontier

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 trans-

action costs. The elasticity of project size with respect to buyer's transaction costs (Figure 20) ranges from 3.7 at a CER price of \$11 to 1.4 at a CER price of \$30. The elasticity of project size with respect to seller's transaction costs ranges from 3.3 at a CER price of

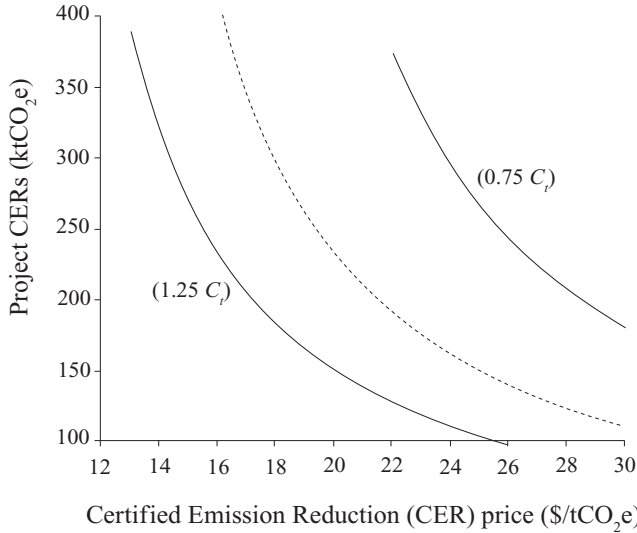


Figure 17. The effect of carbon-sequestration potential on the position of the project feasibility frontier. The dotted line is the base case, and the solid lines an increase (to $1.25 \times$ base) or decrease (to $0.75 \times$ base) in the carbon-stock trajectory.

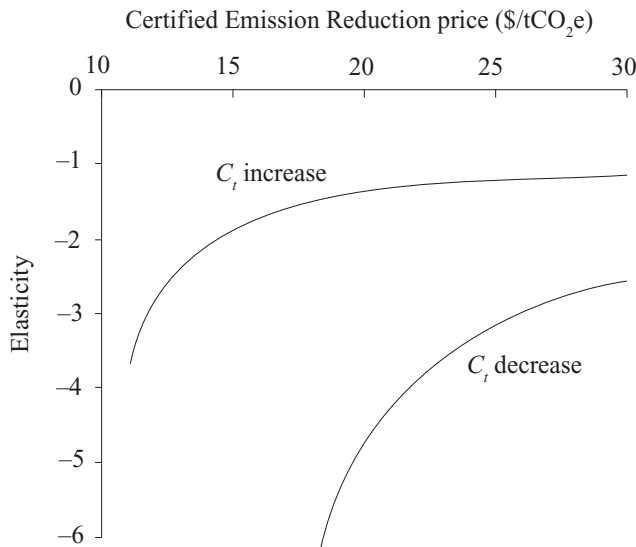


Figure 18. Elasticity of minimum project size with respect to changes in the carbon-sequestration potential of agroforestry

\$11 to 0.2 at a CER price of \$30. A value of 1.0 for the seller's elasticity is obtained at a CER price of \$14. Therefore, at high CER prices there is less pressure to

reduce the seller's transaction costs than the buyer's. So reducing the transaction costs of buyers should be a priority when designing projects.

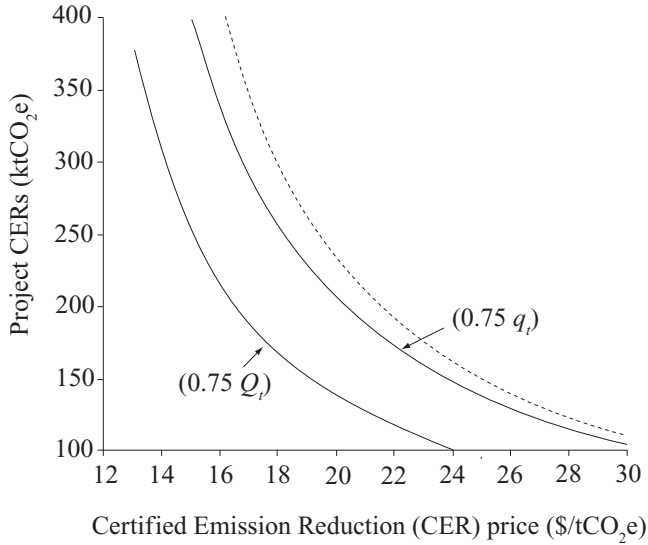


Figure 19. The effect of transaction costs on the position of the project feasibility frontier. The dotted line represents the base case, and the solid lines a 25% decrease in the transaction costs of the buyer (Q_t) or seller (q_t).

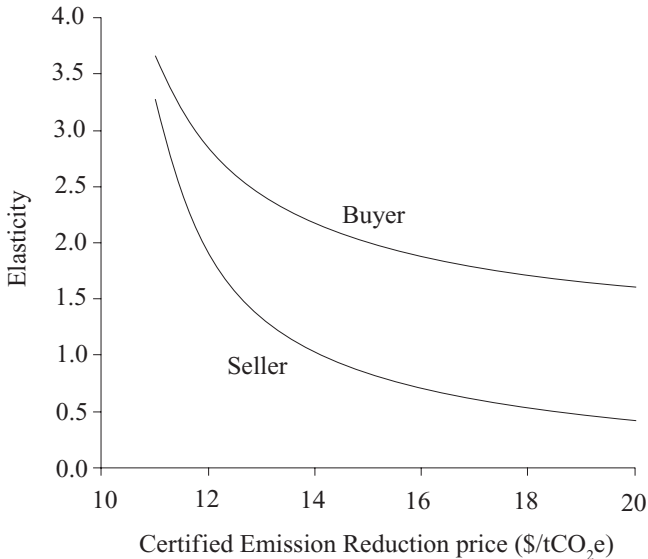


Figure 20. Elasticity of minimum project size with respect to reductions in transaction costs for the buyer and seller

7. Farm heterogeneity and other issues affecting project feasibility

Thus far we have assumed that farms participating in a project are homogeneous. This simplifies the analysis by allowing us to calculate transaction costs, abatement 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 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 expanding the project to other regions in an attempt to gain economies of scale may also increase transaction costs. Furthermore, there is considerable variability between farms in terms of size and productive capacity, as evidenced by the field results reported in Appendix 1. 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.

In this chapter we consider the role of farm heterogeneity, and derive supply curves based on the data for West Java and East Nusa Tenggara reported in Appendix 1. This allows us to evaluate whether it is realistic to expect these regions of Indonesia to contribute to AR CDM projects and, if so, under what conditions this participation is feasible.

Deriving probability functions of farm productivity

In Appendix 1, farm-level data on carbon mean annual increment (CMAI) are presented for two regions of Indonesia. Not surprisingly, we found that West Java (WJ) is more productive than East Nusa Tenggara (ENT), with CMAI values that were almost twice as large (7 kg/tree/year compared with 3.8 kg/tree/year). We converted those results to a per-hectare basis and fitted a cumulative distribution function to the data for each region. Figure 21 presents the farm data along with (a) the curves of best fit and (b) the corresponding probability density functions. It is obvious from these plots that the

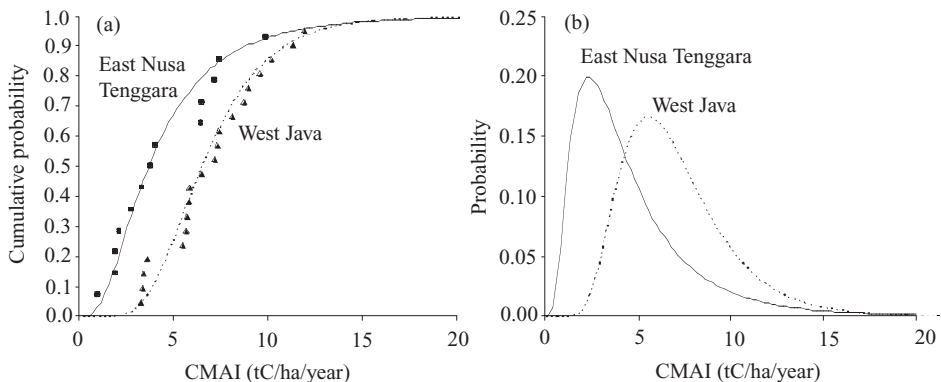


Figure 21. Lognormal probability functions for carbon mean annual increment (CMAI) and observed farm data for two regions: West Java and East Nusa Tenggara. Each point in the left panel represents a farm.

expected CMAI is higher in WJ than in ENT, and that there is considerable variability in both regions.

The curves presented in Figure 21 are lognormal distributions. Several distribution functions were considered but the lognormal provided the best fit (Table 14). The mean CMAI was 7.03 tC/ha/year for WJ and 4.66 tC/ha/year for ENT. The parameters of the distribution (μ and σ) are related to the mean and the variance of the underlying data. Both parameters are statistically significant for both regions, based on their standard errors. The lognormal distribution is restricted to values > 0 ; it has a long right tail, with the main body of the distribution located towards the left. These characteristics represent the farm data well because there are only a few highly productive farms. Most farms are concentrated towards moderate and low productivity. Differences in productivity between farms may be caused by differences in soil nutrients, inputs used, water availability, mix of tree species used and manager's ability.

Table 14. Results of fitting lognormal distributions to carbon mean annual increment (CMAI) results for two regions in Indonesia

	West Java	East Nusa Tenggara
Mean CMAI (tC/ha/year)	7.03	4.66
Standard deviation	2.93	3.56
Coefficients:		
μ	1.871 (0.090)	1.315 (0.188)
σ	0.401 (0.066)	0.677 (0.141)
Log-likelihood	-46.99	-34.91
Number of farms in sample	20	13

Assumptions for further analysis

Farms differ not only in terms of carbon-sequestration potential as observed above, but also in terms of size and profitability. Regarding farm size, results reported in Appendix 1 indicate that the average farm size is smaller in WJ (0.52 ha) than in ENT (1.4 ha). These differences are explained by the higher population density and land productivity of WJ. To simulate the observed variation in farm size, size distributions for the two regions were created based on the observed data (Figure 22).

Regarding farm profitability, we have no information on the variability of agroforestry NPV across farms, but we can make some plausible assumptions about the NPV of the project relative to the baseline. We will assume that the baseline is an *Imperata* grassland with an NPV of zero and a relatively constant stock of soil carbon. We will further assume that the grassland burns every year, releasing the accumulated biomass as CO₂. Therefore, the baseline carbon stock is zero (recall that we are considering only biomass, not soil carbon). Our brief review of the *Imperata* problem in Indonesia (see Appendix 1) indicates that it may take up to 200 person days of labour to clear a hectare of land and remove rhizomes to prevent reinvasion. Assuming the cost of this labour (plus associated materials) is Rp25,000/day, the total cost of preparing the land for tree planting would be \$575/ha (calculated as $200 \times 25,000 / 8,700$).

To concentrate the analysis within an interesting neighbourhood, assume that the NPV of agroforestry is the same as the cost of clearing the land of *Imperata* (\$575/ha). This means that the expected opportunity cost of land-use change is zero, and the average farmer is indifferent between doing nothing and clearing

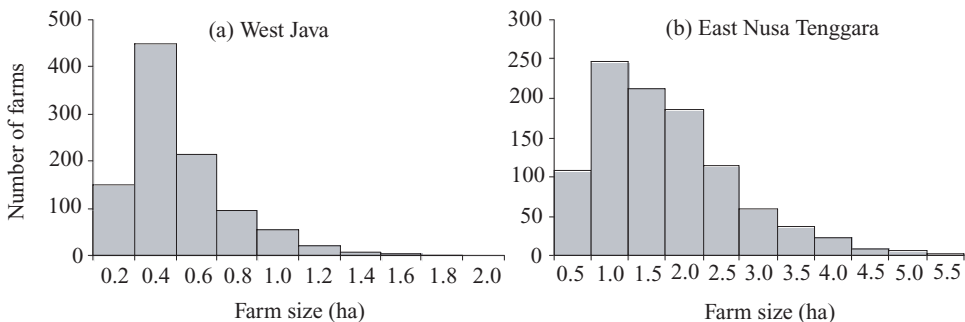


Figure 22. Assumed farm size distribution in (a) West Java and (b) East Nusa Tenggara, Indonesia

grassland to plant trees. Farmers who are below the average NPV will face a positive opportunity cost and those above the average will face a negative opportunity cost. In theory, the farmers in the latter group will not require an incentive to change land use, because a negative opportunity cost means that the land-use change is profitable. However, as discussed earlier, there may be other barriers to adoption, such as lack of access to credit and seedlings. If the mean NPV of agroforestry is \$575/ha and the standard deviation is \$230/ha, then the 95% confidence interval is $-\$377 \leq \text{NPV} \leq \$1,525$, which is a plausible range for the ENT region. West Java is more productive and would be expected to be less variable than ENT because of higher and more reliable rainfall. Based on the data reported in Table A6, we assume that the NPV of agroforestry in WJ is \$843/ha with a standard deviation of \$150/ha, then the 95% confidence interval for WJ is $-\$246 \leq \text{NPV} \leq \$1,938$.

Deriving the supply curve

We derive the carbon supply equation through simulation by the following steps:

1. Assign values to driving variables: total number of farms (n), NPV of agroforestry (mean and standard deviation), cost of clearing *Imperata* land, seller's transaction costs.
2. Draw a set of n random numbers and apply them to the lognormal distribution illustrated in Figure 21. The resulting set contains the carbon-sequestration potential of the farm population.
3. Draw a set of n random numbers and apply them to the farm-size distributions presented in Figure 22. The resulting set contains the area of the individual farms in the population.
4. Draw a set of n random numbers from a normal distribution with the mean and standard deviation of the agroforestry NPV defined in step 1. The resulting set contains the NPV values of individual farms.
5. For each element in the sets created in steps 2, 3 and 4, solve the project-participation model for the seller (see Chapter 6) and calculate the minimum farm price each seller is willing to accept (p_S).
6. Sort the set of p_S values in ascending order, along with the amount of carbon sequestered by the corresponding farm. Plot the cumulative carbon values against their corresponding prices (p_S). This is the supply curve derived for the heterogeneous farm population.

This procedure assumes that farm size, carbon-sequestration potential and agroforestry NPV are not correlated, because the random numbers in steps 2, 3 and 4 are drawn independently of each other. Carbon-sequestration potential and agroforestry NPV may be positively correlated. If this is the case, the supply curve will be flatter than in the no-correlation case. It is also possible that farm size and carbon-sequestration potential are negatively correlated, because smaller farms would tend to have more family labour available per hectare, allowing for better care of trees and crops. If this is the case, the supply curve would be steeper than in the no-correlation case. In the absence of data, any assumptions about the values of the correlation coefficients would be arbitrary and would complicate the analysis unnecessarily, given that the effects of the two plausible types of correlations would tend to cancel each other out. The supply curves derived for WJ and ENT by following steps 1–6 are presented in Figure 23.

Both supply curves (Figure 23) imply increasing marginal cost of carbon sequestration (i.e. the slope of the supply curve increases with carbon sequestered). This occurs because once the most efficient farms have adopted agroforestry it becomes increasingly difficult to capture additional carbon in the less efficient farms. Given our assumptions, WJ is a more efficient provider of carbon than ENT, as indicated by a lower supply curve.

The point where the supply curve crosses the horizontal axis indicates the amount of carbon that would be sequestered in the absence of an incentive. Up to this point, capturing carbon would be more profitable than the alternative (i.e. the abatement cost is negative). This 'critical' point is labelled a for WJ and b for ENT in Figure 23. Under a strict interpretation of the additionality requirement, farmers located to the left of their respective critical point (a or b) would not be eligible to participate in a CDM project unless it could be shown that they face constraints, other than opportunity cost, to adopt agroforestry.

The fact that point a is to the right of point b in Figure 23 confirms that farmers in WJ are more efficient providers of carbon credits and suggests, in addition, that farmers in WJ have the capacity to provide more total carbon than farmers in ENT. This latter result must be viewed with caution because it was generated by assuming that the same total area of land is available for conversion to agroforestry in both regions. This would require over three times as many farms in WJ than in ENT because farms in the

former region are considerably smaller. If we keep the total number of farms constant between regions (rather than the total area), the WJ supply curve would become steeper than the ENT curve.

Project feasibility revisited

Now that we have derived supply curves for two regions, we can study the conditions under which a project would be feasible when the farm population is heterogeneous. We do this by solving the project participation model for the buyer, but we now use the farm population generated in steps 1–6 above instead of assuming all farms are identical. We then plot the minimum price farmers are willing to accept (p_S) and the maximum price the buyer is willing to pay (p_B) as functions of project size measured in terms of CERs. Recall that the project is feasible only if $p_B \geq p_S$.

We found that, with transaction costs assumed for the base case in Chapter 6 and with a CER price of \$20/tCO₂e, a project would not be feasible in either region. Furthermore, we found that p_B was negative in WJ, meaning that the project was not feasible even with very large project sizes. In comparison, p_B was positive for large project sizes in ENT but, because it was below p_S , the project would be infeasible because it could not provide the incentives required by farmers. This result is interesting in that it shows that WJ, although it can provide carbon more efficiently in

terms of abatement costs, underperforms ENT in terms of transaction costs. This difference in transaction costs is caused by the smaller farm sizes in WJ. In light of these results we will concentrate further analysis on the ENT case (Figure 24).

Figure 24 illustrates that a project in the simulated ENT scenario would not be feasible at current CER prices. The project is infeasible at prices as high as \$25/tCO₂e (Figure 24a) but becomes feasible at a price of \$35/tCO₂e (Figure 24b). At the higher price, p_B is above p_S over a small interval, indicating that there is a limited range of feasible project sizes. This feasible range is illustrated in Figure 25, which indicates that the hypothetical project must have between 150 and 250 participating farms to be feasible. The village sampled in ENT is associated with 221 households (most of them farmers). The results thus suggest that the required project size would be feasible in this area, provided the CER price is \$35.

Recent CER prices have ranged between \$3 and \$12/tCO₂e, well below the \$35 that would make our hypothetical ENT smallholder project feasible. In the European Union, carbon market prices have exceeded \$30 in the past, but they have fallen recently and the EU-ETS system does not accept biomass carbon. The evidence therefore suggests it is unlikely CERs will reach a price high enough to shift the p_B curve up into the feasible area (see Figures 23a and b).

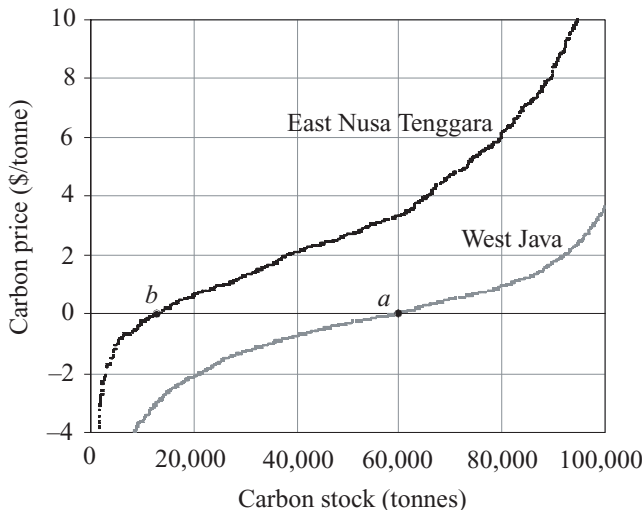


Figure 23. Estimated carbon supply functions for West Java and East Nusa Tenggara (ENT), Indonesia

The remaining question is whether enough of an upward shift in p_B can be obtained by reducing transaction costs, thus making the project feasible. 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 LUCF projects. For our hypothetical ENT project, we may ask: by how much would transaction costs have to be reduced in order to make the project feasible at current CER prices?

Figure 26 shows that decreasing transaction costs to 50% of the base value can produce enough of a shift in p_B to make the project feasible at a CER price of \$15. It remains to be seen whether the simplified rules of CDM for small-scale projects could reduce transaction costs by this much.

Other project design issues

The analytical tools developed in this study can be applied to address a rich variety of questions with relevance to policymakers and project developers. Some interesting questions that are not answered

here, but that could be tackled by applying our model, are discussed in this section.

We have assumed that carbon stocks are measured, verified and certified, and the new batch of CERs is submitted every year, thus supplying the carbon 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 5 years, thus reducing monitoring and certification costs, but also delaying the receipt of payments and therefore increasing the need for credit.

Variations in 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 up-front payment equivalent to 20% of the total amount to be accrued over 20–30 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 dis-

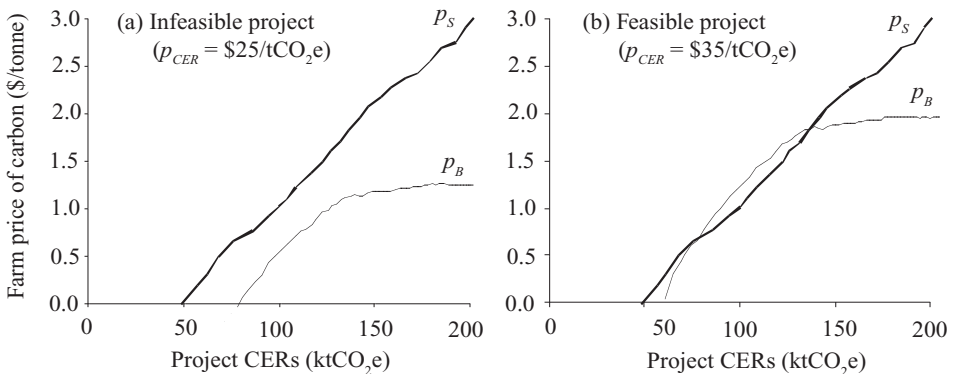


Figure 24. Minimum seller carbon price (p_S) and maximum buyer carbon price (p_B) as functions of project size for two different Certified Emission Reduction prices (p_{CER})

count 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 his own cost constant, thus providing higher incentives with no additional cost (although with some additional risk).

We assume in our analysis 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.

Good project design

The poor in any country have limited opportunities to adopt technologies, particularly when they are not part of the cash economy. Also, environmentally sound technologies with relatively small project sizes and long repayment periods deter banks because of high transaction costs. IPCC (2001) reviews a number of innovative approaches to overcome these problems, including leasing, environmental and ethical banks, micro credit, small grant facilities tar-

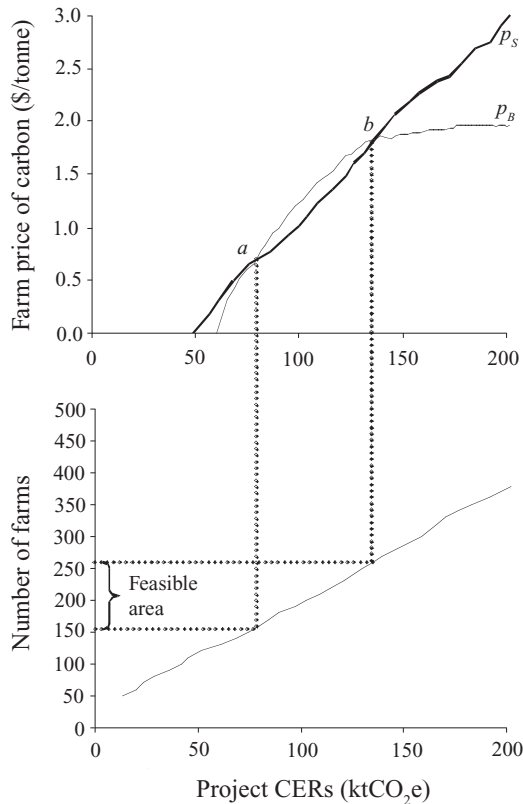


Figure 25. Certified Emission Reductions (CERs) supply (p_s), maximum buyer price (p_B) and feasible number of farms with a CER price of $\$35/\text{tCO}_2\text{e}$

geted at low-income households, environmental funds, energy service companies and green venture capital. In this section we discuss other ideas about the design of projects to encourage participation by smallholders.

Authors such as Smith (2002), IPCC (2001) and Baumert et al. (2000) have recommended strategies to reduce the transaction costs of making the CDM operational in smallholder contexts and thereby contribute to sustainable development. Cacho et al. (2003b) reviewed these and added some ideas of their own. These strategies can be classified into six major categories:

- generate and disseminate information
- teach smallholders to measure carbon
- select areas where community cohesion is strong and encourage community self-regulation
- bundle projects and payments for other environmental services
- promote secure land tenure
- develop smallholder contracts.

Each of these strategies is briefly discussed.

Generate and disseminate information

This includes the sort of research that is undertaken by CGIAR centres and national research agencies. It is also illustrated by the examples presented in

Appendix 1 for Indonesia. By producing information on suitable production systems and their profitability, we can decrease the search costs of starting a new carbon project. Generating information on projects where smallholders are likely to be competitive suppliers (e.g. low opportunity costs) is also needed.

Establishment of baselines can be expensive, particularly in areas subject to rapid changes in population and government policies. Under the CDM, small projects (less than 15,000 tCO₂/year) are allowed to use simplified methods to estimate baselines and monitor emissions. Moura-Costa et al. (2000) suggest that generic baselines based on sector, region or country can be developed and integrated in a system of ‘technology matrices’ similar to those used in the energy sector. These methods need to be developed and may represent efficient use of development research assistance.

Perhaps more work is required in developing efficient ways of storing information and making it available to potential market participants. The Profafor project and the FACE Foundation have made some progress on this front. In all FACE projects, a monitoring and information system is used to determine the amount of carbon sequestered. The system stores administrative, financial and technical information for each forestation plan. It also keeps track of technical assistance and production of seedlings (FACE 2000).

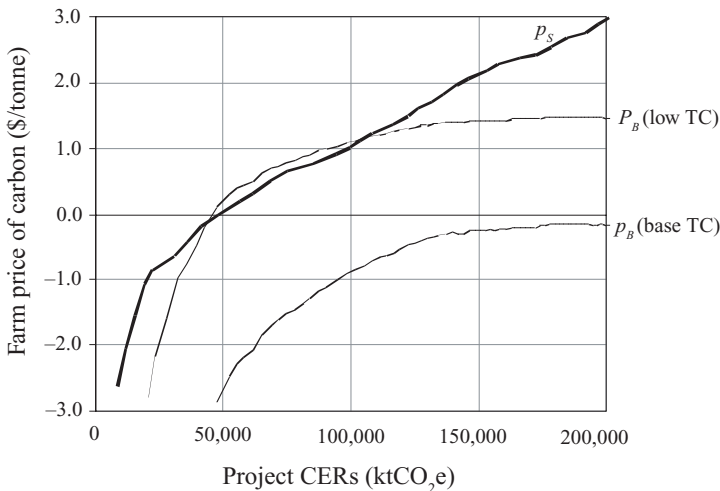


Figure 26. The effect of a decrease of 50% in transaction costs (low TC) on the feasibility of the East Nusa Tenggara project compared with the base values (base TC) at a Certified Emission Reduction (CER) price of \$15/tCO₂e

Dissemination of information among smallholders and farmer groups can reduce transaction and abatement costs. This can be done by host-country extension services as well as by NGOs and international research centres. Once a few examples of successful systems are established, word of mouth may work well. This has been the case in the Profafor project in Ecuador and *Scolec Te* in Mexico, where farmers have approached the investor after learning about the project from other farmers in the area. It is also necessary to disseminate information about the potential of the smallholder sector to supply carbon credits to potential buyers.

Train smallholders

According to ASB (Hairiah et al. 2001), farmers in Sumatra have shown that they are used to assessing the volume of wood in their trees.⁹ This suggests that, if farmers learn the value of carbon biomass, they can monitor their plots at low cost. Delaney and Roshetko (1999) state that it took only 2 days for a crew to learn inventory methods to measure carbon in agroforestry gardens in Java. This provides further evidence that it may be possible to train smallholders to identify and measure their own trees and complete a sample sheet. The sample sheet could then be delivered to the project office in order to receive payment for the carbon sequestered. The project office would enter the data into a database and estimate carbon stocks using allometric equations.

There is an agency problem inherent in expecting smallholders to undertake these tasks, to the extent that scope exists for them to misreport carbon sequestration in their trees in order to reduce their costs of project compliance. However, practical ways to limit this scope may exist. For instance, a system of randomly checking reports from smallholders may, if combined with substantial penalties for misreporting, make opportunism in this area too costly for them to contemplate. Also, if the project benefits the community as a whole, and if rewards from the whole project depend on all smallholders doing the right thing, an incentive exists for community members to monitor and police one another.

The advantage of involving smallholders is apparent when it is considered that the accuracy of carbon measurements depends on sampling intensity. A large group of smallholders could achieve high measurement accu-

racy by allowing intensive sampling at a fairly low cost. This idea is illustrated in Figure 27, which was produced with the model of Cacho et al. (2004) for *Acacia mangium*. Carbon stocks are normally estimated based on sampling of a limited number of plots because it is not practical to measure every single tree in a project. When there is high variability between trees, the number of plots required to achieve a given level of confidence is also high.

Figure 27c presents results from Cacho et al. (2004) for the amount of CERs that can be obtained by a reforestation project based on the reliable minimum estimate (the lower 95% confidence limit) when the coefficient of variation is 0.8. The project is able to obtain a larger number of CERs per ha by increasing sampling intensity (the number of sample plots). Figure 27a shows two marginal cost (MC) curves. MC_1 assumes it costs \$10 to measure each sampling plot and MC_2 assumes \$50 per plot. The optimal sampling intensity occurs where marginal revenue (MR) equals MC. The intersection of MR and MC is indicated by dotted lines for both MC curves. Figure 27b simply translates the horizontal CER axis into a vertical axis to enable mapping between Figure 27a and Figure 27c. In this case the high marginal cost curve (MC_2) results in an optimal number of 24 sampling plots (n_2) and carbon credits of 91 tCO₂/ha, whereas the low marginal cost curve (MC_1) results in an optimal number of 70 sampling plots (n_1) and carbon credits of 101 tCO₂/ha. MC_1 could represent the cost of smallholders sampling each other's plots, and MC_2 may represent the cost of technicians travelling to the area to undertake monitoring. In this example the former strategy results in a 10% increase in carbon credited.

Select cohesive communities and encourage community self-regulation

One way to reduce the costs of smallholder involvement in carbon-sequestration projects may be to develop projects on a community basis rather than with individual smallholders. In Chapter 6 we showed that increasing the average area of the participating farms makes the project more viable by decreasing V_T and therefore increasing the difference between carbon margins and transaction costs. The ultimate effect of an increase in farm area is a shift in the PFF (Figure 28).

Figure 28 suggests that contracting with communities or farmer groups is more likely to bring success

⁹ Interestingly, in farmers' minds, trees without wood value have no volume.

than contracting with individual farmers, simply because there are fewer contracts to negotiate, monitor and enforce. To put these results into context, consider that the average size of projects that had been registered with the CDM by May 2006 was about 300 ktCO₂e (indicated by the horizontal dotted line in Figure 28). A project of this size would be feasible only at a CER price of \$18 for the base case (with a farm area of 2 ha). If, however, the project were to contract with groups of farmers supplying an average of 20 ha per contract, it would become feasible at a CER price of \$10.

This example illustrates only one aspect of contracting with farmer groups. Another benefit of a community-based strategy is that it may encourage informal regulation within farmer groups, which could substitute for formal regulation imposed from the outside. Nevertheless, realising the potential of a community-based strategy to promote informal regulation could be expected to depend on community members perceiving the project to be fair. Participatory approaches can promote informal project compliance mechanisms, thus reducing the ex-post

transaction costs of projects at the expense of increases in the ex-ante transaction costs caused by a more inclusive decision process during project design.

A possible implication of selecting cohesive communities already organised into farmer groups may be that cost-effectiveness concerns will lead to attention being directed mostly at communities that already possess much of the capacity required to manage projects. The concern is that the CDM may tend to neglect the communities least able to organise themselves and that presumably are most in need of outside help to alleviate their problems of poverty. However, the primary goal of the CDM is climate mitigation, and poverty alleviation is a welcome bonus. A good example of this is provided by the PDDs that are being drafted with funding from ADB (see Appendix 2). In this project, district representatives were invited to submit proposals largely based on their capacity to design and implement reforestation projects. This selection process is justified, particularly during the learning phase of the CDM, where it would be wasteful to attempt to establish

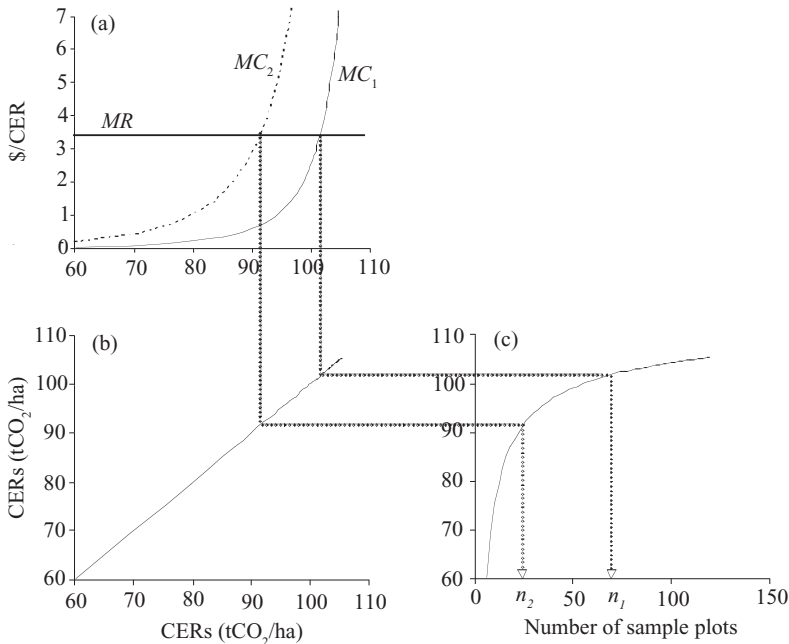


Figure 27. The effect of the marginal cost of sampling carbon (\$/Certified Emission Reduction (CER)) on the optimal monitoring intensity (number of sample plots)

projects with communities that do not have the appropriate social infrastructure. Arguably, capacity building of disadvantaged communities should be funded by development aid rather than by the CDM.

Project and payment bundling

The creation of institutions and financial intermediaries to bundle carbon-sequestration projects into a portfolio, such that investors would not be tied to a particular project, is desirable (Michaelowa and Dutschke 2000). Such an approach is likely to increase the attractiveness of investing in small-scale projects to a wider set of investors who are either risk averse or financially constrained by the high pre-implementation costs. It is also likely to provide potential project hosts with access to a broader capital base and thus access to more diverse projects than available under a bilateral system (Wexler et al. 1994). Another advantage of this approach is that transaction costs can be reduced by pooling technical skills for developing baselines and monitoring plans (Baumert et al. 2000).

The potential for project bundling is illustrated by the FACE Foundation in the Netherlands, which has several projects in Latin America, Europe, Asia and Africa, and has developed infrastructure including geographical information systems, database and modelling tools, and protocols for monitoring and

certifying carbon stocks. This means that project design and baseline estimation costs should be lower for new projects.

There is also scope for exploiting synergies between the UNFCCC and other international agreements such as the Convention on Biological Diversity (CBD). Where projects provide services relevant to both conventions, it may be possible to bundle payments to smallholders and communities. This may be through co-financing project design and implementation, or by providing payments to bridge the gap required to effect land-use change.

Land tenure

In reporting on a study of agroforestry management in Sumatra, Suyanto et al. (2001, p. 140) state: ‘The expansion of formal credit institutions into these relatively remote areas and the establishment of official land title will become increasingly important as further intensification of the land use is required’.

In a large study in Uganda, Ghana and Sumatra, Otsuka and Place (2001b) found that commercial trees have been planted on communal land as much as on private land. They went on to observe (Otsuka and Place 2001b, p. 368):

It is widely believed ... that because of weak individual rights or tenure insecurity, trees are not planted and well managed under communal ownership ... If the com-

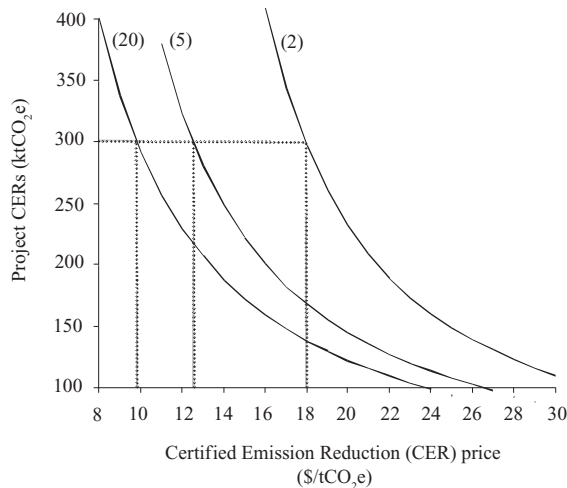


Figure 28. The effect of average farm size (2, 5 and 20 ha) on the project feasibility frontier

munal tenure institutions provide sufficient incentives to plant and manage trees, however, the enhanced efficiency of land use can reduce the incidence of poverty in marginal areas. Furthermore, the establishment of agroforestry in sloping land will help reduce soil erosion and contribute to the partial restoration of tree biomass and biodiversity.

Tomich et al. (1997) suggest that, where *Imperata* grasslands are a problem, smallholders could be granted tenure of land that they convert to forest, to provide an incentive to undertake an activity that is expensive and labour intensive.

Outgrower schemes

Outgrower schemes can inject capital, technical knowledge and access to inputs. Typical outgrower schemes consist of contracts between smallholders and agribusiness companies to produce high-value foods. Although these schemes are often associated

with lower output prices and are viewed negatively by NGOs (Smith 2002), there are examples of successful contracts (Glover and Kusterer 1990). Smallholders may wish to participate in contracts based on revenue implications, cost implications and exposure to risk. They may receive advantages such as access to product markets and credit, and more stable prices (Simmons 2003).

Although smallholder contracts may be subject to high ex-ante transaction costs, these may be ameliorated by farm groups or other community organisations playing a part in negotiations. A contract is more likely to be successful if it provides benefits to the community as a whole. If it creates inequalities, it may be possible to compensate the losers in some way. There is evidence that interaction between farm groups and NGOs can increase the chances of success of a contract (Simmons 2003).

8. Conclusions

This study was motivated by the possibility that markets for greenhouse gas emissions may benefit smallholders in developing countries, by compensating them for adopting agroforestry systems that capture more CO₂ from the atmosphere than traditional cropping systems. The research project was based in Indonesia but the principles identified and the techniques developed have application to other countries and, indeed, to environmental services other than carbon sequestration. Furthermore, although the analysis of transaction costs has focused on the Clean Development Mechanism (CDM) of the Kyoto Protocol, the analytical techniques can be applied to other project-based mechanisms, such as the Prototype Carbon Fund of the World Bank.

We emphasised the need to consider both abatement and transaction costs when assessing the viability of landholders undertaking agroforestry projects to supply carbon-sequestration services. Abatement costs are the costs of producing one unit of (uncertified) carbon-sequestration services. 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 proposed land use. In order to participate in the carbon market, it is not enough for projects to cover their abatement costs; they also incur transaction costs to certify the abatement services they provide. We outlined a typology of transaction costs in the context of landholders supplying carbon to the market. Five types of transaction costs were identified: search and negotiation, approval, project management, monitoring, and enforcement and insurance. Such a typology helped us to identify the institutional arrangements most likely to promote the competitiveness of projects in specific circumstances.

We posed three questions: (i) how do smallholders compare with other landholders in terms of efficiency in sequestering carbon? (ii) how likely is it that smallholders will want to adopt carbon sequestering activities? (iii) what sorts of policies and projects will make this more likely?

To answer the first two questions, we studied several agroforestry systems that have been adopted by smallholders in three regions of Indonesia. These systems were evaluated in terms of their economic performance, labour requirements and carbon-sequestration potential. It was found that some of these systems are competitive with other climate-mitigation measures in terms of abatement costs per tonne of CO₂ emissions reduced. It was argued that carbon sequestration may be a desirable activity for smallholders in remote areas because they do not need to transport their product to markets and they do not face the quality differences that may affect other, especially perishable, products. Obviously, smallholders cannot participate directly in the international carbon market, but they could participate in carbon-sequestration projects designed by intermediaries. A possible obstacle to the participation of smallholders in carbon markets is the need for monitoring, verification and enforcement of project activities, and their associated transaction costs. Hence the importance of the third question.

To answer the third question, we obtained evidence on the transaction costs that may be faced by projects involving smallholders. Costs of the projects studied ranged from \$477/ha to \$2,066/ha. Depending on the carbon-sequestration potential of these projects, these costs would be equivalent to between \$2.17/tCO₂ and \$18.76/tCO₂. The highest cost corresponds to a proposed project in West Nusa Tenggara and is based on an average carbon stock of 30 t/ha. This project is being designed for submission to the CDM and is expected to experience higher transaction costs than reforestation projects that do not require certification of carbon stocks. These cost estimates include some abatement costs in addition to transaction costs, and it was not possible to disaggregate them in order to evaluate the effect of project design.

Project-based carbon-sequestration projects were analysed based on a model of project participation. The conditions for a buyer (project developer) and a group of sellers (farmers) to participate in an agroforestry project were identified. The model accounts for

abatement costs, transaction costs and carbon payments as functions of a set of variables that include discount rates, the price of carbon, and the number and size of participating farms. Three important project-design variables were identified: the farm price of carbon, the number of participating farmers, and the area of their farms. These variables are under the control of the project developer, subject to constraints imposed by international carbon prices and the availability of enough farmers in an area who are able and willing to change land use from the baseline to the project activity. The model allows us to estimate the conditions under which a project will be feasible. Economies of scale were shown to be an important factor, with costs per tonne of carbon sequestered dropping considerably as the area covered by the project increased.

We derived a project feasibility frontier (PFF) that shows the minimum project size that is viable for a given carbon price. We found the PFF to be a useful tool for project evaluation and to perform sensitivity analysis. Project viability is highly sensitive to not only transaction costs and carbon-sequestration potential, but also the size of participating farms. Project viability is particularly hampered when participating farms are smaller than 1 ha.

The importance of heterogeneity among farms in terms of size and productivity was studied through simulation. We estimated probability functions and generated supply curves for West Java and East Nusa Tenggara based on the farm data collected. The project-participation model was modified to include the supply curves instead of a fixed farmer price. Whereas in the fixed-price case the project size was only bound from below and could become as large as desired, in the supply-curve case the viable project size was bound on both sides. The lower bound was caused by the need to cover fixed transaction costs, and the upper bound by increasing marginal cost of carbon sequestration.

Our results indicated that a project involving smallholders with individual contracts required CER prices ranging between \$12/tCO₂ and \$18/tCO₂. These prices exceed the average market price experienced in 2005 (\$7.22/tCO₂e). Although recent prices have been higher (\$11.45/tCO₂e), there is no certainty that they will remain high in the future.

Our results need to be qualified in two respects. They are contingent on the level of transaction costs assumed, and they are based on modest estimates of carbon-sequestration potential. We were intention-

ally conservative to avoid painting an overly optimistic picture, and did not include carbon stored in soil and roots in our calculations.

Model results indicated that project viability can be increased significantly by contracting with communities or farmer groups rather than individuals. For example, when the participating farms have an average area of 2 ha, a project sequestering 300,000 tonnes of CO₂ over 25 years would require a CER price of \$18 to become feasible. In contrast, when contracts are based on farms with an average area of 20 ha, the project would be feasible at a CER price of \$10. This means that pooling their land would make farmers more competitive in the CER market.

It was also found that project viability is significantly enhanced by selecting fast-growing tree species. The elasticity of minimum project size with respect to carbon-sequestration potential was below -3.0 at CER prices of \$12 or less. This means that a 1% increase in carbon captured decreases the minimum size required for a viable project by 3% or more. Similarly, minimum project size was found to be elastic with respect to transaction costs, with elasticities > 3.0 at CER prices of \$12 or less. This means that a 1% decrease in transaction costs decreases the minimum size required for a viable project by 3% or more.

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 results suggest that the best strategy for achieving success is to concentrate on degraded lands that have low opportunity cost and low carbon stocks. There are millions of hectares of *Imperata* grasslands in Indonesia that may be ideal candidates for CDM projects. It is expensive (in terms of labour and materials) to clear these lands and establish trees. Carbon credits could provide funding to allow this to happen. The incentives to participate would be enhanced if communities and individuals were offered tenure of the degraded land they restore.

Based on the evidence gathered and the modelling undertaken, we answered the first two questions in the positive: (i) some smallholder systems are competitive in terms of abatement costs; and (ii) some smallholders view agroforestry as a desirable activity and have adopted it even in the absence of incentives. The role of a carbon-sequestration project would therefore be to stimulate adoption by those smallholders who may need only a small incentive to switch land use. The answer to question (iii) is more complex. Suitable policies coupled with projects that target land of low

opportunity cost may produce the incentives required to enhance the adoption of agroforestry systems while contributing to greenhouse gas abatement. The most desirable policies would be those that reduce

transaction costs while ensuring that carbon changes are real, directly attributable to a given project and additional to any changes that would have occurred in the absence of the project.

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Appendix I

Agroforestry systems studied

Overview of study sites

Three general areas in Indonesia were selected in this study: southern Sumatra, West Java and East Nusa Tenggara. The selection was based largely on the availability of data on agroforestry systems adopted by smallholders, but was also influenced by the need to find a balance between the more developed and productive areas of western Indonesia and the drier, less productive and poorer areas of eastern Indonesia. The economic analyses presented in this appendix were undertaken using spreadsheet models.

The economic performance of the different agroforestry systems was examined following the guidelines established by the Alternatives to Slash-and-Burn (ASB) group (Tomich et al. 1998; Budidarsono et al. 2001b). The net present value (NPV) of a land-use system with J different outputs and I inputs is calculated using equation (A1), in which $y_{j,t}$ is the yield of output j in year t and p_j is the price per unit of output; $x_{i,t}$ is the amount of input i used in year t and c_i is the cost per unit of input; and r is the discount rate. The discount rate was set at 15% for Indonesian farmers (i.e. $r = 0.15$). This value is within the range expected for farmers in developing countries who may have limited access to credit. For tree-based systems, the value of c_i in year 0 represents the cost of preparing the land and planting the trees; and generally $y_{j,0} = 0$ because there is a lag between planting and production of fruit and timber outputs. For a project lasting T years, $y_{j,t}$ values can be represented as elements in (spreadsheet) matrix \mathbf{Y} of dimensions $(T+1) \times J$. Similarly, $x_{i,t}$ values can be contained in a matrix \mathbf{X} of dimensions $(T+1) \times I$. These matrices have $T + 1$ rows because time is counted from year 0, when the trees are planted.

If NPV for a particular land use is > 0 , then the land use is profitable. Comparing NPVs of different land uses allows the ‘best’ option to be determined in terms of profit, but there may be other factors, such as labour requirements and establishment costs, that are also important to farmers. Return to labour was calculated as the wage rate that makes the NPV = 0, so it provides a measure of how attractive the activity is relative to alternative employment opportunities for the farm family. Establishment costs were calculated as the present value of expenses until a positive cash flow was obtained.

Economic analysis measures profit as it ‘should be’ in an ideal world with no price distortions; thus, family labour is paid the going market rate and the cost of cleared land is accounted for, and NPV represents the returns to management and capital. From a social standpoint, other outputs such as biodiversity preservation should also be taken into account. While we did not attempt to do this, we comment on the biodiversity value of different agroforestry systems where appropriate.

It is important to point out that the carbon stocks reported here are conservative, as we consider only above-ground biomass. As explained earlier, below-ground biomass (roots) may represent up to one-third of total living biomass, and soil and litter may also contain considerable amounts of carbon. For example, an *Acacia mangium* plantation may contain 200 tC/ha, of which 105 tC/ha are above-ground biomass and litter and the remaining 95 tC/ha are contained in roots and soil (Tomich et al. 1997). We decided to err on the side of caution to avoid overly optimistic estimates of the potential of smallholder carbon projects, particularly considering that measuring carbon in roots and soil may be difficult and expensive.

$$NPV = \sum_t \left[\sum_j y_{j,t} p_j - \sum_i x_{i,t} c_i \right] (1+r)^{-t} ; \quad j \in (1, \dots, J); i \in (1, \dots, I) \quad (\text{A1})$$

Another important point is that carbon stocks are reported as time-averaged values rather than peak values. This is because biomass carbon accumulation is a slow process and it is not appropriate to attribute the carbon content of a forest in 25 years' time to the project today. The time-averaged carbon value can be directly calculated from a carbon growth curve, but an acceptable approximation can be obtained by averaging the initial and final carbon content of the forest. For example, considering only above-ground biomass, an *A. mangium* plantation started on bare ground (0 tC/ha) and expected to accumulate 105 tC/ha in 20 years has an average carbon stock of 52.7 tC/ha.

Southern Sumatra

The diversity of agroecological zones in the southern part of Sumatra is reflected in its agroforestry and land-use systems. The western part of the study area includes highlands, a buffer zone and piedmont, covering the Kerinci district and the upper regions of Sarolangun and Bungotobo districts in the province of Jambi. The middle part consists of a peneplain, and the eastern part includes coastal areas covering swamp and mangrove forests. To the south is the Lampung province, where Krui, on the west coast across the mountains of the Bukit Barisan range, is known for its complex agroforests. Important agroforestry systems in the highland, buffer zone and piedmont areas include damar agroforestry and multicropping, involving complex multistrata agroforestry systems such as cinnamon plantations with potatoes or coffee as secondary crops. Major land-use systems in the peneplains include rubber agroforestry with food crops such as upland rice, and simple tree-crop systems, including large-scale timber plantations, oil-palm monoculture and industrial-timber monoculture. The agroforestry systems studied in this region are described below. More details on these systems are reported by Ginoga et al. (2002, 2005). The economic analysis is then described and results are summarised in Table A1.

Rubber agroforests

Rubber agroforestry refers to land use involving rubber as a main tree, with secondary crops such as rice. It represents the most common smallholder system in the peneplain of Sumatra. Rubber plantations in Sumatra and the rest of Indonesia cover about 2,579,528 ha and 3,662,472 ha, respectively. Hence,

about 70% of Indonesian rubber is grown in Sumatra (Ministry of Agriculture 1999). This production system is usually operated by smallholders on areas of between 1 and 5 ha. The type of planting material used includes cloned and traditional unselected seedlings (Tomich et al. 1998).

Rubber agroforests usually replace 'old jungle rubber' or secondary forest. The data on which our analysis is based was collected by ICRAF as part of an ongoing project in Jambi. The project is located in the Rantau Pandan and Bungo Tebo districts. Old rubber jungle was cleared and produced a negligible amount of saleable wood (Budidarsono, pers. comm.). The project experienced some problems with the supply of cloned planting materials, resulting in a much lower planting density than the traditional systems. Hence, in this paper, rubber agroforests are evaluated by modelling. The BEAM model (Grist et al. 1998) was calibrated to conditions in Jambi based on data from Tomich et al. (1998) and other sources.

Local rubber seedlings were used for the traditional system and GT1 clones were used for the clone system. Planting density was 816 seedlings/ha (with trees spaced at 3.5 m). Only the clone system received fertiliser at the time of planting, which accounts for more intensive labour use during establishment. Economic evaluation of rubber systems was based on a 40-year cycle.

Cinnamon multicropping

The area of cinnamon plantations in Indonesia is about 119,905 ha, of which around 116,761 ha (97%) are located in Sumatra, about 49% of these in Jambi. In the upper region of Kerinci, the most common farming system is multicropping involving cinnamon (*Cinnamomum burmanni*) and annual crops (Wibowo 1999). Potato is the most popular annual crop, with a relatively small amount of scallion and maize. In the lower region of Kerinci, a similar multicropping system is typical, but the most common secondary crops are coffee and chilli, with a small amount of maize.

Cinnamon trees are usually planted in rows about 4 m apart and spaced about 1–2 m apart along each row (Wibowo 1999). Multicropping is practised until cinnamon trees reach an age of about 6 years, after which the system becomes a monoculture of cinnamon, with negligible amounts of annual crops or bananas grown on the edges. Economic evaluation of cinnamon systems was based on a 12-year cycle.

Oil palm

About 8%, or 222,096 ha, of oil-palm plantations in Indonesia are located in Jambi (Ministry of Agriculture 1999). The average production between 1990 and 1998 was about 142,864 tonnes. Oil-palm plantations are usually operated by large-scale companies or state companies. Only about 23% of oil-palm plantations are operated by smallholders. ICRAF has established oil-palm plantation and industrial-timber estate projects in Jambi and Lampung, but none has reached maturity. Therefore, the project used for this analysis was taken from the nearby province of Riau, where plantations were established earlier and have reached maturity. The sample plantation consists of 10,700 ha established over a period of 10 years. The first fruit crop was harvested in year 4 and maximum production was reached in year 21. Economic evaluation of cinnamon systems was based on a 12-year cycle. Economic evaluation of the oil-palm system was based on a 25-year planning horizon.

Damar agroforests

Damar agroforests follow a multicropping scheme, in which the main trees are planted along with food crops, fruit trees and other perennials, including trees for fuelwood. The main tree species is damar (*Shorea javanica*), which produces a resin used in paints and other products, while duku, durian, pepper and coffee are planted as the secondary perennials. The most common food crops grown are rice and a negligible amount of vegetables. The damar agroforest reviewed here is located in Krui, Sumatra. It is a traditional system following forest or bush clearing, and has been developed by local people since 1927 (de Foresta et al. 2000). There are approximately 55,000 ha of damar agroforests in Krui, producing about 80% of Indonesian damar resin. There are two types of damar agroforestry, based on farming inputs used: traditional and semi-intensive. The latter includes application of chemical fertilisers and insecticides to perennial crops such as coffee and pepper, to lengthen their harvestable life (Budidarsono et al. 2001a). Economic evaluation of the damar systems was based on a 25-year planning horizon.

Coffee multi-strata agroforestry systems

Multi-strata agroforestry gardens based on coffee cover about 130,000 ha of land in Lampung (Fadilarsari 2000) and produce 60% of Indonesia's coffee

exports. Coffee multi-strata agroforestry systems are classified according to the tree species that dominates the system. The three common systems are timber based, fruit based and shade based. In the timber-based system the strata are dominated by timber-producing forest trees. In such cases most of the land is categorised as forest land by the government. The dominant species are sonokeling (*Dalbergia latifolia*) and sengon (*Paraserianthes falcataria*), which are species used for 'regreening' by forest officers, as well as fruit trees such as jackfruit (*Artocarpus heterophyllus*) and bananas in other strata of the systems. In the fruit-based system (Figure A1) the strata are dominated by fruit trees such as jackfruit, guava and avocado. In the shade-based system the strata are dominated by trees such as *Gliricidia sepium*, *Erythrina subumbrans* and *Leucaena leucocephala*. In such cases the system is considered a young established garden rather than a forest. Economic evaluation of coffee systems was based on a 20-year planning horizon.

Sengon plantation

Sengon is grown in both community forests and state timber plantations. In 1989 the Ministry of Forestry initiated a community-based afforestation program based primarily on sengon trees. In addition to increasing wood supply, this program also aimed to raise land productivity, provide additional wood for industry and generate employment. Sengon wood is usually used for packaging, furniture and construction. Sengon leaves are sometimes used as fodder for goats. The life cycle of this tree is usually no longer than 15 years because root rot sets in. In the system studied here, wood is harvested in year 8 and the system is managed as a monoculture timber plantation.

Acacia mangium plantation

Acacia mangium is a fast-growing nitrogen-fixing tree used for furniture, firewood and pulp. This species is very popular in Indonesia and represents one of the main plantation trees in Sumatra. Its quick growth and dense shade make it effective in reforesting *Imperata* grasslands and reducing fire risk. Its ability to grow well on infertile soils, especially those low in phosphorus, make it a favourite for rehabilitating eroded sites. The wood of *A. mangium* can be used for sawn timber, mouldings, furniture, veneer, charcoal and firewood. It is also used for particle-

board, pulp and paper. Its leaves can be utilised as fodder and for medicine. The system studied is an estate managed by PT Musi Hutan Persada in South Sumatra at altitudes between 100 and 400 m above sea level. The system is intensively managed, with harvest and replanting every 8 years.

Selected fruit trees

The systems detailed here are based in Jambi, southern Sumatra, and the data were generously provided by Hendri of IPB. In this analysis all the fruit trees are planted with other food crops (rice and vegetables) for the first 3 years. Economic evaluation was based on a 40-year planning horizon.

Duku

Duku (*Lansium domesticum*) is widely distributed in Indonesia and is usually referred to as a fruit tree, although its timber is also used. The duku fruit is very popular in South Sumatra because of its sweet taste and large size. The wood of the duku tree is durable, strong, elastic and very suitable for construction (ICRAF 2000). In Indonesia, duku is grown in and around villages (*kampungs*). It does not require intensive cultivation and maintenance.

Durian

Durian (*Durio zibethinus*) is one of the most popular fruits in Indonesia. Durian trees are widely distributed and are mostly planted in drylands and gardens. Durian wood can be used for construction, furniture, cabinets, fittings, panelling, partitioning, plywood, chests, boxes, wooden slippers, low-quality coffins and ship building (Lemmens et al. 1995). Its use is generally limited to building construction and packaging.

Candlenut

Candlenut (*Aleurites moluccana*) is a fast-growing tree species that is often planted as the main tree in reforestation programs. The advantages of candlenut are that it has few input requirements, it can grow in arid land and it is a good pioneer species for reclaiming land left fallow after shifting-cultivation practices. Farmers grow candlenut for its fruit, spices and traditional medicines. The Indonesian Bio-diesel Institute is planning to use the candlenut fruit as an alternative source of biodiesel. This is because candlenut fruit yields oil that has characteristics similar to those of petroleum oil. This, and its ability to grow quickly (and hence capture and store carbon rapidly),

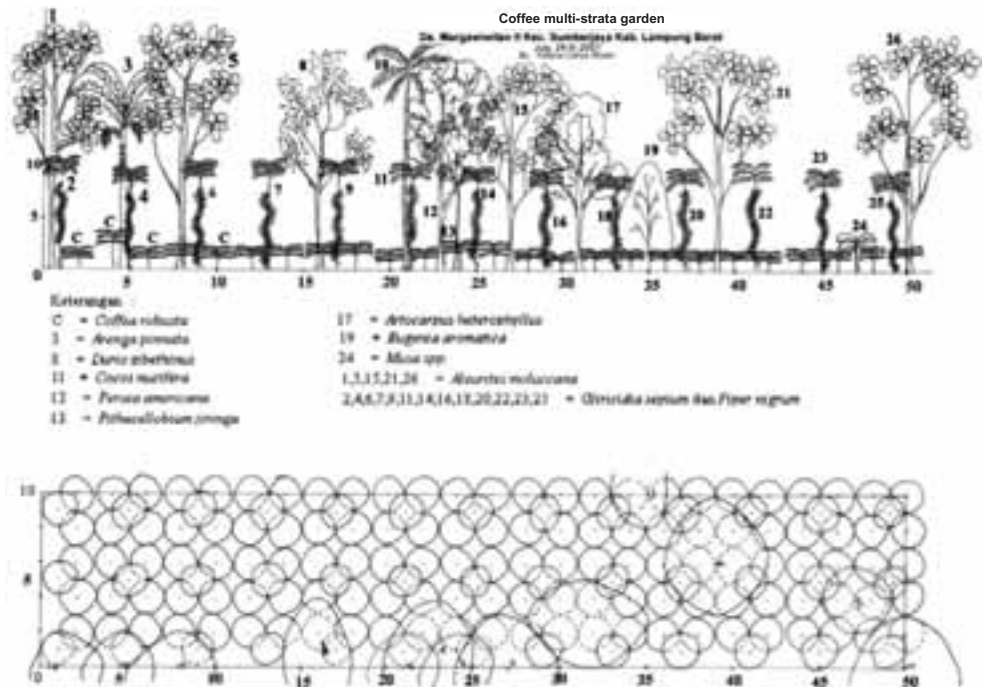


Figure A1. The profile of a fruit-based, multi-strata coffee agroforest (Wulan 2002)

make candlenut a very attractive species for inclusion in carbon-sink projects.

Macang

Macang (*Mangifera* spp.) is a generic term that includes a number of different fruit trees. The wood of these trees is generally used for light construction, ceilings, door panels, interior finishing, floor boards, moulds, crates, good quality charcoal, gunstocks, veneers and plywood (Lemmens et al. 1995).

Mango

The mango tree (*Mangifera indica*) is a tall, ever-green tropical tree that typically grows between 10 and 30 m and has a dense and heavy crown. This species is very popular in Indonesia and is grown in both drylands and home gardens. People plant this species primarily for its fruit but its wood can also be used as fuel.

Pinang

The Pinang tree (*Areca catechu*) is grown for its fruit (betel nut), which is chewed as a mild stimulant. It is also used as an ornamental garden tree. Betel nut has traditionally been used by large numbers of people for cosmetic and health purposes. The nut contains large quantities of tannin together with smaller concentrations of garlic acid, fixed oil gum, volatile oil, lignin and various saline substances.

Rambutan

Rambutan (*Nephelium lappaceum*) is one of the most popular fruits in Indonesia. Rambutan is a medium-size tree that produces a red or yellow fruit, round to oval in shape, with hairs or tubercles on its skin. The flesh is translucent and sweet. Most rambutan trees that have been propagated from seed are not true-to-type and the fruits are usually sour. Rambutan produces a small crop in June and July and a large crop between November and January.

Economic evaluation

The analysis presented in this section is derived from Ginoga et al. (2002, 2005). Some results differ from those reported in the original sources because the analysis was repeated using current prices and wages. The original sources included financial as well as economic evaluation but only the economic evaluation is reported here (Table A1). The NPVs calculated with equation (A1) cannot be used to directly compare the economic performance of different agroforestry systems because they have dif-

ferent durations. For example, mangium and sengon systems are based on an 8-year rotation, whereas the damar system is based on the 25-year planning horizon required for a complex agroforest to develop. To make results comparable, we calculated the NPV values in perpetuity (NPV_{INF}) using the equation:

$$NPV_{INF} = NPV(T) / [1 - (1 + r)^{-T}] \quad (A2)$$

where $NPV(T)$ is the NPV calculated over T years using equation (A1). Cacho et al. (2003a) provide more information on this equation.

The carbon stocks in above-ground biomass range between 22.7 and 91.2 tC/ha. The NPVs of the rubber systems are negative, whereas they were positive in the original analysis of Ginoga et al. (2002). This difference was largely driven by increases in wage rates. The return to labour is Rp14,900/day for the traditional rubber system and Rp17,950/day for the clone system (Table A1), and these values are below the current (2006) wage rate of Rp25,000/day. All other systems have positive NPVs, indicating that they are economically attractive. There are large variations in establishment costs, years to positive cash flows, labour requirements and return to labour. Fruit trees tend to be more profitable than timber trees because they start producing income earlier and future income is heavily discounted (at 15%). Mango, duku and durian are the most profitable trees. However, these species would not be established as monocultures in large areas, but would be part of a mix of species. Because these rankings are sensitive to changes in input and output prices, it is important to obtain local data and undertake sensitivity analysis when designing an agroforestry system for a carbon-sequestration project.

West Java

The Citanduy watershed was selected as the study site representative of West Java. This is one of 22 critical watersheds in terms of hydrology and erosion in Indonesia. Due to its critical status, the watershed has been prioritised for land rehabilitation and conservation. The Citanduy watershed lies in the south-east of West Java, encroaching on a small part of Central Java (Figure A2). The Citanduy River is the main river in the watershed. It flows to the Indian Ocean and forms an estuary called *Segara Anakan* located on the border between the West and Central Java provinces. The total watershed area is 352,080 ha. It comprises five subwatersheds, the largest of which is the Upper

Citanduy with an area of 95,500 ha, or 27% of the watershed. The Citanduy watershed, like elsewhere in West Java, is densely populated, with an average population density of approximately 833 people/km².

Vegetation cover in the watershed generally consists of perennial crops, horticultural crops and trees. Vegetation in state-protected forests is dominated by tree species such as rasamala (*Altingia excelsa*), pupsa (*Schima noronhae*) and mahogany (*Swietenia macrophylla*), while in state-production forests dom-

inant species are teak (*Tectona grandis*) and pine (*Pinus merkusii*). Agroforests belonging to small-holders are also present, and these are characterised by three main species: sengon (*Paraserianthes falcataria*), mahogany (*Swietenia macrophylla*) and teak (*Tectona grandis*). These are usually mixed with perennial and horticultural crops.

Land ownership in the Citanduy watershed can be divided into two categories: state land and small-holder or private land. State lands can further be

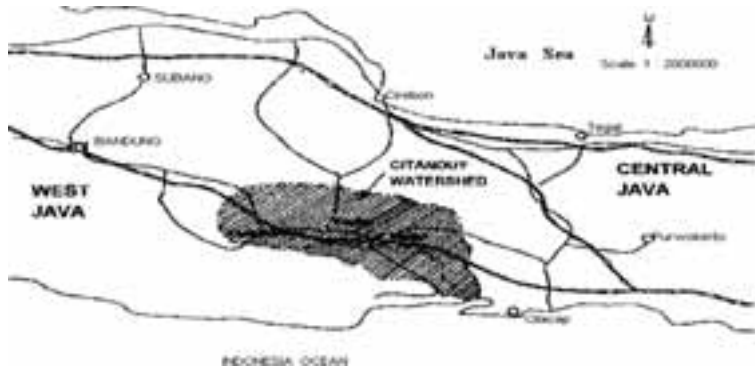


Figure A2. Location of the Citanduy watershed

Table A1. Economic evaluation of agroforestry systems in southern Sumatra

Agroforestry system	Carbon stock (tC/ha)	NPV _{INF} ^a (Rp '000/ ha)	Estimated cost (Rp '000/ ha)	Years to positive cash flow	Labour required (person days/ha/year)	Return to labour (Rp '000/person day)
Rubber, traditional	28.8	-4,021	16,278	-	249	14.90
Rubber, clone	48.1	-4,523	11,686	-	249	17.95
Cinnamon/coffee	27.0	13,189	6,809	13	56	77.16
Cinnamon/potato	22.7	11,965	31,987	12	157	34.58
Cinnamon /chilli	22.7	93,650	4,826	1	237	64.31
Oil palm	27.5	55,734	4,514	1	217	61.25
Damar, traditional	91.2	43,065	19,427	5	141	45.97
Damar, semi-intensive	91.2	59,470	25,230	5	190	59.40
Coffee, timber-based	39.7	65,791	88,318	13	319	29.81
Coffee, fruit-based	42.2	2,125	51,272	18	319	20.80
Coffee, shade-based	43.5	16,039	46,603	10	319	26.05
Sengon	66.4	22,133	6,966	8	59	96.87
Mangium	52.7	13,474	2,823	8	47	124.58
Duku	58.9	110,255	7,141	5	41	424.53
Durian	68.2	109,427	6,724	5	44	374.50
Candlenut	63.9	25,121	8,089	5	38	105.81
Macang	62.1	185,849	7,433	5	33	667.11
Mango	62.1	224,634	6,724	5	31	843.44
Pinang	32.1	9,885	7,563	6	31	56.91
Rambutan	60.5	7,987	6,908	6	32	54.08

^a Net present value of an infinite series of rotations

divided into state-forest land, state land for commercial use (HGU) and other state lands. Land classified HGU provides a 30-year licence to grow commercial estate crops or plantations. Some 68.5% of land in the Upper Citanduy subwatershed is privately owned.

The watershed covers part or most of seven administrative districts (*kabupaten*). The Ciamis and Tasikmalaya districts cover 35.5% and 59.5% of the Upper Citanduy subwatershed, respectively. In terms of strategic importance, Ciamis is the most important district in the Citanduy watershed, followed by Tasikmalaya. These districts generally have light to moderate terrain. A field survey was conducted in two subdistricts: Cisayong (in the Tasikmalaya District) and Sadananya (in the Ciamis District). The Citanduy watershed is described in some detail by Dwiprabowo and Wulan (2003). The research sites represent areas that are considered socially and economically disadvantaged due to high unemployment and low income.

Data on smallholder agroforestry systems, inputs, outputs, prices and tree biomass were collected through a field survey. Interviews with the landowners, and observation and measurement of their trees, were conducted in a sample of farms. Systematic sampling was employed to obtain estimates of tree volume and biomass of the various agroforestry systems. A sample of 20 farms was taken, consisting of 8 farms in Tasikmalaya and 12 farms in Ciamis (Table A2). The farms tend to be small, ranging between 0.25 and 1.0 ha, with a mean area of 0.5 ha.

Species identification and tree measurements were conducted in all measurement plots. Tree age was noted based on information from the farmer. Data on establishment costs were collected by interviewing each farmer using a prepared questionnaire. The total number of trees measured was 665 (221 in Tasikmalaya and 444 in Ciamis). The allometric equation of Brown et al. (1995) was used to estimate biomass carbon based on tree diameter and height (see equation (4.1)). Carbon mean annual increment (CMAI) was calculated by dividing the carbon content of a tree by its age.

A good diversity of tree species was found in both districts: 12 species were identified in Tasikmalaya (Table A3) and 29 species in Ciamis (Table A4), although most species were represented by only a few trees.

The main species planted in Tasikmalaya was *Paraserianthes falcataria* (86.9 %) followed by *Agathis dammara* (2.3 %) and *Hibiscus* sp. (2.3 %). *Paraserianthes falcataria* was chosen as a main tree

Table A2. Characteristics of farms sampled in West Java

Location	Farm	Farm size (ha)	Farmer's age (years)	Land-use system ^a
Tasikmalaya	1	0.70	45	1
	2	0.50	50	1
	3	0.38	45	1
	4	0.50	47	1
	5	0.57	40	1
	6	0.60	35	1
	7	0.50	47	2
	8	0.50	58	1
Ciamis	1	0.42	37	2
	2	1.00	42	1
	3	0.50	47	2
	4	0.42	54	1
	5	0.50	67	1
	6	0.25	35	2
	7	0.50	35	1
	8	0.50	56	1
	9	0.47	50	2
	10	0.50	52	1
	11	0.57	38	2
	12	0.50	45	2
Mean		0.52	46.25	
Minimum		0.25	35.00	
Maximum		1.00	67.00	
Coefficient of variation		0.28	0.18	

^a 1 = trees and crops, 2 = trees only

in the area because of the land suitability and easier accessibility to market. Most *P. falcataria* trees were harvested in year 6, when they reached an average diameter of 20–25 cm. The average price received by farmers for wood was Rp140,535/m³.

The main tree planted in Ciamis was *Maesopsis eminii*, representing 26.4% of trees, closely followed by *P. falcataria*, with 26.1% of trees, and *Swietenia macrophylla*, with 17.1% of trees. The two former tree species were harvested in years 5–6 at an average diameter of 20–25 cm. *Maesopsis eminii* trees were sold for about Rp66,670/m³. The species was popular in the area because it grew better than *P. falcataria*.

Other trees planted in Ciamis include kidamar (*A. dammara*), puspa (*Schima wallichii*), pine (*P. merkusii*) and mahogany (*S. macrophylla*). These trees are planted for their wood, for shelter and for

soil protection, while trees such as kemang (*Mangifera* spp.), durian (*D. zibethinus*), cengkeh (*Eugenia aromatica*), alpukat (*Persea americana*), limus (*Mangifera foetida*) and kelapa (*Cocos nucifera*) were planted mainly for their fruit. Most of these products were sold, but the fruit of guava (*Psidium guajava*) and cempedak (*Artocarpus integer*) were mainly used for home consumption.

Not all smallholder agroforestry systems have the same potential. On average, carbon mean annual increment (CMAI) was slightly higher in Ciamis (7.4 kg/tree/year) than in Tasikmalaya (6.7 kg/tree/year). Due to the small number of trees representing most species, it is not possible to undertake a reliable comparison for all species, but the main species exhibited similar rates of carbon accumulation, ranging between 6.5 and 8.8 kg/tree/year for *S. macrophylla*, *M. eminii* and *P. falcataria* (Tables A3 and A4). The general profiles of the smallholder agroforestry systems in the two areas are shown in Figures A3 and A4. Consistent with the previous discussion, it can be seen that systems in Ciamis have more trees and a closer cover of canopy than in Tasikmalaya. To evaluate the various agroforestry systems from an economic perspective, they were grouped into four patterns for each district (Table A5). The patterns differ in terms of diversity of species, tree density and, implicitly, management intensity.

The mean carbon stocks of representative agroforestry systems in Citanduy range between 23.21 and 85.3 tC/ha (Table A6). NPVs have a range of between

–Rp6.9 million/ha and Rp20.3 million/ha. As with the Sumatra systems, there is a wide range of values for establishment costs, years to positive cash flow, labour requirements and return to labour.

East Nusa Tenggara

East Nusa Tenggara is representative of the general characteristics of eastern Indonesia. It consists of small islands with lower population density and a longer dry season than western Indonesia. East Nusa Tenggara lies between longitudes 118°E and 125°E and latitudes 8°S and 12°S. Geographically, East Nusa Tenggara is an archipelago with hilly topography and young volcanic rocks. The province comprises 566 islands. The three main islands are Flores, Sumba and Timor (only West Timor is part of Indonesia). Timor, on which Kupang, the capital, is located, is hilly and steep. Most rivers on the island are temporary, flowing only in the rainy season.

Due to the central highlands and their closeness to Australia, the seasons in East Nusa Tenggara are irregular. Generally, the islands are semi-arid, with a long dry season lasting from March to November and a wet season from December to February. Rainfall varies between 500 and 2000 mm a year. Most of this region exhibits low land fertility and, as a result of wild shepherding and fire, there is low vegetation coverage. This also lessens the capacity of rain infiltration, causing high run-off and occasional floods.

Table A3. Details of species found in Tasikmalaya smallholder agroforests

Common name	Scientific name	Outputs ^a			Trees sampled		Mean age (years)	CMAI ^b (kg/tree/year)
		L	F	W	(n)	(%)		
Afrika	<i>Maesopsis eminii</i>		•	•	1	0.5	3.0	4.4
Alpukat	<i>Persea americana</i>		•	•	3	1.4	6.7	3.6
Cengkeh	<i>Eugenia aromatica</i>		•	•	3	1.4	9.3	1.0
Huru	<i>Litsea monopetala</i>		•	•	1	0.5	3.0	4.1
Kidamar	<i>Agathis dammara</i>		•	•	5	2.3	6.2	4.2
Mahogany	<i>Swietenia macrophylla</i>		•	•	2	0.9	5.0	2.2
Manglid	<i>Manglietia glauca</i>		•	•	4	1.8	6.5	2.5
Nangka	<i>Artocarpus heterophyllus</i>		•	•	3	1.4	6.3	6.9
Petai	<i>Parkia speciosa</i>	•	•	•	1	0.5	15.0	0.6
Sengon	<i>Paraserianthes falcataria</i>		•	•	192	86.9	2.8	7.1
Suren	<i>Toona surenii</i>		•	•	1	0.5	3.0	3.5
Tisuk	<i>Hibiscus</i> sp.		•	•	5	2.3	3.0	6.9
Total:					221	Weighted average:	6.7	

^a L = leaf, F = fruit, W = wood

^b Carbon mean annual increment

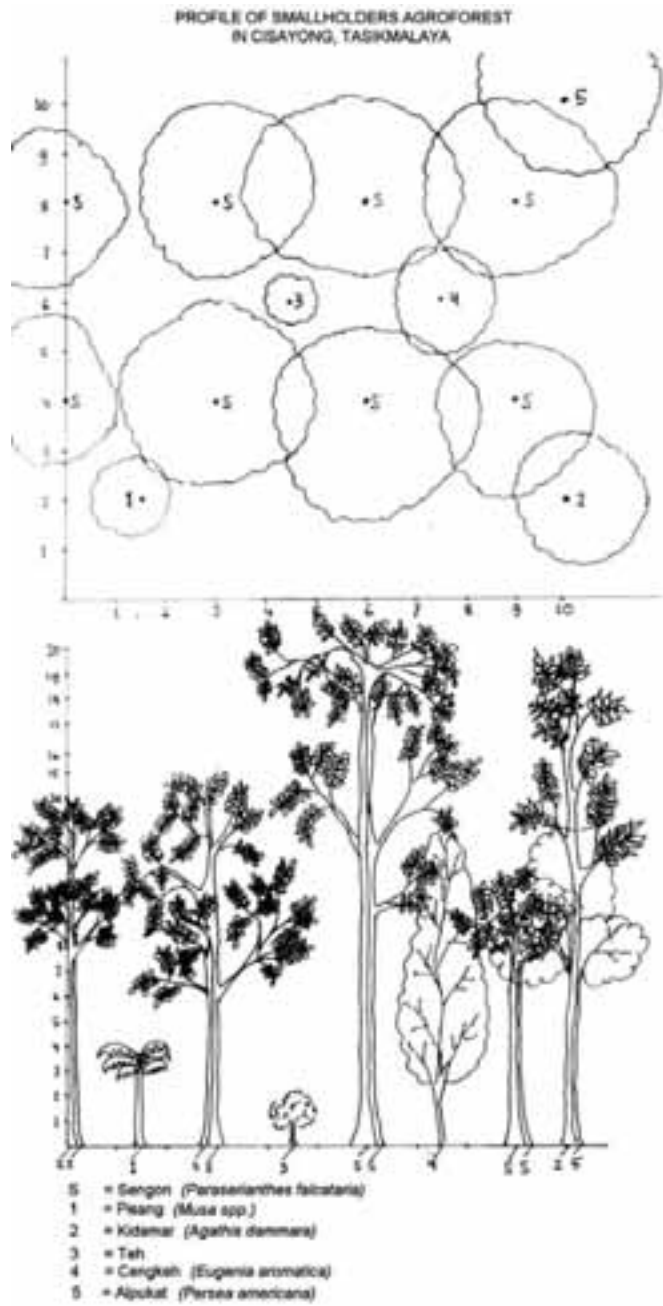
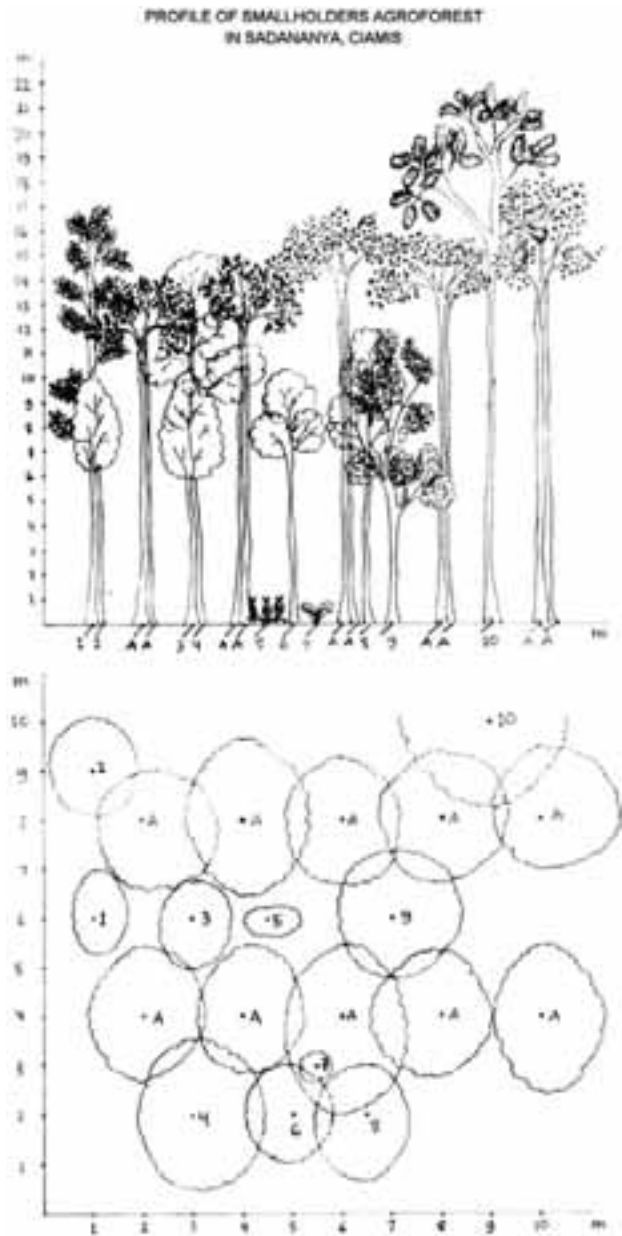


Figure A3. Agroforestry pattern in Cisayong, Tasikmalaya



- A = Kayu Afrika (*Maesopsis eminii*)
- 1,3 = Cengkeh (*Eugenia aromatica*)
- 2 = Kidamar (*Agathis dammara*)
- 4,6,8 = Mahoni (*Swietenia macrophylla*)
- 5 = Nanas (*Ananas comosus*)
- 7 = Kapulaga (*Amomum compactum*)
- 9 = Tangkil (*Gnetum gnetum*)
- 10 = Sengon (*Paraserianthes falcataria*)

Figure A4. Agroforestry pattern in Sadananya, Ciamis

The area used in this analysis is the Manamas village, in the Timor Tengah Utara district. This is a remote village with hilly and steep land. The rainfall is limited to only 4 or 5 months of the year. Land ownership is claimed personally with unclear boundaries, and farmer incomes are relatively low. Agriculture in Manamas is for subsistence: most food crops produced are for home consumption, although farmers raise some livestock (pigs, chicken, goats and a small number of cattle) for sale. Livestock fodder depends on natural availability. This village has 291 households, and about 22% of them belong to a farmer group.

We sampled 14 farms in East Nusa Tenggara (Table A7). The average farm area is 1.4 ha, with

farm sizes ranging between 0.3 and 6.0 ha. These farm sizes are larger than in West Java, reflecting the lower soil fertility and water availability, and the resulting need for larger areas to have a viable business. The average household size is 5.7 people, with a dependency ratio of 1.08 (meaning that each productive-age person has 1.08 dependants). In the Manamas village there is only one primary school building. To attend high school, children must travel to another village, which is relatively distant. As a result, the education level is low (Table A7).

Some 295 trees were measured and 14 species identified (Table A8), including two varieties of *T. grandis* (jati). The most popular species is *Gmelina arborea*, representing 59.3% of the trees sampled,

Table A4. Details of species found in Ciamis smallholder agroforests

Common name	Scientific name	Outputs ^a			Trees sampled		Mean age (years)	CMAI ^b (kg/tree/year)
		L	F	W	(n)	(%)		
Afrika	<i>Maesopsis eminii</i>			•	117	26.4	3.1	8.4
Alpukat	<i>Persea americana</i>		•	•	4	0.9	2.8	5.0
Cempedak	<i>Artocarpus integer</i>		•	•	1	0.2	3.0	2.3
Cengkeh	<i>Eugenia aromatica</i>		•	•	17	3.8	7.0	2.1
Durian	<i>Durio zibethinus</i>		•	•	4	0.9	3.5	3.6
Huru	<i>Litsea monopetala</i>			•	1	0.2	3.0	15.8
Jambu batu	<i>Psidium guajava</i>		•	•	2	0.5	6.0	1.6
Jengkol	<i>Pithecellobium jiringa</i>		•	•	4	0.9	4.5	6.5
Johar	<i>Gliricidia sepium</i>			•	3	0.7	4.0	1.9
Kelapa	<i>Cocos nucifera</i>	•	•	•	4	0.9	20.0	8.1
Kemang	<i>Mangifera</i> spp.	•	•	•	3	0.7	3.0	14.9
Kidamar	<i>Agathis dammara</i>			•	4	0.9	6.8	8.5
Kinyere	<i>Syzigium</i> spp.			•	1	0.2	6.0	11.6
Kiteja	<i>Cinnamomum</i> spp.			•	5	1.1	6.4	11.0
Limus	<i>Mangifera foetida</i>		•	•	4	0.9	11.3	3.1
Mahogany	<i>Swietenia macrophylla</i>			•	76	17.1	5.0	6.5
Nangka	<i>Artocarpus heterophyllus</i>		•	•	13	2.9	6.7	6.3
Petai	<i>Parkia speciosa</i>	•	•	•	12	2.7	11.6	3.4
Picung	<i>Hibiscus</i> sp.			•	2	0.5	8.0	12.9
Pinus	<i>Pinus merkusii</i>			•	1	0.2	3.0	3.1
Pisitan	<i>Lansium</i> sp.		•	•	1	0.2	6.0	2.1
Puspa	<i>Schima wallichii</i>			•	15	3.4	8.5	7.9
Putat	<i>Planchonia valida</i>			•	2	0.5	3.5	9.0
Rambutan	<i>Nephelium lappaceum</i>		•	•	1	0.2	4.0	2.7
Sengon	<i>Paraserianthes falcataria</i>			•	116	26.1	3.2	8.8
Suren	<i>Toona sureni</i>			•	3	0.7	2.7	5.4
Tangkalak	<i>Litsea</i> spp.		•	•	1	0.2	2.0	7.7
Tangkil	<i>Gnetum gnemon</i>	•	•	•	16	3.6	5.4	3.1
Tisuk	<i>Hibiscus</i> sp.			•	11	2.5	3.0	11.5
Total:					444	Weighted average:		7.4

^a L = leaf, F = fruit, W = wood

^b Carbon mean annual increment

followed by the two varieties of jati making up 15.6%. The third most popular species is *S. macrophylla*, with 8.5% of trees. The carbon-sequestration potential of the East Nusa Tenggara systems is relatively low, with an average CMAI of 3.8 kg/tree/year, compared with 6.7 and 7.4 kg/tree/year in the two East Java districts described earlier. There was a wide range of CMAI values. Although the highest value was 19.1 kg/tree/year (Table A8) this represented a single tree that is an obvious outlier. The largest reliable value (with a sample size of 25 trees) was exhibited by jati lokal (7.6 kg/tree/year).

Farmers obtained an average income of Rp1.4 million from cropping (mostly maize, peanuts and vegetables) and Rp335,000 from livestock (mostly poultry). The tree systems sampled were dominated by timber species that have not been harvested, thus it was not possible to undertake the type of economic evaluation presented for other districts. However, the data obtained will later be used to study the feasibility of carbon-sequestration projects in the region.

Imperata as a baseline

Imperata cylindrica is an invasive grass that has occupied deforested areas throughout South-East Asia. Within a few years of deforestation for food production, the land becomes infested with *Imperata* as soil nutrients are exhausted. Garrity et al. (1997) estimate that *Imperata* covers 8.6 million ha in Indonesia, of which 2.1 million ha occur in Sumatra, 0.2 million ha in Java and 1.7 million ha in East Nusa Tenggara.

Imperata grasslands are prone to burning either accidentally or intentionally (van Noordwijk et al. 1997). Fires destroy naturally restored secondary forest and enhance the competitive advantage of *Imperata*. *Imperata* grasslands have low economic value and their control in much of Indonesia is mostly a problem of labour. It is possible to clear *Imperata* grasslands manually and plant crops or trees, but this may take up to 200 person days per hectare, which is more than it takes to open up new forest through slash-and-burn. There are some successful examples of communities establishing agroforests in grassland areas but this is still uncommon (van Noordwijk et al.

Table A5. Smallholder agroforestry patterns in Citanduy

Pattern	Tree species
Tasikmalaya district	
T1	Sengon
T2	Sengon, mahogany, manglid, avocado, kidamar
T3	Sengon, tisuk, suren, jackfruit, parkia, avocado
T4	Sengon, avocado, kidamar, tisuk, cengkeh
Ciamis district	
C1	Afrika, mahogany, sengon, puspa, tisuk, tangkil, nangka, cengkeh, kiteja, kidamar, coconut, avocado, parkia, durian
C2	Sengon, afrika, cengkeh, mahogany, parkia, puspa, jackfruit, tangkil, johar, limus, tisuk, kemang
C3	Kiteja, mahogany, sengon
C4	Sengon, mahogany, afrika, tangkil, jackfruit, cengkeh, kidamar

Table A6. Economic evaluation of agroforestry systems in Citanduy

Pattern	Carbon stock (tC/ha)	Net present value (Rp '000/ ha)	Establishment cost (Rp '000/ ha)	Years to positive cash flow	Labour required (person days/ha/year)	Return to labour (Rp '000/person day)
T1	25.15	-6,871	10,342	-	144	6.17
T2	19.51	2,005	18,384	17	145	17.15
T3	25.30	16,329	9,149	8	66	49.51
T4	23.21	10,900	17,886	10	162	25.05
C1	48.68	-2,999	12,303	-	64	7.78
C2	85.27	11,198	437	11	62	42.89
C3	49.76	20,250	1,863	3	22	181.93
C4	41.61	7,931	11,306	12	89	28.62

1997). In vast grassland areas the cost of converting *Imperata* land is compounded by the risk of fires that move rapidly through the landscape and destroy trees. The vast areas occupied by *Imperata*, combined with its low economic value, the risk of fires and the high labour inputs required to convert the

land, make it an ideal candidate for CDM projects. Not only should conversion of *Imperata* grasslands meet additionality and sustainable-development criteria, but estimation of the baseline should also be relatively simple because the carbon content of biomass and soil is fairly constant.

Table A7. Characteristics of farms sampled in East Nusa Tenggara

Farm	Area (ha)	Farmer's age	Family size	Farmer's education ^a	Land-use system ^b
1	3.0	51	5	4	3
2	0.3	37	4	2	1
3	0.5	34	8	4	1
4	0.5	42	11	2	3
5	0.5	32	7	3	3
6	1.0	56	4	1	1
7	0.4	56	9	1	1
8	0.3	38	7	2	1
9	6.0	42	5	1	3
10	2.0	48	8	4	3
11	1.5	36	3	2	2
12	0.3	36	4	4	2
13	0.3	40	3	2	1
14	3.0	32	2	4	3
Mean	1.40	41.43	5.71	2.57	
Minimum	0.30	32.00	2.00	1.00	
Maximum	6.00	56.00	11.00	4.00	
Coefficient of variation	1.17	0.20	0.46	0.48	

^a 1 = no schooling, 2 = elementary school, 3 = junior high school, 4 = senior high school

^b 1 = trees and crops, 2 = trees and livestock, 3 = trees, crops and livestock

Table A8. Details of species found in East Nusa Tenggara smallholder agroforests

Common name	Scientific name	Trees sampled		Mean age (years)	CMAI ^a (kg/tree/year)
		(n)	(%)		
Ampupu	<i>Eucalyptus urophylla</i>	6	2.0	10.0	1.8
Asam	<i>Tamarindus indica</i>	1	0.3	8.0	19.1
Eucalyptus	<i>Eucalyptus pellita</i>	23	7.8	4.5	4.0
Gmelina	<i>Gmelina arborea</i>	175	59.3	7.9	3.9
Huek	<i>Eucalyptus alba</i>	5	1.7	10.0	2.7
Jati ^b lokal	<i>Tectona grandis</i>	25	8.5	9.4	7.6
Jati super	<i>Tectona grandis</i>	21	7.1	4.4	1.4
Johar	<i>Gliricidia sepium</i>	1	0.3	5.0	0.6
Kabesak	<i>Acacia leucophloea</i>	1	0.3	8.0	0.9
Kemiri	<i>Alewrightia moluccana</i>	4	1.4	13.3	7.1
Mahogany	<i>Swietenia macrophylla</i>	25	8.5	6.9	1.0
Masi	<i>Broussonetia papyrifera</i>	1	0.3	8.0	7.0
Sengon	<i>Paraserianthes falcataria</i>	3	1.0	4.0	4.0
Tastasi	<i>Vitex trifolia</i>	1	0.3	1.0	0.1
Turi	<i>Sesbania grandiflora</i>	3	1.0	8.0	0.3
		Total: 295		Weighted average: 3.8	

^a Carbon mean annual increment

^b Jati is the local name for teak.

Appendix 2

Projects studied

Overview of projects

The analysis in Appendix 1 focused on specific agro-forestry systems suitable for adoption by smallholders. The analysis was based on standard discounted cash flow techniques supplemented by measurement of trees in the field to calibrate models of carbon accumulation. Those models are implemented on spreadsheets and require information on inputs, outputs, prices and discount rates. Those data are laborious to collect but their application in estimating abatement costs is straightforward. In contrast, estimating transaction costs is not a straightforward process, as it requires assumptions about particular aspects of the project to be implemented. At the time of writing, there were no approved AR CDM projects that could be studied to estimate transaction costs. We therefore resorted to studying existing Indonesian reforestation projects as reported in this appendix. This gave us insight into the process of designing and implementing projects involving smallholders and communities, and the associated costs. Four projects were visited, one in West Java, one in West Nusa Tenggara and two in East Nusa Tenggara. Project managers were interviewed and data on costs were collected where available. These projects are described below.

Two additional Indonesian projects are briefly presented in this appendix to round out the discussion. The first is an ADB technical-assistance project that has funded the development of four AR PDDs in Indonesia for submission to the CDM. This project has not been completed, but examining its progress gives insight into the process of search for sites and selection of communities with which to collaborate. In this appendix we also present a brief description of the GERHAN project, a national movement of land and forest rehabilitation with ambitious goals.

Finally, the information obtained from the Indonesian projects was supplemented by studying several

Latin American projects originally established as Activities Implemented Jointly (AIJ). The AIJ program was created by the UNFCCC to facilitate the implementation of the Kyoto flexibility mechanisms (which include the CDM).

JIFPRO project in Cianjur, West Java

This CDM-like project was initiated through an agreement between the Directorate General of Land Rehabilitation and Social Forestry and a director of JIFPRO (Japan International Forestry Promotion and Cooperation Centre). The project consists of establishing a private forest in the Cianjur District, West Java. The implementer of the project is the Citarum–Ciliwung Watershed Management Agency (BPDAS) in collaboration with the District Office of Forestry and Soil Conservation and other related institutions. The field implementers are local people belonging to farmer groups.

A model plan was produced by BPDAS to provide technical and administrative guidance for the smooth operation of the project. The plan covers infrastructure requirements, socioeconomic aspects and a schedule of main activities. The specific objectives of the plan are: (i) to guide the implementation of private forest management in accordance with local biophysical, social and economic characteristics, considering the needs of landowners for sustainable forest management and (ii) to contribute to wood supply for community needs. Before field implementation, training of farmers was conducted following participatory rural appraisal principles to enhance the probability of success of the project. The process of control, monitoring, evaluation and reporting was conducted by BPDAS through field inspections.

The total area of the project is 17.5 ha, divided into two phases. The first phase established 10 ha in 2000–01 and involved 54 farmers. The second phase established 7.5 ha in 2002–03 and involved 14 farmers. The land-use plan includes a mix of annual crops, seasonal crops and mixed cropping. Financing for the project (a total of Rp136,233,500) was provided by Home Direct Co. Ltd, Japan, through a grant distributed by JIFPRO.

We collected primary data about stakeholders' perceptions and cost structures. We also obtained secondary data from the Forestry Provincial Office, the District Office of Forestry and Soil Conservation, the Citarum–Ciliwung Watershed Management Agency, the Sub-District Office and the farmer group. Twenty-four people were interviewed.

The selection of agroforestry systems in the project was limited, consisting of suren (*Toona sureni*), coffee, mahogany (*S. macrophylla*) and crops under trees. Some farmers planted other trees in their own land such as rambutan (*N. lappaceum*), alpukat (*P. americana*), pala (*Myristica fragrans*), pisang (*Musa* spp.), and jengkol (*Pithecellobium jiringa*). Most of the additional trees are multipurpose species that produce harvested outputs every year, and thus produce a stream of income while waiting to harvest the main trees.

Most of the land cultivated in the project is owned by the government and distributed by the head of the village. The average land owned by farmers in the project ranges from 0.185 ha to 0.536 ha per person. Five respondents (24%) used rented land, ranging from 300 m² to 1,200 m², with land rental payments of Rp1,500,000 per ha per year.

The costs of establishing the agroforestry systems are presented in Table A9. The total cost of establishment (materials and labour) was approximately Rp4.5 million/ha, which corresponds to about \$520/ha. The 7.5-ha phase was more expensive per hectare than the 10-ha phase (Rp4,942,300 versus Rp4,143,000) because of the higher cost of seedlings in the former. The price of suren and mahogany seedlings in 2001–02 was four times higher than the price in 1999–2000. Subarudi et al. (2004) provide more details on costs.

The total cost of the project (including design and administration costs) was Rp136,233,500, or Rp7,784,770 per hectare (Table A10), which is equivalent to \$895/ha at the current exchange rate of Rp8,700 per US dollar. The amount of carbon sequestered in this project is expected to be similar to

the amounts in Tasikmalaya agroforestry systems reported in Appendix 1, which ranged between 19.50 and 25.15 tC/ha. This results in carbon costs of between \$35.60 and \$45.90 per tonne. Since 1 tonne of biomass carbon is equivalent to 3.67 tonnes of CO₂, these costs correspond to between \$9.70 and \$12.50 per tonne of CO₂ sequestered. These costs are high, considering that the BioCarbon Fund of the World Bank quotes prices between \$3 and \$5 per tonne of CO₂. However, from a development standpoint, other environmental and social benefits must be considered. In Cianjur the project is helping to prevent soil erosion, maintain water quality in the catchment, and improve farmers' skills and knowledge, in addition to increasing their incomes.

Table A9. Establishment costs of Japan International Forestry Promotion and Cooperation Center project in Cianjur

Cost description	10-ha phase 1999–2000 (Rp '000)	7.5-ha phase 2001–02 (Rp '000)
Materials		
– planting	21,610	24,987
– first-year tree maintenance	2,740	1,500
Total materials	24,350	26,488
Labour cost		
– planting	13,550	9,430
– first-year tree maintenance	3,530	1,150
Total labour	17,080	10,580
Total cost	41,430	37,068
Cost per hectare	4,143	4,942

Source: BRLKT (2001, 2002c)

JIFPRO project in Lombok, West Nusa Tenggara

In support of the Indonesian Government's reforestation and rehabilitation programs, the Japanese Government, through JIFPRO, has implemented a two-phase reforestation project in West Nusa Tenggara over the past 10 years. The first phase of the project took place between 1996 and 2001, and involved the reforestation and protection of 350 ha of land in Sekaroh, East Lombok. A further 130 ha were reforested and protected in Rembitan, Central Lombok, during the second phase of the project between 2002 and 2005. Table A11 presents information on the

institutions involved in the implementation of the project. Since this project was not implemented under the CDM, the institutions involved and the roles undertaken to plan, develop and monitor the various phases may be fewer and simpler than would be required for CDM projects.

Data were collected from primary and secondary sources. Primary data were collected from the field and from several individuals and organisations, including the Provincial Forestry Office (PFO), the Office of Nature Conservation, the District Office of Forestry and Soil Conservation, the Watershed Management Agency, the University of Mataram, the Regional Environmental Office, the Regional Planning Agency and affected landholders. Activities contributing to transaction costs, and estimates of these costs, were

gathered during interviews with relevant people in the institutions involved in both the development of the proposal and the implementation of the project.

Four to five sites were proposed by the Provincial Forestry Office based on general criteria set by JIFPRO:

- The land must be accessible and have enough water.
- The land must have potential to provide ecosystem functions and environmental services.
- Grazing activities in the region must be limited.
- The status of the land must be protected forest, but the land must be bare (the area was deforested in the 1970s and 1980s).
- Some kind of historical, social or environmental value must be associated with the land.

Table A10. Total costs of the Japan International Forestry Promotion and Cooperation Center project in Cianjur

Financial description	10-ha phase (Rp '000)	7.5-ha phase (Rp '000)	Total cost (Rp '000)
Measurement and production of model plan	1,930	1,930	3,860
Seedling provision	9,460	17,825	27,285
Tree planting	26,140	16,592	42,732
Tree maintenance	6,710	2,650	9,360
Watershed support building	5,120	5,070	10,190
Gully plug making	1,153	5,120	6,273
Farmer training	13,150	4,383	17,533
General costs	9,500	9,500	19,000
Total cost	73,163	63,070	136,233

Source: BRLKT (2000; 2002a,b,c)

Table A11. The institutions involved and their respective roles in the development of Japan International Forestry Promotion and Cooperation Center (JIFPRO) projects in East Lombok implemented between 1996 and 2005

Steps	Institutions involved	Role
Preparation	Proponent (PFO ^a) Investor (JIFPRO) Ministry of Forestry DG of LRSF ^b	Planning (measurement and mapping) and species matching, seedlings criteria control Funding source Project liaison
Implementation	PFO Farmer group	Project manager Land preparation, seedling provider, planting, maintenance
Validation	DFO ^c NGO ^d	Land suitability Seedling provider
Monitoring	PFO, DFO Farmer group	Replanting and maintenance; community development Replanting and maintenance
Evaluation	University of Mataram	Tree maintenance; income and employment generation

^a Provincial Forestry Officer; ^b Director General of Land Rehabilitation and Social Forestry; ^c District Forestry Office; and ^d non-government organisation

The land is moderately settled and there is temporary grazing of buffalo and cattle. However, there is limited access to safe drinking water; reforestation is expected to increase the quality of the water. In theory, the use of (currently deforested) protected forest for the development of a CDM project makes it easier to implement and manage, and increases its likelihood of success, since there are no disputes about land tenure.

The final choice of sites is presented in Table A12 and the species planted are listed in Table A13. The tree species planted in the project are a mix of timber and fruit trees.

Table A12. Japan International Forestry Promotion and Cooperation Center projects implemented in protection forests on Lombok Island, West Nusa Tenggara.

Year	Area (ha)	Location ^a
1996–97	50	Sekaroh
1997–98	150	Sekaroh
1998–99	150	Sekaroh
2001–02	20	Rembitan
2002–03	100	Sekaroh and Rembitan
2003–04	10	Rembitan

^a Sekaroh is in East Lombok and Rembitan in Central Lombok

Deciding on the project sites took some time, requiring three visits to the sites over 4 days by three to five people from JIFPRO and a further four visits by two to three people from the Ministry of Forestry. The selection process also involved inputs of time and money from the University of Mataram. Information was exchanged between the PFO and JIFPRO mainly through email, but a JIFPRO liaison officer within the Directorate General of Land Rehabilitation, Ministry of Forestry, also aided in the exchange of information. Experience with previous JIFPRO projects indicates that it takes approximately 1–2 years for a project to be approved by JIFPRO. In the case of a CDM project this may take even longer, since approval is needed not only from JIFPRO but also from the many other stakeholders involved. Once the project has been approved the management responsibilities generally fall on the PFO. The main office normally will be located in either the Provincial or District Forestry Office building. Although a base camp will be built near or on the site it will not be fitted with computers and software. This base camp is used for shelter and administration by

farmers and farmer groups, and for the training and coordination of field crews.

Table A13. Tree species planted in the Japan International Forestry Promotion and Cooperation Center project in Lombok

Site	Species
Rembitan	Coconut (<i>Cocos nucifera</i>)
	Jackfruit (<i>Artocarpus integra</i>)
	Mahogany (<i>Swietenia macrophylla</i>)
	Mango (<i>Mangifera indica</i>)
	Serikaya (<i>Annona squamosa</i>)
	Sonokeling (<i>Dalbergia latifolia</i>)
	Teak (<i>Tectona grandis</i>)
Sekaroh	Cashew nut (<i>Anacardium occidentale</i>)
	Johar (<i>Gliricidia sepium</i>)
	Leucaena (<i>Leucaena leucocephala</i>)
	Neem (<i>Azadirachta indica</i>)
	Randu (<i>Ceiba pentandra</i>)
	Sengon (<i>Paraserianthes falcataria</i>)
	Serikaya (<i>Annona squamosa</i>)
	Tamarind (<i>Tamarindus indica</i>)
	Teak (<i>Tectona grandis</i>)

Information gathered through interviews with government officials at both the district and provincial levels indicates that it does not take long to get the required letter from the head of district certifying the eligibility of the land for the development of a CDM project, provided there are no problems or conflicts over the land. Several estimates about the time taken to issue this letter have been put forward. If there is a one-stop service for CDM projects and there is no conflict over the land, it could take as little as 1–5 days. If, however, these criteria are not met, it can take up to 6 months. The amount of information already available about the various stakeholders, such as affected villages and community groups, can also influence the amount of time taken to issue this letter.

Currently, the PFO and JIFPRO are negotiating the implementation of another 150-ha AR project in East Lombok. This project is planned for the Sambelia subdistrict and is expected to qualify for CERs under the CDM. Thus far, it has taken approximately 1 year of negotiations between the government, local authorities and JIFPRO to plan the project and for JIFPRO to release the funds for implementation. The proposed budget for this project is presented in Table A14. The total cost is Rp2,696 million, equivalent to \$309,917, to reforest 150 ha, resulting in a cost of \$2,066/ha. Some 65% of this cost is for planting and maintenance of the trees. The baseline

scenario of the proposed project is shrubs and *Imperata* grasslands.

OEFC project, East Nusa Tenggara

This community forest, or hutan kemasyarakatan (HKM), project in East Nusa Tenggara (1999–2001) covered planning, planting, capacity building, community development and infrastructure building, including roads. The objective of HKM projects is to ensure forests are managed sustainably with involvement of the local community. The project was funded by the Overseas Economic Cooperation Fund (OEFC). It covered four villages in three districts: Kupang, Alor and East Sumba (Table A15). The project covered a total of 2,000 ha.

The baseline was typified by bush fallow or secondary forest with *Eucalyptus* dominant. The

Kupang district, because of its lower elevation and easier access, has higher population density than the Alor and East Sumba districts. The project started with a process of socialisation of farmers, with training to help them understand the roles and obligations of the community in terms of forest status and function. As most of HKM participants have only an elementary school education, field workers from NGOs were available for socialisation for about 20 months. The harvesting and use of forest is trusted to the community under guidance from the government. The farmer group organises marketing of the timber and other products of the forest.

Mixed agroforestry systems were established, comprising timber and multipurpose tree species. The wood-tree species planted are mahogany (*S. macrophylla*), teak (*T. grandis*), johar (*Cassia siamea*) and gmelina (*G. arborea*). Multipurpose tree species include candlenut (*A. moluccana*), jambu

Table A14. The proposed budget for the 150 ha Clean Development Mechanism – Japan International Forestry Promotion and Cooperation Center (JIFPRO) project

Steps	Activities	Institutions ^a	Costs (Rp '000) ^b	Percentage of costs
Preparation	Project design	PFO, DGLRSF	15,000	0.56
Implementation	Establishment: seedlings, land preparation, planting and maintenance	Farmer group, NGOs, DFO, PFO	1,761,875	65.34
Project management	Infrastructure and equipment Project administration	Project	344,100	12.76
		Project	200,400	7.43
Monitoring	Community development	PFO, DFO and farmer group	174,500	6.47
Evaluation	Coordination, monitoring and evaluation	University of Mataram	200,400	7.43
Total (Rp)			2,696,275	

^a PFO = Provincial Forestry Officer; DGLRSF = Director General of Land Rehabilitation and Social Forestry; NGO = non-government organisation; DFO = District Forestry Office; PFO = Provincial Forestry Office.

^b JIFPRO provides 78.34% of funds, PFO 13.26% and East Lombok district 8.4%.

Table A15. Overseas Economic Cooperation Fund project district characteristics

	District		
	Kupang	Alor	East Sumba
Elevation (m above sea level)	200–350	300+	600–850
Topography	Flat to steep	Very steep	Very steep
Baseline	Bushland and secondary forest	Secondary forest	Bushland/grassland
Distance to subdistrict (km)	27	90	95
Land status	Limited production forest	Unclear	Protected forest
Population density (persons/km ²)	109	36	26
Land ownership (ha/household)	2.6	2.0	4.0

mete (*Anacardium occidentale*) and other species. Other crops and trees that provide steady income flows vary between sites, but they include paddy rice, maize, peanuts, tamarind, coconut, mango, jackfruit, banana, betel nut, avocado, almond, cassava, sweet potato and a variety of vegetables.

There was no detailed cost information for this project but rough information could be gathered (Table A16). The total cost of Rp8,300 million to reforest 2,000 ha results in a cost of Rp4.15 million/ha, or \$477/ha. This cost is lower than in the JIFPRO Lombok project discussed in the previous section.

Table A17 shows that there are differences between planted area and target area, with only 10–65% of the target area planted. The differences are partly influenced by site characteristics. Field observation in September 2004, 3 years after the completion of the project, revealed several problems: (i) the survival rate of the main plantation is only 50–60% in the area planted, and the area planted is only 10–55% of the target area; (ii) intercropping with trees was abandoned in some areas; and (iii) many plots are not being maintained and have been invaded by cattle. These conditions have been noticed by district officers but there is no further funding for monitoring

and control. Since farmers consider the plots as government land, they are unwilling to incur maintenance costs. In addition, there is no contract or specific arrangement about how trees would be shared, so farmers are reluctant to maintain plots.

This experience indicates that the participatory approach is not sufficient to ensure sustainability in reforestation projects, as the newly planted trees had very low survival rates. It would appear that the success rate would be higher if there were security in land and tree ownership.

IFSP project, East Nusa Tenggara

The Indonesia Forest Seed Project (IFSP), funded by Danida, was launched in July 2000 with the purpose of helping smallholder farmers and NGOs strengthen their existing technical awareness and capacity and enhance their access to high-quality germplasm. This project is being implemented by ICRAF and Winrock International. Project activities include:

- surveys, meetings and participatory appraisal to identify NGO/smallholder current pathways, as well as their seed technology awareness, capacity and constraints

Table A16. Overseas Economic Cooperation Fund project costs in East Nusa Tenggara (1999–2001) for 2000 ha

Activities	Costs (Rp million)	Percentage of costs
Planning	400	4.8
Planting	6,000	72.3
Controlling	900	10.8
Co-working with non-government organisations, including training and capacity building	1,000	12.0
Total	8,300	

Table A17. Area planted and survival rate of trees in Overseas Economic Cooperation Fund project in East Nusa Tenggara

Village:	Kupang		East Sumba	Alor
	Haeknutu	Tesbatan	Probur	Meu Rumba and Kambata
Total area (ha)	600	400	500	500
Area planted to trees (ha)	331	261	50	179
Percentage area planted (%)	55	65	10	36
Survival rate (%):				
2001	83	70	91	81
2004	60	–	–	–

- participatory training activities (four types of training activities were held in the first year: (i) timber and fruit tree propagation; (ii) nursery management; (iii) seed-source management and seed collection; (iv) calliandra production and utilisation; all training involved 150 NGO staff, farmers and government field staff)
- production of technical documents in English and Indonesian (during the first year, five occasional documents were produced to support the opening seminar and training activities)
- the design and establishment of a smallholder demonstration trial (there were two types of demonstration trial: seed gardens and smallholder tree farms planted to test and show the advantages of superior quality seed)
- evaluating the suitability of guiding the formation of NGO or smallholder-based seed procurement.

The project has locations in southern Sumatra, Central Java and Nusa Tenggara. These locations were chosen because ICRAF and Winrock had productive relationships with local NGOs and farmer groups. The project studied here is located in the Manamas village, within the Timor Tengah Utara district. To improve the effectiveness of the participatory approach, IFSP adopted a full NGO partnership before, during and after the project, as reforestation occurs over a relatively long time period.

The NGO involved in this project is Yayasan Mitra Tani Mandiri (YMTM), an organisation involved in dryland agriculture. YMTM has been active in the region since 1990 and provides field assistance in every village it is associated with. The project provides improved tree seeds to farmers. The planting technique involves application of organic fertiliser, which is abundantly available from cattle and goats, in a 50 × 60 cm hole prepared 1 week before planting. In addition to the seeds provided by the project, farmers plant other trees such as banana, cashew and orange on their land, to supplement their income. To fulfil food needs, farmers in groups of two or three plant vegetables such as maize, paddy rice, tomato, eggplant, chilli and cabbage. Any surplus production is sold in the local market.

A demonstration plot was started in 2000. The tree species planted were teak (*T. grandis*), eucalyptus (*Eucalyptus* spp.), mahogany (*S. macrophylla*), and gmelina (*Gmelina arborea*). One year before planting on steep slopes, conservation activities such as terracing were undertaken. To evaluate tree

growth in the demonstration plot, tree height and diameter are measured regularly using simple tools (a rope and a bamboo stick). The survival rate has been relatively high: 100% for gmelina and superior teak, 94% for eucalypts, 89% for gold teak and 88% for mahogany.

Project costs per hectare are presented in Table A18. These are estimates obtained from the NGO working for the project. Most costs (46%) are associated with monitoring, which requires technical expertise and co-working with farmers, followed by tending of trees (24%). Land preparation and planting together also represent a significant cost (25%). The total cost is equivalent to \$870/ha, which is intermediate relative to other projects reviewed here.

The main problem faced by farmers in the project is dryland cultivation technology, which is a general problem in East Nusa Tenggara. All the farmers interviewed pointed out that training about the advantages of settled farming, seed handling, land cultivation, planting and stand maintenance are very useful. Once the farmers understand the benefit of settled farming, they claim that they would not undertake their previous practice of slash-and-burn. Yet, some farmers outside the group still followed their conventional system of slash-and-burn, despite the fact that it is prohibited by local government.

ADB project, carbon sequestration through CDM

This project is a technical assistance funded by the Asian Development Bank designed to help Indonesia develop four AR PDDs for the forestry sector. A national project identification workshop was held to identify possible projects. Districts were invited to participate in the workshop on the basis of four key factors:

- readiness of district stakeholders to implement AR-CDM projects
- analysis of district level conditions and availability of eligible CDM lands (Murdiyarsa et al. 2006)
- a balanced geographical representation from across the country
- other factors that may indicate a particular district has high potential to implement an AR-CDM project.

Thirteen districts were invited to participate from three regions: (i) Sumatra and Java (west Indonesia), representing the most developed and densely popu-

lated area of Indonesia; (ii) Sulawesi and Irian (east Indonesia), representing the least developed, drier and poorer area of the country; and (iii) Kalimantan, representing an intermediate case. A ranking process was undertaken to select the sites that would develop PDDs. The project is still in progress, so actual costs of designing and implementing these projects are not available yet. However, a description of the selection process provides insights for further analysis.

Table A18. Indonesia Forest Seed Project (IFSP) costs

Activities	Costs (Rp '000/ ha)	Totals (Rp '000/ ha)
<i>Preparation</i>		
Land clearing	600	
Tree supports and digging holes	600	
Subtotal		1,200
<i>Planting</i>		
Gliricidia seedlings	300	
Local teak seedlings	40	
Labour	1,000	
Subtotal		1,340
<i>Tending</i>		
Weeding	1,200	
Pruning	1,200	
Subtotal		2,400
<i>Administration</i>		
Mailing, telephone and facsimile	300	
Reporting	200	
Subtotal		500
<i>Monitoring</i>		
Field co-worker	1,920	
Supervisor	1,440	
Coordinator	1,200	
Subtotal		4,560
<i>Total</i>		10,000

The screening used a scoring system based on the following criteria:

- presentations made by the district representatives at the workshop
- responses to questionnaires completed by district representatives at the workshop
- geographic characteristics and other factors that indicate high potential of success.

Eleven evaluators were involved in this process, five from Winrock International and six from the National Steering Committee (NSC) / Technical

Team (TT). The presentations were scored based on the level of detail provided by district representatives and their answers to questions asked by evaluators.

The questionnaires represented an intensification of the evaluation process used to select the initial 13 candidates. Scoring of these was based on four criteria:

1. socioeconomic condition of the area and presence of conflicts
2. presence of networks
3. experience in undertaking forest-rehabilitation projects
4. readiness and commitment of local government in managing the environment.

Criterion (1) was further disaggregated into the following factors: (i) land-ownership conflicts; (ii) proportion of households under the poverty line; (iii) proportion of households whose main income comes from agriculture; and (iv) number of undeveloped villages within the district. Scoring of this criterion was designed to screen out areas with land-tenure conflicts but also to favour poorer, more agriculturally based districts. Under criterion (2), functional networks were evaluated based on the number of activities conducted by groups of stakeholders. Criterion (3) required the submission of documentation as evidence of successful participation in previous projects. Criterion (4) was scored based on the presence of environmental and forestry forums and the number of stakeholders involved.

Districts with the highest score in each region were recommended for selection to prepare a PDD. In cases where the scores were very close, additional criteria were used to select candidate sites. These included the presence of carbon investors interested in the site and the ability of the district to replicate capacity-building activities to help neighbouring districts.

The selected sites are presented in Table A19 and their locations are shown in Figure A5. Project areas range between 600 and 7,500 ha and the baselines vary, including *Imperata* grasslands and slash-and-burn agriculture. Two areas are classified as protection forest, but they have been deforested, and three sites are degraded state land. CIFOR are now using the CO2Fix model to estimate the carbon-sequestration potential of the areas selected. ICRAF is using the FALLOW model to investigate leakage and additional associated with the possible land-use systems.

GERHAN

To overcome the problem of forest degradation, the Indonesian Government implemented a national movement of land and forest rehabilitation (*gerakan nasional rehabilitasi hutan dan lahan* or GERHAN). GERHAN is designed to cover 3 million ha in the period 2003–07. It is a multisectoral project involving central, provincial and district agencies. In

2004, GERHAN was covering 31 provinces, 375 districts and 141 watershed areas.

Data were collected mainly from secondary sources, but some primary data were obtained through interviews of selected respondents and a field visit. The land includes private land and conservation forest. The stakeholders are the Ministry of Forestry, BPDAS, the District Forestry Service, NGOs and communities. Funding is provided by

Table A19. Description of the five sites selected for project design document assistance in Asian Development Bank – Clean Development Mechanism project.

	Location				
	Sindenreng Rappan, South Sulawesi	Bombana, South East Sulawesi	Deli Serdang, Sumatra	West Lampung, Sumatra	Hulu Sungai Selatan, South Kalimantan
Area proposed (ha)	600	700	3,000	7,500	2,500
Original land cover (baseline)	<i>Imperata</i> grassland	Grassland	Agriculture (3-year slash-and-burn cycle)	Coffee systems	Grassland
Proposed systems	Mixed fruit and timber	Cashew and teak plantation	Rubber and mixed fruit	Multi-strata coffee with fruit trees	Mixed rubber agroforest
Land status	Degraded state land	Degraded state land	Degraded state land	Protection forest	Protection forest

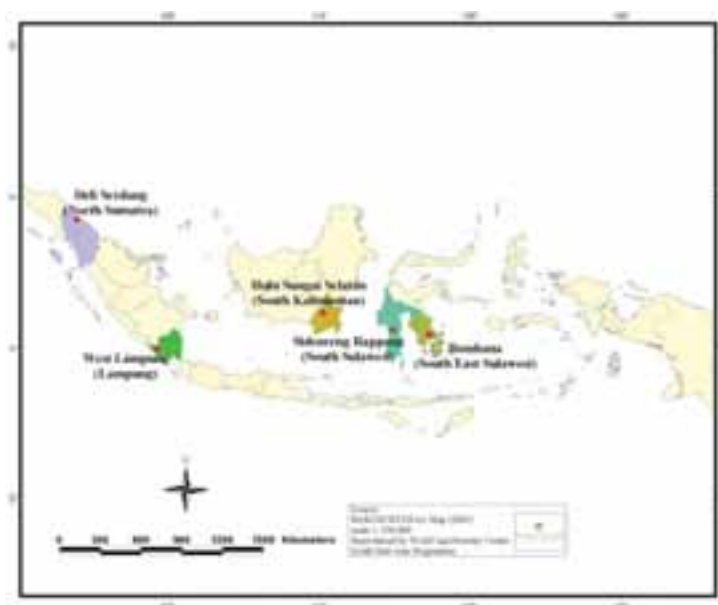


Figure A5. Location of selected sites for development of project design documents for the Asian Development Bank Clean Development Mechanism project

interest paid by the reforestation fund deposit. The planting pattern is 30% timber and 70% multipurpose tree species. The costs of the GERHAN project for 2003–04 are presented in Table A20.

The average cost per hectare for 800,000 ha reforested in 2003–2004 was Rp3.13 million/ha. This is equivalent to \$360/ha and would appear to compare favourably with other projects evaluated above. The average realisation of targets, accounting for area planted and tree survival, is 73% (Table A20). When the costs per hectare are adjusted by the percentage realised, the resulting cost of \$493/ha still compares favourably with other projects. Thus, GERHAN could be categorised as a successful forestry program and may offer a good model for large-scale project design. However, some environmentalists have argued that the realisation data are unreliable due to the non-transparency of data analysis. Furthermore, some researchers argue that the implementation of the program needs to be improved (Gintings 2005).

Perceived deficiencies include poor coordination among agencies, especially between seedling providers and plantation teams in the field, poor maintenance of trees and lack of enforcement to prevent plantation failure.

Selected AIJ projects

Activities Implemented Jointly (AIJ) were designed as pilot projects to provide lessons for future carbon projects under the Kyoto Protocol. As a result, they incurred unavoidably high transaction and learning costs for all partners, particularly as the international carbon market was not yet fully operational, and uncertainty regarding the rules of the CDM was high.

To obtain the actual and expected transaction costs of existing forest carbon projects, a written survey was sent to 11 AIJ forest-carbon project teams. Details of the survey are presented in Milne (2002). A number of the selected projects were found to be no

Table A20. Costs and performance of the GERHAN project in 2003 and 2004

	Year		Total
	2003	2004	
Target area (ha)	300,000	500,000	800,000
Costs (Rp million)			
National demonstration plot	4,500	–	4,500
Project administration	4,688	12,996	17,684
Technical planning	14,682	30,349	45,031
Seedling procurement	353,879	609,198	963,078
Tree planting	559,828	552,342	1,112,170
Land conservation buildings	15,853	42,648	58,501
Road construction (250 km)	2,500	91,690	94,190
Institutional buildings	45,271	132,733	178,003
Technical guidance and monitoring	8,128	12,645	20,773
Provincial monitoring and evaluation	19,666	18,539	38,204
Total costs	1,028,994	1,473,139	2,502,133
Cost per target area (Rp million/ha)	3.43	2.95	3.13
(\$/ha)	394.25	338.65	359.50
Project performance			
Area planted (ha)	295,509	428,419	723,928
(a) percentage of target	98.5	85.7	90.5
(b) survival rate of trees (%)	75.0	84.0	80.6
Percent realisation (a × b)	73.9	72.0	73.0
Soil conservation buildings			
target	1,764	6,257	8,021
realised	1,263	4,753	6,016
percentage realisation	71.6	76.0	75.0
Cost per ha realised (Rp million/ha)	4.64	4.09	4.29
(\$/ha)	533.66	470.52	492.75

Sources: Dirjen RLPS (2005); Warta Gerhan (2006)

longer operational and, for those that were, the concept of transaction costs could not be successfully communicated by way of a written survey. As a result, a number of the project managers were interviewed by telephone and, where possible, quantitative estimates of time expended and financial costs incurred were estimated.

At the time, no small-scale forest-carbon projects had been established in Indonesia. Hence, we spoke

to developers of outgrower schemes (partnerships between community and private sector) about the transaction costs in establishing and running small-scale plantation schemes, and the constraints and opportunities of these types of operations in Indonesia. An international plantation company based in Indonesia was also contacted regarding the risks and opportunities facing foreign investors interested in forestry projects in Indonesia.

Table A21. Selected Activities Implemented Jointly afforestation and reforestation projects

	Project name, country				
	Profafor, Ecuador	Scolet Té, Mexico	Klinki, Costa Rica	SIF, Chile	Virilla, Costa Rica
Land type	Andean highlands (>2,800 m)	Highland and lowland tropical communities	Pastures and marginal farmland	Pastures and marginal farmland	Pastures
Duration (year)	25	30	25	51	25
Target area (ha)	75,000	2,000	6,000	7,000	1,000
Area planted	22,500	500	48	na	131
CO ₂ sequestered (kt)	35,000	1,210	7,216	1,414	847
Carbon, total (kt)	9,537	330	1,966	385	231
Carbon per year (t/ha/year)	5.09	5.50	7.12	1.08	9.23
Project cost (\$1,000)	8,810	3,681	10,703	20,600	3,395
Annual cost (\$/ha/year)	4.70	61.35	38.78	57.70	135.81
Carbon cost (\$/tC)	0.92	11.16	5.44	53.47	14.71
Sources ^a	a, b, c	d, e	f, g	h	i

^a Sources: (a) Verweij and Emmer (1998); (b) Milne et al. (2001); (c) FACE (2001); (d) UNFCCC (1997); (e) Hellier, pers. comm. (2002); (f) UNFCCC (1998); (g) Barres, pers. comm. (2002); (h) UNFCCC (2001); (i) UNFCCC (2000)

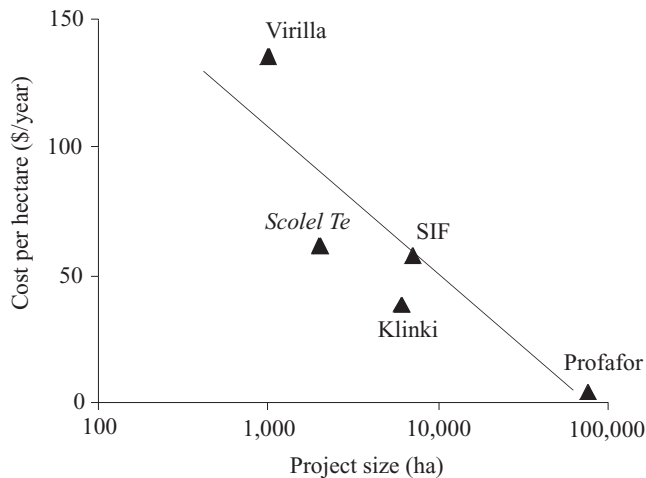


Figure A6. Annual costs per hectare of selected Activities Implemented Jointly afforestation and reforestation projects

All AIJ reforestation and afforestation projects approved by the UNFCCC were initially selected. Of the 11 projects, 8 were located in Latin America, 1 in Asia and 2 in the Russian Federation. The AIJ projects were at varying stages of the project cycle. For the case study analysis, it was decided that projects that were not yet operational would not be included [Milne (2002) presents a detailed description of these projects]. As a consequence, the sample was reduced to six projects. This analysis was later updated by Cacho et al. (2003b) and was reduced to the five projects that involved farmer participation (see Table A21). The sixth project (Rusafor) was a large reforestation project. Milne (2002) noted that, under Rusafor and the other Russian project (Virilla), about the same size area was to be planted. But the Virilla project, which involves payments to private landholders, was projected to cost 30 times more than Rusafor, which involved reforestation of state land.

Although the CDM market was not yet operational, both *Scolec Te* and Profafor were selling carbon off-

sets. *Scolec Te* was trading Verifiable Emission Reductions (VERs) and Profafor had its carbon offsets certified by a third party for sale to the FACE Foundation in the Netherlands. Projects in this sample (Table A21) covered areas ranging from 1,000 to 75,000 ha, with annual costs ranging between \$4.70/ha and \$135.81/ha. Costs of carbon sequestration ranged between \$0.92/tC and \$53.47/tC. Carbon-sequestration costs were estimated by dividing total project costs by projected total carbon sequestration; thus they assume that carbon will be stored in perpetuity and do not account for the timing of sequestration.

Evidence of economies of scale is presented in Figure A6. These data were from reports submitted voluntarily to UNFCCC and the numbers are not independently verified. Also, the sample is too small to draw any definite conclusions. Although the trends are interesting, as indicated by the slope of the line (Figure A6), we could not tell whether the economies of scale were in monitoring or other activities.