LETTER

Carbon payments as a safeguard for threatened tropical mammals

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Abstract

One reason for the rapid loss of species-rich tropical forests is the high opportunity costs of forest protection. In Kalimantan (Indonesian Borneo), the expansion of high-revenue oil palm (*Elaeis guineensis*) plantations currently threatens 3.3 million ha of forest. We estimate that payments for Reduced Emissions from Deforestation and forest Degradation (REDD) could offset the costs of stopping this deforestation at carbon prices of US$10–33 per tonne of CO_2, or $2–16 per tonne if forest conservation targets only cost-efficient areas. Forty globally threatened mammals are found within these planned plantations, including the Bornean orangutan (*Pongo pygmaeus*) and Borneo pygmy elephant (*Elephas maximus borneensis*). Cost-efficient areas for emissions reductions also contain higher-than-average numbers of threatened mammals, indicating that there may be synergies between mitigating climate change and conserving biodiversity. While many policy and implementation issues need clarification, our economic assessment suggests that REDD could offer a financially realistic lifeline for Kalimantan's threatened mammals if it is included in future climate agreements.

Introduction

Tropical deforestation is a major driver of the current human-induced biodiversity crisis (Whitmore & Sayer 1992). Indonesia has been at the center of tropical deforestation, clearing 1.8 million ha per year through the 1990s, more than any other country except Brazil (FAO 2006). Since then, its rate of deforestation has increased from 1.7% to 2% per year (FAO 2006). High species endemism and rapid deforestation have caused most of Indonesia to be classed as a biodiversity hotspot (Myers *et al.* 2000). Today, much of Indonesia's deforestation occurs in Kalimantan (Indonesian Borneo), where oil palm (*Elaeis guineensis*) plantations are expanding at the expense of native forests (Koh & Wilcove 2008). Monocultures of oil palms do not provide viable habitat for most forest-dependent species and their establishment in forested areas causes the local extinction of many species (Fitzherbert *et al.* 2008). In Kalimantan, oil palm drives deforestation both as the primary motive for deforestation and as a partner to a timber and pulp industry that seeks access to timber revenues from clearfelling forests as the first step in plantation development (Fitzherbert *et al.* 2008).

Conservation organizations are working hard to protect tropical forests from the industries that threaten them, often using charismatic species of mammals such as the orangutan (*Pongo pygmaeus*) to harness public support and generate money for conservation. Still, the rate of conversion of Indonesia's forests to other land uses is accelerating (Sodhi *et al.* 2004). At present, there are insufficient funds to protect Indonesia's forests from conversion to production landscapes (Curran *et al.* 2004; Koh & Wilcove 2007).

In Indonesia, as in other developing countries, payments for Reduced Emissions from Deforestation and forest Degradation (REDD) could slow deforestation and help safeguard threatened forest species. REDD is a proposal to provide financial incentives for developing countries that voluntarily reduce national deforestation rates and associated carbon emissions below a reference level (Gullison *et al.* 2007; UNFCCC 2007). Countries may be compensated either through a grant funding mechanism or through the sale of carbon credits on international carbon markets (Gullison *et al.* 2007; Ebeling & Yasue 2008). REDD has considerable potential in Indonesia, which is the world's largest emitter of land-based greenhouse gases, releasing almost twice the amount as the second greatest source, Brazil (Houghton 2003). REDD is not part of the Kyoto Protocol's Clean Development Mechanism, which restricts the mechanism to voluntary carbon markets. However, at the United Nations Climate Change Conference in Bali (December 2007) climate policy makers supported REDD as an emissions reduction strategy (UNFCCC 2007)—a move that will help grant access to regulatory markets under a post-2012 climate agreement.

Recent commitments from the World Bank ($165 million), Norway (more than $2.5 billion), and Australia ($200 million) are providing funding to develop REDD programs and the necessary organizational structures. Still, revenues from forest conversion and the development of agro-industrial or silvicultural plantations are high, providing a rapid path to economic development. It remains unclear what scale of incentives will be needed to convince tropical nations to incur the opportunity costs (the perceived foregone profit) of protecting forests from conversion into production landscapes. Furthermore, while it is widely hoped that REDD will also provide benefits to threatened biodiversity (Miles & Kapos 2008), these cobenefits are yet to be determined and biodiversity remains largely external to the negotiations shaping the REDD mechanism.

Here we determine if a REDD mechanism has the financial capacity to stop planned deforestation for oil palm in Kalimantan, and measure the biodiversity outcomes of doing so. To do this we first determine the extent to which planned oil palm plantations threaten forests, forest carbon, and forest biodiversity in Kalimantan. For our measure of threatened forest biodiversity we focus on globally threatened (*Critically Endangered*, *Endangered*, and *Vulnerable*; IUCN 2008) mammals, as distributional data are publicly available for this taxon (www.ieaitaly.org/samd). We focus on the economic potential of REDD, though policy, implementation, and monitoring issues will also influence the capacity for REDD to protect threatened forests.

Methods

We investigated the relationships between the carbon, biodiversity, and production values of forests planned for conversion to oil palm in five steps. First we mapped future deforestation for oil palm using a 2006 map of planned and ongoing oil palm developments (Ramdhani & Taufik 2006) overlaid with a high resolution (300 m) land cover map (ESA 2008) where forest was considered as all natural terrestrial vegetation >5 m in height and with >15% canopy cover. Using a map of peat forest (Wahyuntok *et al.* 2004), we then determined the area of threatened forest on peat and mineral soils. Next, we used validated distribution models of 1077 Southeast Asian mammals (www.ieaitaly.org/samd), defining species as residing in Kalimantan and threatened forests if areas that were modeled as highly suitable lie within Kalimantan and threatened forests, respectively (Catullo *et al.* 2008). Then, we estimated the CO_2 emissions that would result if land clearing and oil palm developments go ahead. Finally, we calculated the carbon prices necessary to prevent this deforestation. Due to uncertainties surrounding how land-use decisions will be made and how costs will accrue to the palm oil industry, we calculated a range of carbon prices based on two scenarios of compensation (high and low) and two scenarios of oil palm development (high and low).

To estimate the emissions associated with conversion of Indonesian lowland tropical mineral and peat rainforest to oil palm plantations, we used the same data as Fargione *et al.* (2008) supplemented by additional data on carbon stores and fluxes (see Table S1) and a forest carbon map (Ruesch & Gibbs 2008). We considered the following emission sources: (1) decomposition of forest timber products, (2) burning of unharvested aboveground vegetation, (3) decomposition of unburned above and below ground vegetation, (4) peat oxidation and (5) the increased probability of peat burning. See Appendix S1 for our full carbon accounting methods. As the policy surrounding the REDD mechanism is still under development, we cannot be sure that our methods for calculating carbon emissions will not differ from those used when implementing the REDD mechanism. We therefore caution that our study's emissions estimates should be considered indicative and updateable.

The carbon price required to change land-use trajectories will be related, but not necessarily equal to the opportunity cost of foregoing development. For example, in 2007 Ecuador publicly offered to forgo mining their largest untapped oil reserve, if compensated at a rate of 50% of expected oil profits. Decisions such as this may be motivated by knowledge that conservation payments ensure the provision of ecosystem services and may be paid to governments, which can direct these revenues to socially beneficial uses such as education, health care, and alternative economic development. Reflecting this, we calculated the carbon price necessary to alter land-use decisions under two payment scenarios: (1) the full opportunity cost must be met, as may be the case if oil palm companies lead land-use decisions, and (2) 50% of the opportunity costs must be met.

In Kalimantan, much of the land cleared for oil palms is not subsequently planted (BisInFocus 2006). We used an oil palm suitability map (FAO 2008), and two oil palm planting scenarios to determine the expected revenues from oil palm. First, under our "high oil palm" scenario, all plantations on land mapped as marginally to highly suitable for oil palm (2.28 million ha) are planted after forest clearing and second, under our "low oil palm" scenario only land of higher suitability (moderate to highly suitable; 0.75 million ha) is planted with oil palms. The lower costs to the oil palm industry under the "low oil palm" scenario may reflect a low baseline development scenario, or the case where oil palm planned on marginal land is instead diverted to already degraded land elsewhere in Kalimantan.

We determined the opportunity costs to the timber and oil palm industry by calculating the net present value (NPV) of expected timber and oil palm revenues. NPV was calculated using 30 years of net annual revenues, which were extracted from the scientific literature and company financial reports (see Table S1 and Appendix S1), discounted using a discounting rate of 8%. We assumed that deforestation occurs over the planning horizon of district governments (5 years) and that oil palms, which take 5 years to mature and have a productive life of 20 years, are planted over the first 5 years following deforestation (see Bowen *et al.* 1999). Our estimates of palm oil profits are for large, well-run plantations that also generate revenue by processing palm fruit and producing secondary palm oil products.

When calculating the carbon price required to alter land-use decisions, we include estimates of the transaction costs of REDD in the price of carbon (Table S1) and assume that carbon payments will be made in the year that emissions would have occurred (see Appendix S1). Our carbon prices have not been adjusted by the proportion of emissions reductions that are "leaked" into other countries as increased emissions from deforestation there (Murray 2008). Early evidence suggests that without policy interventions between 48% and 76% of emissions reductions could leak into other countries (Murray *et al.* 2004; Gan & McCarl 2007). However, there are a range of policies to reduce leakage (reviewed in Murray 2008), in particular increasing developing country participation could reduce leakage to near zero (Murray 2008). As an upper bound, leakage adjustment may increase the carbon prices presented here by four times (Gan & McCarl 2007). All figures are converted to 2007 USD using the United States consumer price index (www.bls.gov).

Results

We found that there are 8.09 million ha earmarked or undergoing oil palm development in Kalimantan (Figure 1), of which 3.34 million ha is forested, 0.38 million ha is peat forest with the remainder on mineral soils. Forty of Kalimantan's 46 threatened mammal species are found within the area of planned oil palm developments, and therefore directly impacted (Appendix S1). None of these mammals have their entire range within the threatened forests. On average, plantations threaten 5.9% of a species range. The Borneo pygmy elephant will be most heavily impacted, with 31% of its Kalimantan distribution affected. Oil palm threatens 750,000 ha of orangutan forest, or 5.5% of the Bornean orangutan distribution.

Based on spatially explicit emissions estimates, we calculate that in the 30 years following development, mineral soil forest cleared for oil palm releases on average a net 389 ($\pm$ 246 SD) tonnes of CO_2 per ha from the decomposition and burning of forest vegetation and wood products (Figure 2). Cleared and drained peat swamp forest will release on average 2249 ($\pm$ 388 SD) tonnes of CO_2 per ha (Figure 2). We calculate that if all oil palm developments go ahead, 2.1 billion tonnes of CO_2 will be released into the atmosphere over the next 30 years.

We estimate that the oil palm developments will generate a NPV of $16.6 billion from the initial timber harvest and palm oil profits under a high oil palm baseline scenario, and a NPV of $10.7 billion under a low oil palm scenario. To change land-use decisions under our scenarios of oil palm development and compensation, REDD will need to compensate avoided emissions at a carbon price varying from $9.85 to $33.44 per tonne of CO_2 (Table 1). There is considerable spatial variation in the cost of carbon and targeting low-cost areas could reduce the price of carbon. By targeting only peat areas, the cost drops to a range of $1.63 to $4.66 per tonne of CO_2 (Table 1). If the cheapest 50% of mineral areas were targeted, the cost would range from $5.02 to $15.56 per tonne of CO_2. Our carbon prices are fairly robust to variation in the discounting rate, varying by a maximum of 9% as we changed the discounting rate from 6% to 10%.

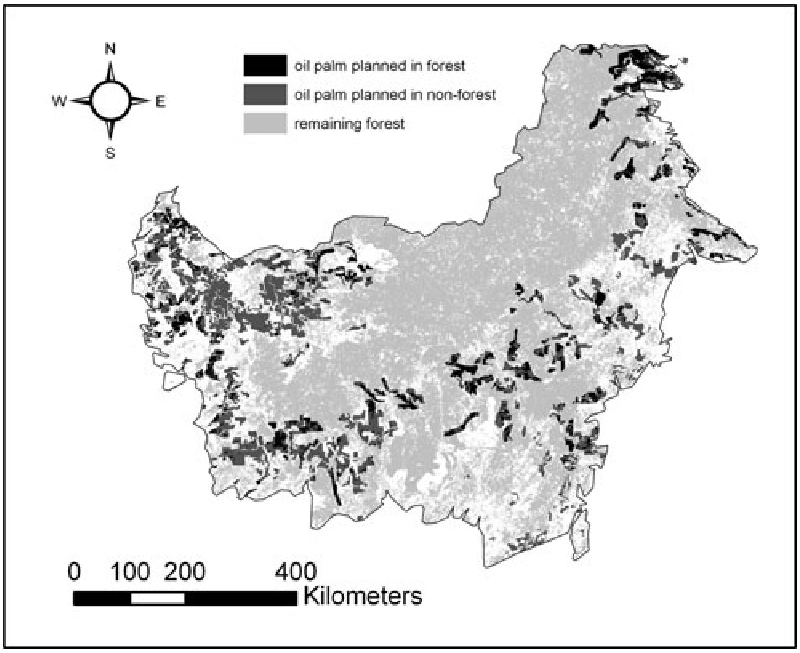

Figure 1 Map of Kalimantan showing the extent of forest and planned oil palm plantations within forest habitat and in nonforest. The map is developed using a 2006 map of planned and ongoing oil palm developments (Ramdhani & Taufik 2006) overlaid with a high resolution (300 m) forest cover map (ESA 2008).

If all forests cannot be protected, there may be synergies between prioritizing for carbon and biodiversity. We found that carbon priorities, defined as the 50% of plantations where carbon is the cheapest, contain on average almost twice the number of threatened mammals per km^2 as nonpriorities (mean = 10.5 and 5.4, respectively; $t = 10.2$, df = 806, $P < 0.001$). We also found that planned plantations harboring orangutans or elephants (29% of plantations), the conservation priority of many conservation NGOs working in Kalimantan, store more forest carbon per ha than plantations without these species (mean = 168 and 136 tonnes, respectively; $t = 9.15$, df = 806, $P < 0.001$).

Discussion

By modeling the economics of oil palm versus REDD, a recent article published in this journal (Butler *et al.* 2009) concluded that REDD could compete financially only if carbon credits were sold on the compliance markets of the Kyoto Protocol, or its post-2012 successor. At present, carbon sells for around \$2 per tonne of CO_2 on voluntary

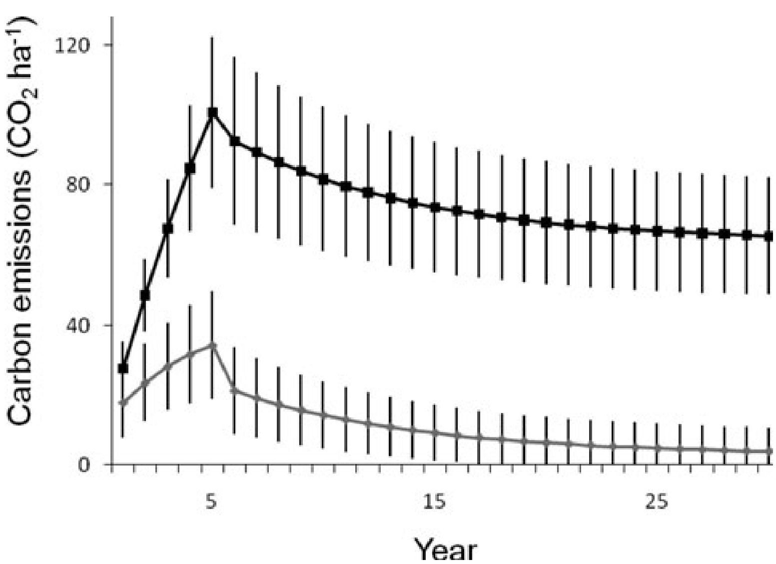

Figure 2 Annual CO_2 emissions from oil palm development on Kalimantan tropical mineral soil rainforest (♦) and peat swamp rainforest (■). Means and standard deviations are based on spatial estimates of carbon emissions and represent the spatial variation in emissions. The early increase in emissions is due to the assumed delay in deforestation.

Table 1 The carbon price required to compensate for avoided emissions from planned oil palm plantations under a high and low oil palm development scenario, and a high and low compensation scenario. All values are in 2007 USD

Compensation	High oil palm	Low oil palm
High (100%)	33.44 (4.66*)	19.62 (3.16*)
Low (50%)	16.77 (2.37*)	9.85 (1.63*)

*Values are average carbon prices for plantations predominantly on peat soils.

markets (www.chicagoclimatex.com), and around $30 on Kyoto compliance markets. Our analysis estimates that stopping deforestation for oil palm in Kalimantan would cost between $10 and $33 per tonne of CO_2, confirming the findings of Butler *et al.* (2009), though even at voluntary prices we found that REDD could compete with oil palm in carbon-rich peat forests (Table 1). It appears likely that a post-2012 climate agreement will include a REDD mechanism (UNFCCC 2007). Like Butler *et al.* (2009), we urge that REDD methods and policy is finalized in time to include REDD in future climate agreements, as this will increase its economic competitiveness and potential to contribute to climate mitigation and forest conservation.

Our article builds on previous analysis by providing a quantitative link between REDD and biodiversity conservation. We found that over 3 million ha of Kalimantan's 27 million ha of forest habitat (Fuller *et al.* 2004) is currently threatened by planned and ongoing oil palm plantations. We discovered that 40 of Kalimantan's 46 threatened mammals occur within areas slated for oil palm developments (2% to 31% of their Kalimantan range). REDD is unlikely to abate all threats to Kalimantan's mammals, especially threats such as poaching or introduced species, but stopping the conversion of forests into monocultures of oil palm would be a major success for conservation.

To protect forests, REDD investments are likely to focus initially on areas where emissions reductions are cheapest. In our case, these areas are also good for conserving threatened mammals. Planned oil palm plantations where carbon is cheapest contain almost twice the mammal species density as more expensive areas. However, this sort of win–win scenario may not always be the case. For instance, a global analysis suggests that at the global scale, REDD priority areas rank low in measures of biodiversity (Ebeling & Yasue 2008). In Kalimantan and elsewhere, specific steps could encourage forest protection to occur in areas and address threats that deliver biodiversity outcomes. In particular, we recommend that biodiversity agencies collaborate with REDD program developers in the planning, funding, and implementation of forest protection. Aside from ensuring that biodiversity outcomes are explicitly considered, the contributions that biodiversity agencies make could lead to an overall strengthening of REDD programs. For instance, with over $6 billion spent each year on conservation (James *et al.* 1999), biodiversity agencies have substantial funds to help develop REDD programs. Also, biodiversity agencies have valuable expertise in spatial prioritization, stakeholder involvement, park enforcement, and effectiveness monitoring. In addition to this sort of collaboration, biodiversity outcomes could be encouraged by explicitly recognizing the potential for REDD to provide biodiversity cobenefits in a post-2012 climate agreement, though this may add complication to an already difficult set of negotiations.

To determine if REDD has the potential to protect forests threatened by oil palm, our study focused on the economics of oil palm versus REDD. There is evidence that presenting decision makers with the economic value of standing forests has in the past swayed land-use decisions in Kalimantan (see Naidoo *et al.* 2009). Still, issues of how to design effective policies for implementing the REDD mechanism will also present formidable challenges. Some of these issues, such as setting meaningful emissions "baselines," minimizing and accounting for leakage, and monitoring emissions reductions to ensure that they are real and lasting, are general to all countries and have been reviewed elsewhere (e.g., Angelsen 2008; Ebeling & Yasue 2008). Some issues may be more specific to Kalimantan, though by no means endemic. We feel that it will be particularly important to determine how best to allocate both REDD responsibilities and funds among national and regional governments, oil palm companies, and local communities to maximize the mechanism's efficiency and equity. Also, long-standing land tenure issues of forested and degraded lands will need to be resolved (Majid 2006). Clarifying the tenure of degraded lands will make it possible to grant "permit swaps," which trade oil palm permits on forested land for permits on degraded land and reduce the opportunity costs to the oil palm industry. Finally, forest conservation will need to be effectively enforced, a task which has proved elusive in the past (Curran *et al.* 2004). Resolving these issues will be no small task, but we are hopeful that a concerted effort by Indonesia, aided by capacity building and technology transfer, will ensure that REDD's strong financial incentives are realized.

Based on estimates of carbon and development revenues, we have shown that REDD payments may have the financial capacity to fund the protection of forests and forest mammals threatened by oil palm, especially if included on compliance carbon markets. This study has focused on a local and industry-specific example, but we feel that efforts to mitigate climate change through a well-designed REDD mechanism could offer a compelling life-line for many of the world's most biodiverse areas.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1: Input data for conversion of Indonesian tropical mineral and peat soil rainforest to oil palm plantations.

Appendix S1: Latin names of threatened mammals considered in this study, their category of endangerment and their modeled area of occupancy within Kalimantan and areas planned for conversion to oil palm plantations.

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