LETTER

REDD in the red: palm oil could undermine carbon payment schemes

Rhett A. Butler[1], Lian Pin Koh[2], & Jaboury Ghazoul[2]

[1] Mongabay.com, P.O. Box 0291, Menlo Park, CA 94026, USA
[2] Institute of Terrestrial Ecosystems, ETH Zürich, Universitätstrasse 16, Zürich 8092, Switzerland

Keywords
Biodiesel; biodiversity; biofuels; climate change; Southeast Asia.

Correspondence
Lian Pin Koh, Institute of Terrestrial Ecosystems, ETH Zürich, Universitätstrasse 16, Zürich 8092, Switzerland. Tel: +41 44 632 6836; fax: +41 44 632 1575. E-mail: lian.koh@env.ethz.ch

Received: 23 September 2008; accepted 17 December 2008

doi: 10.1111/j.1755-263X.2009.00047.x

Abstract

Mechanisms to reduce carbon emissions from deforestation and forest degradation (REDD) have been gaining momentum as a way to combat global warming, fund forest conservation, and deliver economic benefits to rural populations. However, the economic viability of REDD schemes will depend on the profitability of alternative land uses. Oil palm agriculture has become a major driver of tropical deforestation over the last few decades. Here, we model and compare the profitability of converting forest to oil palm versus conserving it for an REDD project. We show that converting a hectare of forest for palm oil production will be more profitable (yielding net present values of $3,835–$9,630) to land owners than preserving it for carbon credits ($614–$994), which are currently restricted to voluntary carbon markets. Giving REDD credits price parity with carbon credits traded in compliance markets would boost the profitability of avoided deforestation (up to $6,605). Unless post-2012 global climate policies legitimize the trading of carbon credits from avoided deforestation, REDD will not be able to compete with oil palm agriculture or other similarly profitable human activities as an economically attractive land-use option, in which case REDD will not be able to fulfill its primary function of avoiding deforestation.

Introduction

Tropical deforestation is both a major source of carbon dioxide emissions and a leading cause of species extinctions (Page *et al.* 2002; Ramankutty *et al.* 2007; Sodhi *et al.* 2007). Financial mechanisms to reduce carbon emissions from deforestation and forest degradation (REDD) have been proposed to compensate land owners, organizations, or countries for the value of carbon stored in forests that would otherwise be released into the atmosphere by deforestation (Myers 2007; Nepstad *et al.* 2007; Miles & Kapos 2008; United Nations Framework Convention on Climate Change 2008). Additionally, carbon credits generated from this mechanism can be a potential source of income to drive forest conservation in developing countries (Laurance 2006; Tollefson 2008). However, REDD faces several political and technical challenges, including concerns over national sovereignty and land rights of forest users (e.g., indigenous communities); system "leakages" (when conservation measures in one area displace deforestation or forest degradation to another); and the establishment of appropriate deforestation baselines (Myers 2007; Miles & Kapos 2008). Owing in part to these unresolved issues, REDD is not sanctioned under the clean development mechanism (CDM) established by the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) (United Nations Framework Convention on Climate Change 2001). As such, carbon credits from avoided deforestation projects cannot be purchased by industrialized nations for meeting internationally mandated emissions targets. Instead, REDD credits can only be traded on voluntary markets (e.g., Chicago Climate Exchange; www.chicagoclimatex.com) or paid for using designated carbon funds (e.g., Forest Carbon Partnership Facility [FCPF] of the World Bank; carbonfinance.org), where carbon prices are substantially lower and less responsive to price fluctuations in competing commodities than are those in compliance markets. Therefore, the economic viability of REDD schemes and their adoption by those who would be investing in such projects are dependent on both the eligibility of REDD for the CDM after 2012 when the first commitment period of the Kyoto Protocol will expire, as well as the profitability of alternative land uses.

Oil palm agriculture (*Elaeis guineensis*) deserves special attention because over the past few decades it has become a major driver of deforestation in the tropics (Fitzherbert *et al.* 2008; Koh & Ghazoul 2008; Koh & Wilcove 2008a, b). The global land area under oil palm cultivation has more than tripled since 1961 to over 13 million ha (Food and Agriculture Organization of the United Nations 2008). This crop is most extensively planted in Indonesia and Malaysia, which are currently the world's largest producers of palm oil—exporting a combined total of 28.6 million tons of crude palm oil (CPO) in 2007–2008 (Food and Agriculture Organization of the United Nations 2008). In these two countries, more than half of oil palm expansion since 1990 has come at the expense of forests (Koh & Wilcove 2008a). The spread of oil palm has been accompanied by a doubling in CPO prices, from $478 per ton in 2006 to $1,196 per ton in the second quarter of 2008 (World Bank 2008a). Because most of the CPO traded internationally is imported by emerging economies such as China (6.2 million tons in 2007–2008), India (4.9 million tons), and Pakistan (2.5 million tons)—82.3% of which is used by the food processing industry (United States Department of Agriculture—Foreign Agricultural Service 2008)—palm oil price trends are closely tied to those of other vegetable oils, such as soybean (Figure S1). The diversion of large swaths of agricultural land in the United States to produce energy crops (e.g., maize, *Zea mays*), coupled with rising food demand from developing countries (e.g., China), and rising crude oil prices (leading to higher food production, processing, and distribution costs), have synergistically contributed to the rise in price of food crops worldwide, including vegetable oils (World Bank 2008b). As such, the price of palm oil is heavily influenced by global market trends of both food and energy commodities (Figure S1). In this article, we investigate whether high palm oil prices could undermine REDD schemes in the tropics by comparing the returns of oil palm operations to profit models for early stage REDD projects.

Material and methods

We based our analysis on a hypothetical 10,000 ha concession of old-growth forest in Sumatra, Indonesia, where much of future oil palm expansion in Southeast Asia is expected to occur. We assumed that the concession will either be developed by a large plantation company or preserved for carbon credits from REDD.

Converting forests for palm oil production

Under the scenario of forest-to-oil palm conversion, we assumed a constant conversion rate of 1,250 ha per year over 8 years. To determine profitability, we collected data on yields for oil palm products—fresh fruit bunches (FFB), CPO and palm kernel (PK), potential revenues from these products based on alternative pricing scenarios (either constant price or variable price), as well as plantation setup and annual operations costs (Appendix S1–S4).

Given the growing number of highly efficient, modern oil palm companies operating in Indonesia, we assumed that the average productive lifetime FFB yield of our hypothetical Sumatran concession will range from 17 tons/ha (low-yield scenario) to 20.5 tons/ha (high-yield scenario) based, respectively, on Indonesia and Malaysia's average FFB yields in 2007 (Food and Agriculture Organization of the United Nations 2008). We then applied a standardized yield curve to each yield scenario to calculate year-by-year FFB yields over the concession's productive lifespan (Appendix S3). This yield curve was derived from empirical data on FFB yields compiled by the Indonesian Oil Palm Research Institute (Appendix S3). Under the low yield scenario, FFB yields were assumed to increase from 5.9 tons/ha in the third year of planting when palm trees reach maturity to 21.9 tons/ha in the ninth year, before decreasing to 12.1 tons/ha in the twenty-fifth year. Under the high-yield scenario, FFB yields were assumed to increase from 7.1 tons/ha in the third year of planting when palm trees reach maturity to 26.4 tons/ha in the ninth year, before decreasing to 14.6 tons/ha in the twenty-fifth year. We assumed a CPO yield of 21% of FFB production (i.e., oil extraction ratio) and a PK yield of 5% of FFB production based on industry data (Appendix S4).

CPO prices have been highly volatile since 1990, but have risen sharply since 2006 (World Bank 2008a). Our model relies on the most recent commodity price data (World Bank 2008a) and commodity price forecasts (World Bank 2008b) from the World Bank, which projects prices through 2020. Under a high-yield constant price (HYCP) scenario, we assumed CPO prices to maintain at $749 (the average price from January 2006–November 2008) from 2009 to 2039 (World Bank 2008a). Under a low-yield variable price (LYVP) scenario, we assumed CPO prices to follow World Bank forecasts, declining from $533 per ton in 2009 to $488 per ton in

2010, before recovering to \$643 in 2015, and decreasing to \$510 in 2020 (World Bank 2008b), at which we assumed it will remain until 2039. PK price was assumed to be approximately 60% of CPO price based on industry data (Appendix S4).

We based the costs of establishing and operating an oil palm plantation on midpoint values of published estimates for tropical forest in Sumatra (Rötheli 2007): setup costs of \$3,441–\$4,190 per ha; annual operations costs (maintenance, harvest, milling, and transport) of \$253–\$308 per ton CPO produced. In some oil palm developments that involve new plantings, the sale of timber products from clearing of land may be used to subsidize plantation development (Casson 1999). In our calculations, we also included an estimated logging income to defray plantation setup costs (Tomich *et al.* 2002; Grieg-Gran 2008). Production, yield, and cost data were then used to determine profit.

Reducing deforestation and forest degradation

Under the alternative scenario of preserving the concession for REDD, we assumed that the entire 10,000 ha forest area will be left undisturbed and thus be eligible for carbon credits via the REDD mechanism. In our calculations, we included no compensation for other ecosystem services (e.g., erosion control, watershed protection) or economic activities (e.g., sustainable harvesting of forest products) that may continue on the land.

While estimates for forest carbon stocks are variable (Rafli *et al.* 2007), default values from the United Nation's Intergovernmental Panel on Climate Change have been adopted as the best practices for estimating forest carbon when information is limited (Rafli *et al.* 2007). Preserving the forest concession will avoid 5.46 million tons of carbon dioxide emissions relative to converting it for oil palm over the 30-year period, based on the difference in aboveground biomass between lowland tropical rainforests (225 Mg C per hectare) and oil palm plantations (76 Mg C per hectare) for tropical insular Asia (Eggleston *et al.* 2006; Rafli *et al.* 2007; Gibbs *et al.* 2008).

We used two approaches to carbon credit allocation. In the first approach—the equal allocation model (EA)—we assumed that carbon credits will be allocated and sold on an equal annual basis over the 30-year period at an annual site-specific deforestation rate of 3.3%. In the second approach—the front-weighted allocation model (FWA)—we assumed that the credits will be allocated and sold only during the period where the forest would otherwise be converted for oil palm (e.g., years 1–8) at an annual site-specific deforestation rate of 12.5%. Thereafter funds would be used at the discretion of the landowner, assuming some provision would be made to insure against the possibility of deforestation or forest degradation in the subsequent 22 years, for example, by holding some of the carbon proceeds in escrow (Ebeling & Yasué 2008). While earnings during the period from interest and other investments may boost the net present value (NPV) of the project, we chose not to speculate on the value of these returns. Similarly, due to the uncertainties in accounting methods for leakage, we chose not to incorporate this in our calculations. However, our models of REDD and oil palm profitability published in the Supplementary Information do allow the examination of the effects of incorporating return on investments and potential carbon leakage (Appendix S1 and S2).

We modeled the operating profit under five carbon pricing scenarios using forward prices of carbon derivatives traded in either voluntary or compliance markets (Capoor & Ambrosi 2008; Appendix S1 and S2). For compliance market scenarios, we assumed REDD credits would track current voluntary market prices until 2012, before diverging thereafter. These carbon-pricing scenarios are described below:

Voluntary (constant price)—Based on Voluntary Carbon Financial Instruments (CFI) from the Chicago Climate Futures Exchange (CCFE; www.chicagoclimatex.com). We assumed a carbon price of \$4.40 per ton CO_2e in 2010, and used the current December 2010 futures contact price of \$4.65 per ton CO_2e as the carbon price from 2011 to 2039.

Voluntary (annual appreciation)—In this variation of the voluntary market scenario, we assumed that prices in the voluntary market would appreciate by 5% annually, increasing from \$4.40 per ton CO_2e in 2010 to \$18.23 per ton CO_2e in 2039.

Compliance (JI)—Based on Joint implementation, as defined in Article 6 of the Kyoto Protocol, which "allows a country with an emission reduction or limitation commitment under the Kyoto Protocol (Annex B Party) to earn emission reduction units (ERUs) from an emission-reduction or emission-removal project in another Annex B Party, each equivalent to one ton of carbon dioxide-equivalent emissions (CO_2e), which can be counted towards meeting its Kyoto target" (United Nations Framework Convention on Climate Change 2001). We used the 2007 average price for JI projects (Hamilton *et al.* 2007; Capoor & Ambrosi 2008) of \$12.17 per ton CO_2e for post-2012 profit projections.

Compliance (CER)—Based on Certified Emission Reductions, which are tradable credits issued under the Kyoto Protocol's Clean Development Mechanism (CDM). CERs are usually generated by sustainable development projects in developing countries (Capoor & Ambrosi 2008). We used the current market price for

2012 CER futures contract of \$37.57 per ton CO_2e as the basis for the forecasts.

Compliance (EUA)—Based on European Union Allowances, which are credits issued under the European Union Emission Trading System. We used the current market price for 2012, 2013, and 2014 CER futures contracts—\$46.89, \$50.29, \$52.44 per ton CO_2e, respectively—for the basis of our calculations. We used the 2014 price as the carbon price from 2015 to 2039.

We estimated the development cost of establishing a REDD project to meet the standards of the World Bank's Forest Carbon Partnership Facility (FCPF; carbonfinance.org) at \$25 per ha based on the costs of funding the project design document, governance and planning, enforcement and zonation, land tenure and acquisition, monitoring and measurement, surveying and research, and other costs (Eggleston *et al.* 2006; Thoumi 2009). Annual maintenance costs are estimated at \$10 per hectare. These include, but are not limited to, governance and planning; enforcement and zonation; infrastructure maintenance; information, education, and communication; monitoring; sustainable livelihoods (when applicable); marketing; and finance and administration (Eggleston *et al.* 2006; Thoumi 2009).

Results and discussion

Our analysis reveals that the development of the concession for oil palm agriculture will generate an NPV ranging from \$3,835 to \$9,630 per hectare over a 30-year period (Figure 1). Under the second scenario of REDD, we determined that voluntary markets will limit REDD operating profit to \$614–\$994 per hectare in NPV over the 30-year period—substantially less than profits from oil palm conversion. However, giving REDD credits price parity with carbon credits in compliance markets would boost the profitability of avoided deforestation to \$1,571–\$6,605 per hectare (Figure 1; Appendix S1 and S2), and possibly as high as \$11,784 per hectare if carbon payments are

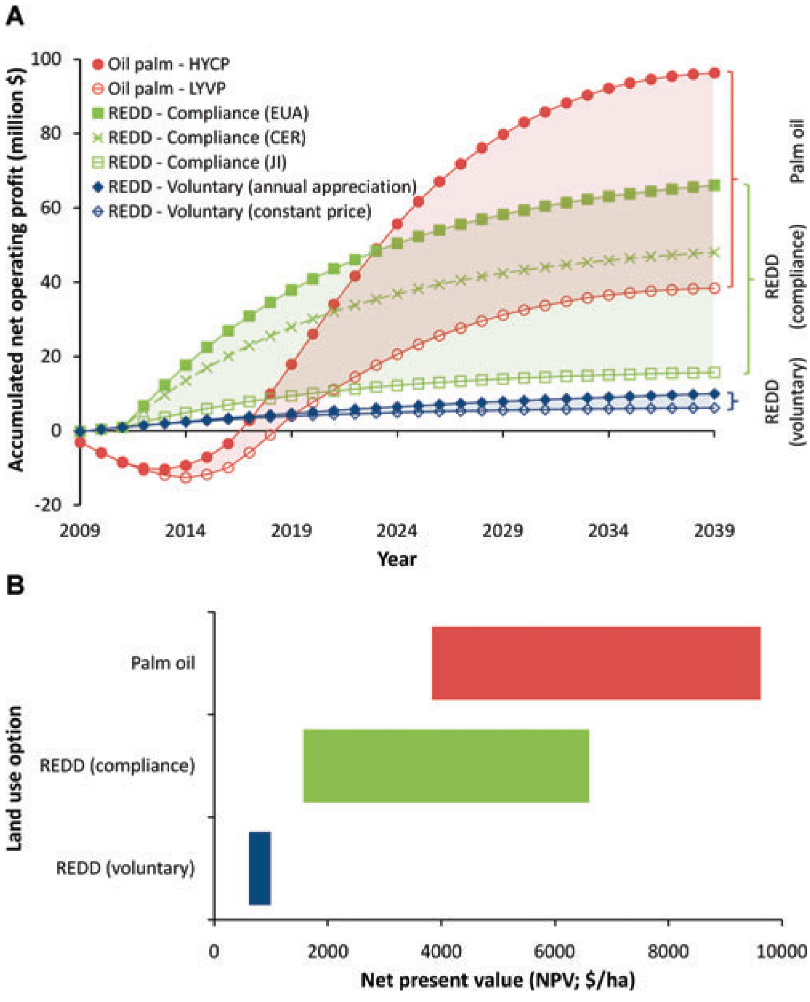

Figure 1 Comparing the profitability of preserving a 10,000 ha forest to reduce emissions from deforestation and forest degradation (REDD) versus converting it for palm oil production over a 30-year period. (A) Accumulated net operating profit from 2009 to 2039. (B) Net present values. REDD profitability is based on carbon prices of voluntary and compliance markets, including Voluntary Carbon Financial Instruments (CFI) from the Chicago Climate Futures Exchange, Joint Implementation (JI) under Article 6 of the Kyoto Protocol, Certified Emission Reductions (CER) under the Kyoto Protocol's Clean Development Mechanism (CDM), and European Union Allowances (EUA) issued under the European Union Emission Trading System. Palm oil production profitability was modeled for the scenarios of high-yield and constant price (HYCP), and low-yield and variable price (LYVP). Model details are provided in the Supplementary Information (Appendix S1).

front-weight, that is, if credits are allocated and sold during the first 8 years when deforestation actually occurs instead of distributing the credits over the full 30 years (Appendix S2). Results from our analysis suggest that unless post-2012 global climate policies legitimize the trading of carbon credits from avoided deforestation, REDD will not be able to compete with oil palm agriculture or other similarly profitable human activities as an economically attractive land-use option, in which case REDD will not be able to fulfill its primary function of avoiding deforestation.

Given the growing demand for palm oil from emerging economies such as China and India (United States Department of Agriculture—Foreign Agricultural Service 2008), and the widespread suitability of presently forested land for this crop (Stickler *et al.* 2007; Gibbs *et al.* 2008), the conversion of tropical forests for palm oil production will likely continue over the next decade. This outcome would have implications for carbon sequestration and biodiversity conservation because oil palm plantations are depauperate in both respects relative to natural forests (Fargione *et al.* 2008; Gibbs *et al.* 2008; Koh & Wilcove 2008a). Furthermore, palm oil prices are expected to remain above the 1980–2005 average for the next decade (World Bank 2008a). Therefore, from an investment perspective, oil palm agriculture will remain an attractive alternative land use to REDD schemes, although in some forest areas REDD schemes may be more profitable than oil palm developments because of poor infrastructure, unsuitable soils, inappropriate climate, and topography. Furthermore, there are considerable uncertainties involved in predicting future REDD and oil palm operations costs, as well as carbon and palm oil prices. To assess the robustness of our findings to variability in these and other model assumptions, we performed a sensitivity analysis on key variables in our models (Appendix S5). We found that these uncertainties would not affect the main conclusion of our study: to improve the long-term economic prospects of REDD, the mechanism will need to be elevated to Kyoto-sanctioned status. Trading in compliance carbon markets will ensure a stable supply of funds at higher carbon prices, and allow REDD to be buffered against uncertainties and fluctuations in opportunity costs such as palm oil price increases.

Future research efforts could also improve the landscape for REDD. For example, certain habitats such as peatlands may provide higher returns for REDD projects than the lowland forests we used as the basis for calculations, given the vast amount of belowground carbon in such habitats. However, there may be prohibitive technical and financial costs associated with assessing the value of belowground carbon, and their treatment by carbon markets remains uncertain. An important limitation of our analysis is that it excludes payments for environmental services (PES) beyond carbon, including forest-derived goods and services that benefit local and regional economies. While there have been some notable pilot PES projects in both the public and private sectors, their success remains equivocal and uptake uncertain (Wunder 2006). Nevertheless, such PES schemes could boost the value of standing forests and complement returns from REDD, which may make the preservation of forests economically competitive with oil palm agriculture or other competing land uses. A broader assessment of the value of ecosystems in generating and sustaining environmental services, such as maintaining rainfall for agricultural production, will be needed to establish and legitimize such markets. We recognize that land-use decisions are not solely economic but are also made in the context of the national policy environment. Exploring synergies between existing policy frameworks, conservation efforts, and carbon finance could reveal new approaches to addressing environmental problems associated with forest loss.

Acknowledgments

We thank J. Barlow, C.J.A. Bradshaw, B. Phalan, L.T. Gan, G.A. Thoumi, H.K. Gibbs, D.S. Wilcove, S.L. Pimm, W.F. Laurance, J.W. Terborgh, and one anonymous reviewer for comments. L.P.K. is supported by an ETH Fellowship for postdoctoral research.

Supporting Information

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

Figure S1. Global price trends of crude oil, soybean oil, and palm oil from January 2000 to June 2008.

Appendix S1. REDD (equal allocation) and oil palm profitability models.

Appendix S2. REDD (front-weighted allocation) and oil palm profitability models.

Appendix S3. Empirical FFB yield data of oil palm.

Appendix S4. Oil palm plantation statistics of nine publicly listed companies.

Appendix S5. Sensitivity analysis of REDD (equal allocation) and oil palm profitability models.

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Editor: Barlow Jos

