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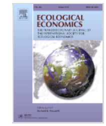

Analysis

Benefits and costs of deforestation by smallholders: Implications for forest conservation and climate policy

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Highlights

- Tropical deforestation causes high rates of biodiversity loss and CO_2 emissions.
- Much of the land at the forest frontier is managed informally by smallholders.
- Opportunity cost (OC) of avoided deforestation by farmers in Sumatra is estimated.
- Payments requested by these farmers exceed OC estimated from survey data.
- Our results have implications for the design of policies on avoided deforestation.

Abstract

Deforestation is a leading cause of biodiversity loss and an important source of global carbon emissions. This means that there are important synergies between climate policy and conservation policy. The highest rates of deforestation occur in tropical countries, where much of the land at the forest frontier is managed informally by smallholders and where governance systems tend to be weak. These features must be considered when designing policies to reduce emissions from deforestation such as REDD +. Deforestation is often accompanied by fires that release large amounts of carbon dioxide. These emissions are especially high in the case of peatlands which contain thick layers of carbon-rich matter. In this paper we derive marginal abatement cost (MAC) curves using data from a farmer survey in Sumatra, where rates of peatland deforestation are high. Comparing these results with farmers' stated willingness to accept payment not to clear forest to establish oil palm suggests that REDD + policies may be more expensive than MAC estimates suggest The extent to which this is true depends on the types of soils being deforested.

Keywords

REDD +; Oil palm; Deforestation; Smallholders; Opportunity cost; Marginal abatement cost

1. Introduction

Land-use change and agriculture account for approximately one third of global greenhouse gas emissions (FAO, 2011 and Smith et al., 2007), but these sectors also have considerable potential as carbon sinks, mostly in the form of forests (Bloomfield and Pearson, 2000, Cacho et al., 2008 and Watson et al., 2000). For this reason, there has been much interest in the synergies between forest conservation and climate policy (e.g. Kindermann et al., 2008, Pfaff et al., 2010 and Venter et al., 2009). Reducing emissions from deforestation and forest degradation, in its most recent form as REDD +, is currently the most prominent international mechanism to capture these synergies (Angelsen et al., 2009, Harvey et al., 2010 and Sandker et al., 2010). The key feature of this policy should be the ability for developing countries to capture carbon offset payments in return for reductions in deforestation. A core idea of REDD + is performance-based payments that are conditional on the outcome of an action. Funds may be spent on (i) capacity building and 'readiness', (ii) policies to address the drivers of forest carbon loss and (iii) rewards for performance (i.e. quantified forest carbon change or emissions avoided).

The open-access nature of tropical forests, the contested nature of property rights, public policies that have encouraged deforestation, and alternative land uses that are more profitable than forests, have combined to result in large scale loss of forest through both legal and illegal activities (FAO, 2001, Geist and Lambin, 2002 and WWF, 2006). Wertz-Kanounnikoff and Angelsen (2009) argue that the success of REDD + within countries requires three key elements: performance-based incentives, reliable information, and effective institutions to manage information and incentives. The emerging critique of REDD +, however, suggests that there are profound challenges to achieving these conditions and meeting the in-built assumptions of REDD + policy in practice (e.g. Mahanty et al., 2013a, Mahanty et al., 2013b and Milne, 2012).

A particular challenge for REDD + is the fact that conservation efforts tend to be static whereas opportunity costs are dynamic. Recent empirical studies have found evidence that opportunity costs of forested land vary widely over time and space (Lu and Liu, 2013 and Wheeler et al., 2013), implying that forest conservation schemes need to incorporate arrangements for adjusting compensation as economic conditions change (Tacconi et al., 2013). Another challenging factor for REDD + implementation is its voluntary and contractual nature, meaning that REDD + agreements should be non-coercive and attractive to stakeholders, while also adhering to social safeguards such as free prior and informed consent for local communities and land-holders. Butler et al. (2009) suggest that unless global climate policies legitimize the trading of carbon credits from forestry, REDD + will not be able to compete with more profitable alternative land-uses, as carbon prices in voluntary markets tend to be lower than in compliance markets (Linacre et al., 2011). The recent collapse of the carbon price in the EU emissions trading scheme may be another obstacle to REDD + implementation, at least in the short to medium term.

Despite the uncertainty about the future of REDD +, given the lack of progress on a global climate change agreement, there has been continuing significant interest in REDD + activities in the top carbon emitters from deforestation and degradation: Brazil, Indonesia and Congo. Sills et al. (2009) identified 60 REDD + projects in the pipeline, 35 of them in Indonesia, a country that has one of the highest rates of tropical forest loss in the world, losing 64 million ha in the period 1950–2000 (FWI/GFW, 2002). This has made Indonesia one of the epicenters of deforestation and degradation, and hence REDD + interventions.

Land-use decisions for conservation are particularly complex in the tropics for three reasons: (1) much of the land at the forest frontier is managed by semi-subsistence farmers and shifting cultivators, often informally; (2) tropical forests contain high concentrations of valuable timber and non-timber forest products, and their exploitation can be highly profitable; and (3) as global demand for agricultural commodities rises, land grabbing and encroachment into forested regions has accelerated rapidly (Borras et al., 2011 and Nevins and Peluso, 2008). These factors in combination with poor governance make it extremely difficult to reduce tropical deforestation. A basic requirement for climate mitigation activities is, therefore, the willingness of farmers to participate in forest conservation efforts (Cacho et al., 2005 and de Jong et al., 2000).

The high profitability of land-uses like oil palm, rubber, and forestry plantations for pulp and paper, combined with a policy environment that effectively subsidizes such land-uses, increases the opportunity costs of conserving tropical forests. The establishment of oil palm and timber plantations has now become the main drivers of deforestation in Indonesia (Butler et al., 2009 and Koh and Wilcove, 2008). In this process, the political economy of forest land allocation and the incentives received by local politicians and bureaucrats play an important role in determining the rate of deforestation in Indonesia (Brockhaus et al., 2012 and Burguess et al., 2012). For example, oil palm and timber plantations generate substantial royalties, fees and taxes for governments at all levels (Irawan et al., 2013).

It is normally assumed that national REDD + systems should be designed to pass down conditional payments from the international level to the local level, but other policy options are also being considered for implementing REDD + at the national and local levels (Sills et al., 2009). In particular, there is an emerging preference for national REDD + systems to be compliance-based, rather than governed by voluntary carbon market transactions (UN-REDD, 2012). Clearly, the distribution of REDD + payments among governments, firms and individuals must reflect the costs and incentives faced by each group, keeping in mind that some group members derive benefits from deforestation that is illegal or illegitimate, and should not be compensated.

In this paper we build upon previous analyses by evaluating the motivations that drive land conversion by smallholders whose collaboration is essential for the success of forest conservation policies in Indonesia. This analysis fills a gap in the understanding of economic issues faced in the implementation of REDD +, given that the focus of existing analyses has been mostly on large scale activities carried out by companies (e.g. Butler et al., 2009, Irawan et al., 2013 and Koh and Wilcove, 2008). Thus, this study focuses on areas where smallholders are driving forest clearing for palm oil plantations. A particular contribution of this paper is the comparison of the estimated returns from oil palm with the farmers' stated willingness to accept compensation for avoiding deforestation.

2. Method

2.1. The Farmer's Decision

Consider the decision faced by a farmer assessing land-uses for possible adoption. The decision is motivated by a desire to maximize wellbeing in terms of expected utility. We assume that utility is positively related to both the level of income and the level of non-market benefits obtained from each land-use. Therefore, the land-use decision involves maximization of a conjoint utility function with two components: monetary net earnings and non-market net benefits associated with the alternative land uses. This utility function represents the discounted flow of expected net monetary and non-monetary benefits, evaluated in perpetuity in year t. If the farmer could capture the non-market benefits when considering the conversion from one land use to another, his decision would involve maximizing utility such that:

$$LU_{ijt} = ArgMax\{NPV_{ijt} + \mu_{ijt} - S_{ijt}\}, i = (1 \ldots N), j = (1 \ldots M) \quad (1)$$

Turn on

where LU_{ijt} is the land use j allocated to parcel i in year t; NPV_{ijt} is the net present value of the land use; μ_{ijt} is the value of non-monetary benefits; S_{ijt} is the land-use conversion cost (the cost of switching land uses), N is the number of parcels and M is the number of alternative land uses. Each alternative could also be subject to legal, environmental, socio-economic and institutional constraints that could contribute to the conversion cost or could enter the problem as constraints on the maximization. A problem is that the variable μ cannot be directly observed and its value may be only partially considered by the landholder depending on the proportion of non-market benefits he can capture.

In practice, the landowner will choose land use k over land use j when:

$$(NPV_{ikt} + \mu_{ikt} - S_{ikt}) > (NPV_{ijt} + \mu_{ijt} - S_{ijt}), \forall i, j, t, j \neq k.$$

In practical terms, if the current use is LU_k the landholder will keep it, but if it is LU_j, he will convert the land-use from j to k. Farmers are unlikely to capture the full social and ecological benefits from tropical forests, although they may obtain food, medicine and spiritual values. This means that their decisions are mostly explained by the expected financial returns from alternative land uses, such as oil palm plantations and μ may not enter the decision.

2.2. Measuring the Opportunity Cost of Avoided Deforestation

The NPV of a farm producing J outputs using I inputs over a period of T years is:

$$NPV(T) = \sum_t \left[\sum_j y_{j,t} p_j - \sum_i x_{i,t} c_i\right] (1+r)^{-t}; t \in (1, \ldots, T); j \in (1, \ldots, J); i \in (1, \ldots, I) \quad (2)$$

where $y_{j,t}$ 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; c_i is the cost per unit of input; and r is the discount rate. This equation measures only the monetary value of the land use.

To compare the present value of land uses that may have different time horizons we calculate the NPV in perpetuity (NPV_{INF}) using Faustmann's formula:

$$NPV_{INF} = \frac{NPV(T)}{1-(1+r)^{-T}} \quad (3)$$

where NPV(T) is the net present value calculated over T years using Eq. (2) (e.g. see Cacho et al., 2003).

For any given farm k, let NPV_{INF} for the current and proposed land-use systems be expressed as $NPV_{C,k}$ and $NPV_{P,k}$ respectively. The benefit (per hectare) of changing land use for farmer k can now be expressed as:

$$B_k = NPV_{P,k} - NPV_{C,k} - S_k. \quad (4)$$

From society's point of view the benefit of land-use change by farmer k is:

$$BS_{,k} = NPV_{P,k} - NPV_{C,k} - S_k + (\mu_{P,k} - \mu_{C,k}). \quad (5)$$

If the current land use is tropical forest and the proposed land use is oil palm we expect $NPV_{P,k} > NPV_{C,k}$ and $\mu_{P,k} < \mu_{C,k}$, thus the landholder would overestimate the true benefit to society of changing land use. If the non-market benefits of the forest are high enough relative to those of oil palm, then Eq. (5) will become negative even when Eq. (4) is positive.

B_k in Eq. (4) is the opportunity cost of avoided deforestation from the farmer's point of view — i.e. the net income the farmer would give up by maintaining the forest rather than clearing the land (at cost S_k) and planting a crop. The policy problem then becomes how to compensate the farmer to conserve forest based on the public benefits of this action, assuming that his/her choice over forest conversion is unconstrained by legal or other factors. The minimum amount of compensation acceptable to the farmer is B_k and the maximum cost acceptable to society is $\mu_{C,k} - \mu_{P,k}$. In the case of forest, the non-market values embedded in μ include biodiversity, biomass carbon and other services such as water regulation. Below we focus on carbon storage as the ecosystem service that is already being priced through markets.

2.3. Carbon Abatement Cost

The amount of carbon released by the land-use change is the difference in carbon stocks between the two systems:

$$C_{E,k}=C_{C,k}-C_{P,k}+S_E \quad (6)$$

where $C_{E,k}$ is carbon emissions by the land-use change; $C_{C,k}$ and $C_{P,k}$ are the stocks of carbon of the current and proposed land uses; and S_E is additional emissions produced in the land-use conversion (i.e. to run machinery). In the case of deforestation to plant oil palm $C_{E,k} > 0$, with the release of large amounts of CO_2 to the atmosphere. The carbon stocks in Eq. (6) are contained in biomass (aboveground and belowground), litter, soil, and in some cases peat.

A farmer k who is offered to participate in a program involving payments for conserving forest carbon must consider the total cost of participation. This cost includes the monetary benefits given up (B_K) plus any transaction costs experienced in the process of qualifying for payments ($V_{T,k}$). The cost to the landholder per emission avoided is:

(7)

This is the total cost to the farmer of giving up on the opportunity to plant oil palm in land that is currently forested. Knowledge of this value allows a lower bound estimate to be placed on the level of incentives that would be required to enable REDD + activities through farmer participation.

In this case we have assigned the entire opportunity cost of forest conservation to avoided emissions. The same approach could be used to account for biodiversity conservation and other ecosystem services. Weights could then be introduced to determine the share of opportunity cost that should be covered by each ecosystem service if the appropriate payment mechanisms existed. Busch (2013) shows how payments for multiple services may operate and derives production possibility frontiers for carbon and biodiversity under different payment mechanisms. Here we deal only with carbon payments in the context of REDD +. This means that, although environmental and social benefits will affect the likelihood that a project will receive funding when competing against other projects that do not provide such benefits, these non-market benefits will not affect the actual payment per CO_2e, which we assume is determined in the carbon market.

3. Case Studies

This model is applied to two case studies in the province of Riau on the island of Sumatra, Indonesia. This province is believed to have suffered the highest rates of deforestation in Indonesia in recent decades, having lost approximately 65% of its original forest cover between 1982 and 2007 (Uryu et al., 2008). Most of this forest loss in the 1980s was explained by a few large companies that established plantations for the pulp and paper industry (Barr, 2000 and WWF, 2006), in conjunction with the spread of palm oil interests, land markets and infrastructure associated with fossil fuel exploitation (e.g. Potter and Badcock, 2004). Broich et al. (2011) estimated that 2.86 million ha of forest was lost between 2000 and 2005 in Sumatra and Kalimantan. Local governments in Indonesia historically have encouraged the settlement of migrants from more densely populated areas in the country. This transmigration program facilitated a colonization and deforestation process (Sunderlin and Resosudarmo, 1996), because new arrivals were encouraged to clear forest to build houses and plant crops such as oil palm, which had been the case in Riau since the 1980s (Potter and Badcock, 2004). Although transmigration is officially banned now, it continues in contemporary unofficial forms, especially in association with the establishment of new oil palm plantations (Potter, 2012).

To date, oil palm plantations cover approximately 8 million ha in Indonesia and it is expected they will reach about 13 million ha by 2020 (Rianto et al., 2012). These plantations are largely concentrated in Sumatra, with the Riau province being one of the long-term focal areas for production. In 2010, there were 1.8 million ha of oil palm in the province, representing 22% of the country's total (Rianto et al., 2012). The increasing world demand for crude palm oil suggests that expansion of oil palm plantations will continue, as noted above. Indonesia is also stimulating demand for palm oil through policies on biofuels requiring either ethanol or palm-oil biodiesel in the fuel mix, which will likely encourage oil palm expansion (Dillon et al., 2008 and UNEP (United Nations Environment Program), 2012).

Two areas of Riau province were selected (Fig. 1) for interviews with farmers. According to the mapping study of Santosa et al. (2012), both areas experienced increased deforestation in 2005–2008 compared to 2002–2005. This increase was especially dramatic in Sinaboi (from 257 ha to 2703 ha), but was also significant in Dayun, increasing by 23% (from 4115 ha to 5089 ha). Most of the deforestation in Dayun can be explained by the conversion of natural forest to industrial plantations for pulp and paper, mainly Acacia, and oil palm estates (Santosa et al., 2012). Sinaboi was traditionally dependent upon the fishing industry in the Malacca Straits. However, household interviews indicate that fishing income has declined significantly in recent years, and local residents have turned to oil palm as their main income source. Nearby there is also one of Riau's last active logging concessions, which means that (aside from the law) land shortages are not a constraint to agricultural expansion.

Fig. 1.

Location and land uses of case study areas, Rokan Hilir and Siak Districts in Riau Province, Sumatra Island, Indonesia.

Source: GIS data from Santosa et al. (2012).

Figure options

Surveys were undertaken during the period 11–24 April 2011. One purpose of the survey was to estimate the benefits that smallholders obtain from their different land uses, with emphasis on oil palm. This enabled us, using the model developed above, to calculate the opportunity cost of not planting oil palm to obtain an estimate of the minimum REDD + payments that would be required to stop deforestation in the area. The surveys focused on farmers living on the forest fringe. A subset of farmers in each district was asked additional financial questions to calculate NPVs.

A discounted cash flow model for oil palm establishment was created based on survey results. This model consisted of adapting Eq. (2) to the inputs and activities specific to oil palm production. Details are presented in the Supplementary materials.

4. Results

Summary statistics for the two case study sites are presented in the Supplementary materials. The mean farm size is smaller in Sinaboi (4.6 ha) than in Dayun (5.1 ha) but this difference is not significant ($p > 0.1$). The mean household size (~ 5 people) is similar for both districts, as is the dependency ratio (1.0 and 1.2) and the education level of the household head. The main difference between the two districts is in the proportion of migrants into the area, with only 12% declaring that they are local in Dayun and 44% in Sinaboi. This illustrates the effect of 1980 transmigration policies for settlement of Javanese farmers into the Dayun area, as explained by the village head and local authorities interviewed as part of this research.

4.1. Overview of Land-use Changes in the Region

Most land-use changes were to oil palm (Table 1), with 93% of area converted going to this crop (comprising 77% of oil palm monoculture and 16% mixed with other crops). Most of the land converted was forest, with 62% of reported land-use changes representing deforestation (comprising both primary and secondary forest, including swamp forest). This illustrates the importance of oil palm as an incentive for deforestation and hence its relevance to REDD + projects that target smallholders.

Table 1.

Land use changes in study area as percentages of total area of land-use changes reported by farmers.

Percent	To land use					
From land use	Coconut	Oil palm	Oil palm mix	Paddy	Paddy mix	Total
Coconut		2.3	0.6			2.9
Forest		45.8	12.1	1.7	2.9	62.5
Grassland				1.2		1.2
Paddy		11.2	2.3			13.5
Rubber		1.7				1.7
Scrub	0.3	15.9	1.4	0.6		18.2
Total	0.3	76.9	16.4	3.5	2.9	100.0

Table options

4.2. Oil Palm Establishment

Oil palm yields tend to be higher in Dayun than in Sinaboi (Table 2), reflecting the longer history of oil palm production in the former area. The average year of oil palm establishment was 1997 in Dayun compared to 2005 in Sinaboi. The prices received in Dayun also tended to be higher, suggesting a more mature industry with established markets, better road access, and more proximate mills for processing of palm oil fruit into oil.

Table 2.

Summary statistics of oil palm production by district.

		Dayun	Sinaboi
Oil palm yield (t/ha/yr)	Mean	17.68	8.93□□
	sd	7.64	6.81
Oil palm price (Rp/kg)	Mean	1430	1036□□
	sd	172	123
Year established	Mean	1997	2005□□
	sd	6.4	3.7

□□ Means are significantly different ($p < 0.01$).

Table options

The rate of establishment of oil palm in Dayun has been relatively constant since 1995 (Fig. 2) but with a significant increase in the last two years. In Sinaboi, oil palm was relatively unimportant until 2000, when the rate of establishment started to increase, with higher rates of land conversion since 2005. In Dayun transmigration is well established; little encroachment occurs because the situation is stable and properties in the area are well guarded — including a fenced off forested area managed by a company for oil extraction. In Sinaboi, deforestation has been driven in part by the declining profitability of local fishing livelihoods in the Malacca Straits as already noted, which has driven households to find alternative sources of income through forest clearing, land acquisition and establishment of palm oil plantations. This turn 'from the sea to the land' has also apparently been encouraged by the head of the district (bupati), who has subsidized the construction of drainage canals at the forest edge, to make land available for development.

Fig. 2.

Conversion of land to palm oil through time in the two study sites.

Figure options

The main reasons for adopting oil palm were better incomes combined with high frequency of harvest (every two weeks), with 53% of respondents, and low labor and maintenance requirements, with 35% of respondents (Table 3). The main constraints to the establishment of oil palm identified in the region were the need to build canals to drain the peatland and the cost of clearing the land (Table 3); both constraints were mentioned by 56% of farmers. The presence of pests and capital availability were also important, with 31% and 37% of respondents citing these. The two main costs of concern were establishment costs and the cost of fertilizer.

Table 3.

Reasons for adopting oil palm and constraints to oil palm establishment in the study area (note: percentages do not add to 100% because many farmers selected more than one reason or constraint).

	%
Reasons for adopting oil palm	
Better/frequent income	53
High yield	14
Easy/low labor/low maintenance	35
Everyone does it	27
Other	16
Constraints to oil palm establishment	
Canal required to drain land (expensive)	56
Pests (mice, pigs, monkeys)	31
Distance to road/poor access	17
Clearing land is expensive	56
Flooding/sea water intrusion	4
Capital availability/costs	37
Seedling availability	4

Table options

Table 4 presents responses regarding clearing permits. The majority of landholders (65%) did not require a permit to clear land. Of the 35% that required permits, only 28% required written permits, with verbal permits being more common (72%).

Table 4.

Land clearing permits.

	Number	%
Clearing permit required:		
No	53	65
Yes	29	35
Total	82	100
If yes, type of permit:		

Verbal	21	72
Written	8	28
Total	29	100

Table options

These responses suggest that smallholder oil palm is a key driver of deforestation in the area, especially given that obtaining permission to clear forest is not a major obstacle. Now we turn our focus to the profits obtained from oil palm and the associated carbon emissions. This then allows us to calculate the opportunity cost of avoided deforestation in the region and to derive a marginal abatement cost curve.

4.3. Economic Analysis

Two key determinants of profit are the yield of oil palm fruit and its price, both of which exhibited high variability among farmers, particularly yield (Table 2). Part of the yield variation is explained by the age of trees, but even after correcting for age there was wide variation in the yields obtained by different farmers (Fig. 3). These yield differences would be explained by management ability, land quality, seedling quality, fertilizer use, pests and diseases, and other variables that were not measured in the survey.

Fig. 3.

Yields of oil palm fresh-fruit bunches (FFB) plotted against age for the two study sites. The predicted lines were obtained by fitting a Gompertz function to the data, with β_1 = 17.9 for Dayun and β_1 = 14.0 for Sinaboi. The parameters $\beta_2 = 1.9 \times 10^{-7}$ and β_3 = 0.83 were common for both sites.

Figure options

The residuals from the nonlinear regression in Fig. 3 are normally distributed (Fig. 4A); they provide an age-corrected estimate of the oil-palm yield variance among the population of farmers in the area. Prices received by farmers for oil palm fruit (Fig. 4B) ranged between Rupiah (Rp) 800 and 1700 per kg, with a mean of Rp 1290/kg.[1] The areas of the farms where land was cleared to establish oil palm (Fig. 4C) ranged from 1 to 18 ha, with a mean of 6.1 ha. This is larger than the mean for the whole sample (~ 5 ha) because this subsample includes only farmers who have converted land to oil palm. There is evidence that large farmers tend to convert full plots to oil palm monoculture, whereas small farmers tend to mix oil palm with other crops (Feintrenie et al., 2010). This means that farm size may affect abatement cost. The number of adults in the household per hectare of farm (Fig. 4D) ranged between 0.1 and 2.8, with a mean of 0.7. This variable is relevant as a proxy for family labor available, a resource that tends to be more limiting than land in Sumatra (Feintrenie et al., 2010 and Rist et al., 2010). Price of oil palm, farm area and adults per ha conform to a lognormal distribution (Fig. 4B, C and D).

Fig. 4.

Cumulative distribution functions for the deviation of palm oil fruit yield from the expected value for the given age of trees (A); price received by farmers (B); farm area (C); and the number of adults per ha of farm in the household. Dots represent observed values and lines are the best-fit probability distributions: Normal in (A) and Lognormal in (B), (C), and (D).

Figure options

Knowledge of the distributions of yield, price, farm size and family labor available, along with their correlation coefficients, allows us to generate a representative population that is statistically consistent with the smallholder sample. The size of the population generated in this way should be based on census data when available. This would allow the potential supply of emission reductions, and area of forest saved, to be estimated for the area of interest at any given carbon price. Given the lack of farm census data for the area, we generated a large sample (1000 farmers) to represent the possible target population for a project involving payments to farmers for not clearing the forest.

Suppose a project involving smallholders is being designed for the Island of Sumatra and assume that the target area is occupied by 1000 farms on the forest margin that still contain a large number of uncleared parcels. Assume that this area is considered to be under immediate threat of deforestation and the purpose of the project is to offer farmers in the area a payment per hectare of land they agree to keep as forest. The maximum amount the project can pay per ha of land depends on both the market price of carbon and the amount of carbon that is conserved per ha of forest. We considered two scenarios, one where the target area consists of peat soils and one dominated by mineral soils.

We derived a discounted cash flow (DCF) for oil palm establishment on each farm in the sample. This allowed us to calculate the net present value (NPV), return to labor (defined as the wage rate that makes NPV = 0) and years to positive cash flow (YPC). A discount rate of 14% was used as a base case; this is within the range experienced by farmers in the area (Rist et al., 2010). For each farm in the population we also generated two sets of CO_2 emission scenarios, one for mineral soils and one for peat soils. Our field study did not include carbon measurements, but relatively reliable estimates of carbon losses from converting forest to oil palm are available in the literature (Germer and Sauerborn, 2008 and Murdiyarso et al., 2010). Table 5 shows the parameters used to generate the farm population. Results were converted to US dollars for ease of comparison with other studies.

Table 5.

Parameter values used to generate the farm population for economic analysis.

Variable	Distribution	μ	σ	Source
Yield deviation	Normal	0.025	6.817	This study
FFB Price	Lognormal	7.146	0.186	This study
Farm size	Lognormal	1.617	0.641	This study
People per ha	Lognormal	− 0.567	0.654	This study
CO_2 emissions over 25 years:				
Peat soil	Normal	1486	183	Murdiyarso et al. (2010)
Mineral soil	Normal	648	337	Germer and Sauerborn (2008)

Table options

Frequency distributions of variables related to economic performance are presented in Fig. 5. These distributions were calculated from the survey results applied to the discounted cash flow model described in the Supplementary materials. The means of the generated data are consistent with the sample means as a result of the Monte Carlo process explained above.

Fig. 5.

Frequency distributions of Monte Carlo results for net present value (NPV) of oil palm production (A); years to positive cash flow (B); returns to labor of oil palm production (C) and CO_2 emissions produced through deforestation for palm oil establishment in two types of soils (D).

Figure options

The marginal carbon abatement cost (MAC) curves generated from these results (Fig. 6) show that the carbon price required to achieve a given level of emission reductions is considerably lower on peat soils than on mineral soils. This is because each hectare of forest conserved on peat soils avoids more than twice the amount of CO_2 emissions as forest conserved on mineral soils. This is a conservative estimate that would apply to relatively shallow peat soils. Depending on depth the carbon content of peat soils could be much higher and therefore result in lower carbon prices (Yamamoto and Takeuchi, 2012).

Fig. 6.

Carbon abatement curve derived from Monte Carlo simulations for the study area with 1000 iterations, each representing a different farm. This represents a total of 4.68 Mt of CO_2e over 6380 ha of land, equivalent to an average of 734 tonnes of CO_2e that could be avoided per hectare by not converting forest to oil palm.

Figure options

4.4. Willingness to Accept Payment for Conserving Forest

A sub-sample of 50 farmers was asked: 'what payment would you be willing to accept in exchange for not cutting forest?'. The question included both quantitative and qualitative components. The quantitative part was elicited in terms of Rupiah per hectare as a one-off payment. The qualitative part was free-form and 32% of responses contained a qualifying statement of some kind. These qualitative statements fell into two broad categories: (i) those who said that in fact they needed a livelihood rather than a payment, and that due to land shortages a compensation payment would not help them; and (ii) those that said that payment was not necessary because forest clearing was illegal anyway. The former response was most prevalent: 24% of all responses in Dayun, and 15% of responses in Sinaboi. Land pressure is highest in Dayun, which explains the difference in responses between the two sites.

Regarding the payment amount, 38 farmers (76%) provided a value and the remaining 12 farmers stated strongly that no payment would convince them to give up on oil palm (Table 6). Of those that would accept payment, seven expressed them as monthly figures, these are equivalent to a salary and were converted to their present value as one-off payments. One-off payments per hectare ranged between Rp 15 million and Rp 600 million, depending on the location and quality of land. Among those farmers that would not accept payment there was a general wish to see widespread establishment of oil palm: in short, no incentive payment for them could compensate for the removal of potential land acquisition and livelihoods.

Table 6.

Results of willingness to accept (WTA) analysis, mean values of selected variables depending on whether farmers would accept payment for not deforesting.

Variable	Would accept payment		
	No	Yes	p > |t|
N. obs.	12	38	
Age	51.58	47.11	0.09
	(2.78)	(1.63)	
Education	2.92	2.76	0.31
	(0.31)	(0.15)	
Household size	4.67	5.66	0.90
	(0.40)	(0.40)	
Dependency ratio	0.77	1.02	0.83
	(0.21)	(0.13)	
Local	0.17	0.18	0.55
	(0.11)	(0.06)	
Off-farm work	0.58	0.45	0.21
	(0.15)	(0.08)	
Farm area	4.82	5.42	0.68
	(1.09)	(0.64)	

Table options

Analysis of results regarding willingness to accept (WTA) payment indicated that there were no significant differences in household characteristics between farmers that would accept payments and those who would not. The only variable for which there was statistical evidence of differences between the two groups was farmer age (at $p < 0.1$). On average, farmers who would not accept payment were older than farmers who would (51.6 vs 47.1).

Two types of regression analyses were undertaken on the WTA data. A logit model to determine whether the probability that a farmer will accept payment is influenced by household characteristics, and an ordinary least squares model (OLS) using the amount of payment requested as the dependent variable (Table 7). The former test expresses WTA as a binary variable and is based on the full dataset (n = 50), whereas the later expresses WTA in $/ha and is based only on the positive observations (n = 38). Results of these analyses indicate no significant effects, except for farmer age in the OLS model (at $p < 0.1$). This supports the results of the t-test between means presented in Table 6.

Table 7.

Regression results of WTA analysis. The logit model expresses WTA as a binary variable (yes = 1, no = 0) whereas the OLS model expresses it as $/ha.

Variable	Logit model[a] (n = 50)	OLS model[b] (n = 38)
Age	− 0.052	413
	(0.14)	(0.06)
Education	− 0.301	2058
	(0.41)	(0.39)
Farm area	0.036	− 320
	(0.70)	(0.52)

a Numbers in parentheses indicate p > |z| for the corresponding coefficient.

b Numbers in parentheses indicate p > |t| for the corresponding coefficient.

Table options

The lack of statistical significance means no firm conclusions can be drawn except that older farmers are less likely to accept a payment, but if they do accept they will tend to demand a higher payment than younger farmers. The lack of significance is partly caused by the small sample and additional data would be required to draw firm conclusions. However, the signs of the coefficients in Table 7 suggest interesting relationships that could be tested using a larger sample. In the logit model, negative coefficients for age and education suggest that older and better educated farmers will reject a payment, whereas a positive coefficient for farm area suggests that farmers with larger properties are more likely to accept payment. In the OLS model the signs of the coefficients are reversed, meaning that for farmers that would accept payments, older and better educated farmers would demand higher payments, whereas farmers with lager areas would be satisfied with lower payments per hectare on average.

Fig. 7 presents the distribution of results for the 38 farmers that would accept payment compared with the NPV values of oil palm, calculated as described earlier, using two different discount rates.

Fig. 7.

Willingness to accept (WTA) payment stated by smallholders in study area to give up on the opportunity to plant oil palm in forested areas and the net present value (NPV) of oil palm establishment calculated at two discount rates (5% and 14%) based on survey data. Approximately 30% of farmers stated that they were not willing to accept any payment.

Figure options

The WTA values stated by farmers were consistently higher than the NPV values calculated at a discount rate of 14%, the base rate used in the analysis. Reducing the discount rate increases NPV because future profits have higher present values. With a discount rate of 5% the calculated NPV curve is closer to the WTA curve (Fig. 7) at least for 60% of farmers in the sample. However, it is unlikely that these farmers would have such a low discount rate given that the cost of credit they face and other factors may influence their decision (see discussion below).

5. Discussion

5.1. Opportunity Cost of Avoided Deforestation

The opportunity cost of avoided deforestation should be measured relative to the most profitable alternative activity for a particular parcel. Our analysis indicated that oil palm is the most profitable activity for smallholders in the forest margins of Sumatra. Oil palm has a high return to land as well as a considerable advantage over rubber and other crops in terms of returns to labor (Feintrenie et al., 2010 and Rist et al., 2010). Therefore, the opportunity cost of not planting oil palm represents the minimum payment that should be acceptable to a farmer that has perfect information about expected returns of land-use change. In reality, some farmers may be willing to accept incentives that are less than the formal opportunity costs for a range of reasons (Milne and Niesten, 2009), including imperfect information.

Our results are within the range of opportunity costs of avoided deforestation reported in the literature for farmers in developing countries; e.g. \$2.85/t CO_2e in Cameroon, discounted at 5% (Bellassen and Gitz, 2008) and \$4.21 in Indonesia, discounted at 10% (Yamamoto and Takeuchi, 2012). Other studies in Indonesia have reported higher values for oil palm companies and governments. Venter et al. (2009) estimated opportunity costs for oil palm companies at 9.85–33.44 \$/t CO_2e in mineral soils and 1.63–4.66 \$/t CO_2e on peat soils, discounted at 8%. Irawan et al. (2013) estimated these costs at \$18.51 and \$7.75 respectively (at a discount rate of 10%) when considering the opportunity costs to both companies and government. These results compare to \$3.11, \$5.13 and \$12.08 for mineral soils and \$1.06 \$1.73 and \$4.04 for peat soils in our study, when discounted at 14%, 10% and 5% respectively. Warr and Yusuf (2011) estimated that 1.2 million ha of avoided deforestation could be achieved at a cost of US\$1.08/tCO_2e in Indonesia.

The results of our economic analysis are consistent with other reports for the region. Smallholder oil palm systems in the province of Jambi, also on the Island of Sumatra, had a return to labor of ~\$47 per day (Rist et al., 2010), compared with \$49.5 per day in this study. This is important because labor is scarcer than land in the area and farmers tend to go for the crop that provides the highest return to labor.

5.2. Marginal Abatement Cost

The opportunity cost estimates reviewed above are average values. A more realistic measure of the potential mitigation that can be achieved for any given carbon price is provided by the MAC curve, which reflects the heterogeneity of the farmer population. As expected, the MAC curve for peat soils was found to be below and to the right of the MAC curve for mineral soils (Fig. 6). This indicates that, ceteris paribus, peat soils would provide a better return on investment of REDD + funds than mineral soils. For example, at a price of \$3/tCO_2e, a total of 8.8 Mt of CO_2e could be obtained in peat soils over 25 years, compared to 3.1 Mt in mineral soils (compare points a and b in Fig. 6). An alternative way of looking at the difference between soils is that 3.1 Mt of CO_2e could be purchased at \$3 on mineral soils but would cost only fifty cents on peat soils (compare points b and c in Fig. 6). Although there may be differences in establishment costs and yields between the soil types that were not considered here, this illustrates the higher returns on investment of REDD + funds in peat soils.

The MAC curves presented here do not consider the transaction costs involved in managing the scheme, monitoring and certifying emission reductions and other activities (eg. Cacho et al., 2005 and Cacho et al., 2013). Introducing transactions costs would cause both MAC curves in Fig. 6 to shift upwards, meaning that the actual cost of mitigation would be higher than indicated by abatement cost alone. However, the relative cost of abatement should not be affected unless transaction costs differ between soil types.

5.3. WTA Analysis

The payments requested by farmers can be interpreted as the value they place on land, as accepting payment means giving up on the option of using land to generate profits other than those that can be obtained from standing forest, which is generally publically held. In a competitive land market, the value of land is given by the NPV of its most profitable use, which in this case is oil palm. Comparison of the NPV curve with the willingness to accept values stated by farmers (Fig. 7) indicates that farmers value land beyond just its profit-generating capacity. However, a tendency to overstate willingness to accept values may have influenced household survey responses in an attempt to bid up the price in advance of a possible transaction.

It is well known that opportunity cost is only a starting point for assessing the potential cost of REDD + projects in particular areas. Practical, political and ethical factors all come into play when setting payments for avoided deforestation, meaning that they often diverge from opportunity costs (e.g. McKinsey and Company, 2009 and Milne, 2012). Other costs also need to be considered in REDD + design, such as the transaction costs of implementing and managing complex payments schemes across scales (Cacho et al., 2013).

Perhaps the most critical issue, however, is that the perceived opportunity cost on the part of the recipient of compensation may differ significantly from the actual cost, which typically accrues to a range of actors across spatial scales (Busch et al., 2012 and Gregersen et al., 2010). In particular, a farmers' private opportunity cost does not reflect the full cost of achieving regional and/or country-wide emission reductions. This issue applies especially to governments that receive not only taxes from plantations but also taxes and fees for forest clearing, both legal and illegal. Irawan et al. (2013) observe that revenues obtained by the three levels of government in Indonesia (National, Provincial and District) from deforestation mean that, in restricting timber extraction and land conversion, REDD + activities can impose significant opportunity costs not only on landholders but also on governments. This creates tremendous barriers to policy implementation. Recent advances in the spatial modeling of economic incentives (Busch et al., 2012) could help design more targeted payments to overcome this problem, at least to some extent, for example by compensating local governments that have large areas of forested peatlands.

It is interesting to compare the minimum payments estimated by the model in Fig. 6, with the actual payments as indicated by farmers in Fig. 7. To translate the amount requested by farmers per ha of land into a carbon price requires knowledge of the soil type, with requested payments being higher for mineral soils than for peat soils (Fig. 8). The maximum price presented in Fig. 6 is \$10/tCO_2e. This is towards the lower end of payments requested by farmers per ha of land in Fig. 8. A payment of \$10/tCO_2e would satisfy 50% or less of the farmers in the area, depending on soil type.

Fig. 8.

Carbon price required to pay farmers the requested amount based on the type of soils on the farm and based on WTA values stated by farmers in survey.

Figure options

Using high resolution satellite data Miettinen and Liew (2010) estimated that 5.1 million ha of peatswamp forests have been converted to non-forest land since 1990 in Indonesia and Malaysia alone. These areas produce more than 300 Mt of CO_2 emissions per year from peat decomposition alone, which is equivalent to emissions produced from burning fossil fuels in countries such as Australia and Poland. Clearly, stopping deforestation of peatlands should provide a high payoff to REDD + investments as suggested by the opportunity costs in our analysis.

5.4. Policy Implications

Comparing the MAC curve of mineral soil with that of peat soil (Fig. 6), suggests that a land-swap policy that offers farmers on peat soils the option to move to land on mineral soils, before they clear the forest, could save a considerable amount of carbon emissions, even without reducing the rate of conversion to oil palm. This policy may be feasible if (1) enough land is available in areas with mineral soils to replace farms on peat soils, and (2) there are no cultural or other socio-economic reasons why farmers would refuse to move if offered an incentive. The fact that a large proportion of farmers migrated into the area suggests that their attachment to the land may not be a significant obstacle to a land-swap policy. However, this immigration occurred mainly in the 1980s and other barriers to the land-swap idea now exist, including: (1) the fact that most farmers own multiple plots of established farmland around their villages, which they would be unlikely to sell or abandon willingly; (2) the acquisition of forestland for new palm oil plantations is often opportunistic and illegal, aimed at enhancing livelihoods and profits, rather than meeting basic needs (e.g. Galudra et al., 2013); and (3) in Sumatra, especially Riau, the mineral soils are now all cleared of forest and held in private hands (e.g. Santosa et al., 2012).

These processes mean that, although we chose to focus on smallholders as on-the-ground decision makers and agents of deforestation, we must acknowledge that they operate alongside or in the wake of other land-use change processes, such as establishment of concessions, plasma-nucleus estates and other smallholders schemes or less formal land acquisition processes influenced by company and/or state interests (Galudra et al., 2013 and Potter, 2012). These plantation forms often incorporate historical transmigration schemes (Feintrenie et al., 2010), and present an array of modes of 'inclusion' both adverse and beneficial into market and property processes (McCarthy, 2010).

REDD + policy makers must therefore consider factors associated with government and corporate investment that encourage the adoption of oil palm on peat soils. For example, given that oil palm fruit has to be processed within 48 h of harvest (Feintrenie et al., 2010), the presence of a mill and easy transportation means for harvested fruit in the region are prerequisites for oil palm establishment. The expansion of palm oil therefore depends upon road and mill construction — both processes that are well beyond the control of smallholders. Similarly, investments in peatland drainage are also required to stimulate the expansion of palm oil. Our research suggests that district heads can play an important role in this by building the first canal through the peatlands, using public funds. Subsidiary or connecting canals are then built by smallholders into the forest, leading to encroachment for new plantations. Given these factors, a policy that prohibits oil palm mills being established within a certain distance of peatlands could be a useful component of a policy package to reduce emissions from deforestation, possibly in combination with a ban on local government support for peatland drainage. Such measures could help to address the perverse and hidden incentives that hamper REDD + implementation in Indonesia, given the powerful vested interests that benefit from forest clearing and palm oil expansion (Brockhaus et al., 2012).

In more forested contexts, beyond Sumatra, another argument against land-swap policies is that they may cause increased forest loss on mineral soils than would have occurred otherwise. So no reduction in the rate of forest loss is achieved even though carbon emissions are reduced. This is a form of leakage that can be measured as the difference in emissions per hectare between peat soils and mineral soils.

In contrast, a land-swap based on mineral soils that are already deforested would reduce the total deforestation rate as well as reducing carbon emissions. There are large areas of degraded land in Indonesia (Wicke et al., 2011) that potentially could be restored using REDD + funds. Establishment of oil palm in these areas may be more expensive than clearing forest, and yields may be lower without use of fertilizer and/or soil restoration. Given the low carbon prices indicated by MAC curves in our analysis, it seems sensible that some REDD + funds could be used to help restore degraded land by covering the difference in costs of oil palm establishment between peatland and degraded mineral land for farmers willing to move. Two questions need to be addressed, however. The first is whether areas of degraded lands are actually already used by local people; and the second is whether displacement of farmers from peatland would actually reduce the likelihood of palm oil expansion into those areas, given the other interests, drivers and incentives at play (e.g. see Swarna and Tisdell, 2009).

Another obstacle in enabling REDD + in countries such as Indonesia is the extent to which public forests are affected by illegal logging and land clearing. Even when forests are officially protected through reserves, deforestation and encroachment are rarely controlled, due mainly to weak law enforcement (Gaveau et al., 2009). The problem of whether small-holders should receive compensation for ceasing illegal forest clearing requires further analysis and will likely require context-specific solutions. For example customary laws and practices need to be accounted for, and the beneficiaries of agricultural expansion need to be identified and scrutinized. This should enable an assessment of the legitimacy of smallholder land-clearing actions, as opposed to their legality, which may be contested.

Finally, an important issue that arises from farmer comments is what to do with the labor that is freed up by payments not to cultivate oil palm when there are no alternative employment opportunities in the area and there is little availability of non-forested land for palm oil production. Bottazi et al. (2013) suggest that local labor resources freed up by REDD + payments could be redirected to conservation actions rather than remaining idle. This would represent a cost of the implementation of the REDD + and in most cases would need to be subtracted from revenues that are derived from carbon sales.

6. Concluding Comments

The derivation of marginal abatement cost (MAC) curves has become standard procedure in climate policy analysis. MAC curves are useful because they represent the potential supply of carbon mitigation at any given price. Consistent with some other studies in developing countries, we found that the opportunity cost of avoided deforestation from smallholders' activities is less than $5 per tonne of CO_2e in areas of Sumatra where deforestation is driven mainly by oil palm. Although this is useful information for project design, there are other factors that need to be considered in translating global REDD + policies to the local level, especially when smallholders are involved. An interesting issue that arises from this study is that farmers may value their land, or potential access to forested land, beyond its profit-generating capacity and therefore carbon payments required to conserve forest may be higher than suggested by opportunity costs alone. Our data do not provide the means to understand the reasons behind these responses, except anecdotally. A follow-up survey would be required to provide quantitative evidence behind the decision to participate in projects for forest conservation, whether for carbon mitigation or other ecosystem services. However, our results in combination with evidence from the literature suggest that REDD + implementation is not just a matter of “getting the payments right” but must include a whole policy package.

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Appendix A. Supplementary data

Supplementary material.

Help with PDF files Options

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1 At the time of the survey, the exchange rate was US$ 1:Rupiah 8621.