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OIL PALM FOR BIODIESEL IN BRAZIL: POTENTIALS AND TRADE-OFFS

Englund O[1,3], Berndes G[1], Persson, M[1], Sparovek, G[1,2]
[1] Div. of Physical Resource Theory, Dept. of Energy and Environment, Chalmers University of Technology.
SE-41296 Gothenburg, Sweden
[2] "Luiz de Queiroz" College of Agriculture, Department of Soil Science, University of São Paulo.
Av de Pádua Dias, 11, Piracicaba (SP), Brazil, 13418-900
[3] Corresponding author: oskar.englund@chalmers.se

Oil palm is a land efficient feedstock alternative for biodiesel production and can be a very profitable alternative for farmers. In this study, a spatially explicit model is used to: (i) map and quantify areas in Brazil where oil palm establishment for biodiesel production would be profitable (positive net present value, NPV) in different future scenarios; (ii) estimate corresponding biodiesel production volumes and analyze trade-offs between such biodiesel production, greenhouse gas emissions reduction, and nature conservation; and (iii) investigate whether pricing of carbon emissions from land use change might help to steer oil palm production away from lands where conversion would bring the largest impacts on biodiversity or ecosystem carbon stocks. The scenarios include oil, coal, and carbon price pathways from the IEA World Energy Outlook and both the present and prospective situations concerning road infrastructure in Brazil. It is found that palm oil production for biodiesel can be profitable (positive NPV) on very large areas; that such production can conflict with greenhouse gas emissions reduction and nature conservation objectives in many places, but also provide opportunities to meet multiple objectives. Depending on scenario, some 65-80 Mha of land could support biodiesel production corresponding to more than 10% of the global diesel demand, without causing any direct land use change emissions and without inflicting on high conservation value areas.

Keywords: palm oil, biodiesel, land use, resource potential, geographical information system (GIS)

1 INTRODUCTION

Palm oil is the most land-efficient and profitable tropical feedstock alternative for biodiesel [1], [2]. Today, 90% of the global oil palm production takes place in Indonesia and Malaysia, where 6 and 4 million hectares (Mha) of plantations have been established, respectively, mostly at the expense of tropical forests, resulting in severe impacts on biodiversity and large greenhouse gas emissions associated with the forest conversion. While Brazil presently has only about 0.1 Mha of oil palm plantations [3], roughly 565 Mha of land could, to some extent, support oil palm cultivation. Much of the suitable land is forested, but there are also large deforested areas, e.g., cattle pastures, where conversion to oil palm plantations could possibly bring benefits such as carbon sequestration and partial reversal of hydrological changes caused by the earlier deforestation.

The expansion of oil palm cultivation is considered a way to create jobs and improve incomes at the local level: according to government estimates, a family could increase its net income by more than 400% by shifting from traditional crops to oil palm cultivation [1]. The Brazilian government acknowledges the risks of environmental impacts, and the ambition is for plantations to be mainly established on degraded agricultural land [4]. So far, 5 Mha of new oil palm plantations have been authorized, out of a total 29 Mha of land identified as suitable in Brazil's agro-ecological zoning for Oil Palm [5]. However, the profitability of oil palm cultivation could make it an attractive option for existing and aspiring landowners also in areas other than those pointed out by the government.

When effective, legislation, policies and enforcement can prevent cultivated systems from expanding at the cost of forests and other native vegetation, but the effectiveness varies [6]. For example, Yui and Yeh [7] showed that the extent and impacts of oil palm expansion in the Brazilian state of Pará differ dramatically depending on comprehensiveness and effectiveness of enforcement to ensure compliance with regulations. Large forest areas in Brazil can also be legally converted into cultivated systems [6]. The Forest Act, which is the most important legal framework for conservation of natural vegetation on private agricultural lands, has recently been revised because, on the one hand, it has been found ineffective in protecting natural vegetation, and on the other hand, it is perceived as a barrier against development in the agriculture sector [8]. The revised Forest Act allows the planting of oil palm toward compliance with legislation concerning the share of farm land reserved for natural vegetation (in the Legal Amazon and the Forest biome: 80% when the area is on native vegetation and 50% if already converted).

In this study, a spatially explicit model was developed to: (i) spatially determine the net present value (NPV) of establishing new oil palm plantations for biodiesel production, in different future scenarios, in order to map and quantify areas in Brazil where oil palm biodiesel production would be profitable; (ii) estimate the corresponding biodiesel production volumes and analyze trade-offs between such biodiesel production, greenhouse gas emissions reduction, and nature conservation; and (iii) investigate whether pricing of carbon emissions from land use change (LUC) might help to steer oil palm production away from lands where conversion would bring the largest impacts on biodiversity or ecosystem carbon stocks.

2 METHODOLOGY

The net present value (NPV) of establishing new oil palm plantations (Eq. 1) was calculated for each hectare in Brazil for a total of 45 scenarios combining variations of: (i) price projections on oil, coal, and carbon, (ii) LUC carbon price, (iii) establishment year, and (iv) models used for spatially estimating the potential palm oil yield. Results from 27 scenarios are presented in this paper.

The willingness to pay for palm oil biodiesel was estimated based on projected global oil prices in the different IEA scenarios, with costs for refining oil into petrodiesel, and the EU carbon tax, added. The willingness to pay for residues (to use for bioenergy) was estimated based on projected coal prices, in some scenarios with a Brazilian carbon tax added. Different cost parameters for oil palm cultivation and milling were adopted based on a literature survey. Brazilian studies were used when possible.

The amounts of land where oil palm establishments would be profitable, the corresponding biodiesel production volumes, and the carbon stock changes, were quantified for each scenario and for different land use / land cover (LULC) classes.

$$
\begin{aligned}
&NPV_{oilpalm}(t) \\
&= Revenues\ from\ timber - Cost\ of\ establishing\ plantations \\
&- Cost\ of\ establishing\ mill \\
&- Carbon\ costs\ from\ LUC\ (or\ REDD\ revenues\ by\ avoiding\ it) \\
&+ \sum_{n=1}^{25} \left[\frac{Revenues\ - Cultivation\ costs - Milling\ costs - Trp\ costs - C\ costs\ (N2O)}{(1+r)^n} \right]
\end{aligned}
$$

Equation 1: Formula for determining NPV of establishing new oil palm plantations for biodiesel production

2.1 Spatial data used in the model

(1) A *100 m Brazilian LULC map*, with data gaps (i.e., cells classified as “unclassified” or “other”) filled using the Globcover dataset [9];

(2) *Potential production capacity for palm oil*, extracted from GAEZ 3.0 [10], with production capacity of palm kernel oil added to the dataset using a linear relationship between palm oil and palm kernel oil yields;

(3) *Transportation costs*, i.e., a minimum estimate of the cost in each grid cell of transporting one tonne of palm oil to an export port, using either roads or waterways. The dataset was produced by performing a cost distance operation in ArcGIS, using official Brazilian data on roads, waterways and ports as inputs; and

(4) *Carbon stock change*, i.e., the difference in each cell between current carbon stocks and the amount of carbon that would be stored over time in oil palm plantations. Current aboveground, belowground, and litter carbon stocks were estimated based on an aboveground biomass dataset [11].

3 RESULTS

It is found that palm oil production for biodiesel can be profitable (positive NPV) on very large areas in Brazil; (ii) that such production can conflict with greenhouse gas (GHG) emissions reduction and nature conservation objectives in many places, but can also provide opportunities to meet multiple objectives.

3.1 Total profitable area and the effects of a LUC carbon price

Currently, without a price on LUC carbon emissions, it would be profitable to establish oil palm plantations on about 410-430 Mha, corresponding to biodiesel production roughly on par with the present global diesel demand [3] (Table 1, Fig. 1, similar situation in 2025). The oil price data from the IEA scenarios, which is used to calculate the willingness to pay for biodiesel, is however not valid for such a biodiesel scenario since very large biodiesel production would affect the global oil price. Nevertheless, the results give a clear indication of the geographical pattern of exploitation pressure in a situation where biodiesel prices follow the trajectories given in the IEA scenarios. Notably, establishment of oil palm plantations has a positive NPV in almost all forest lands in the legal Amazon (see Fig 2). To illustrate the GHG dimension: if this forest land would be converted to oil palm plantations, up to ca. 50 Gt C, or roughly 5.8 times the global CO2 emissions from fossil fuels in 2012, would be emitted to the atmosphere. Naturally, large scale forest conversion would also cause large biodiversity impacts.

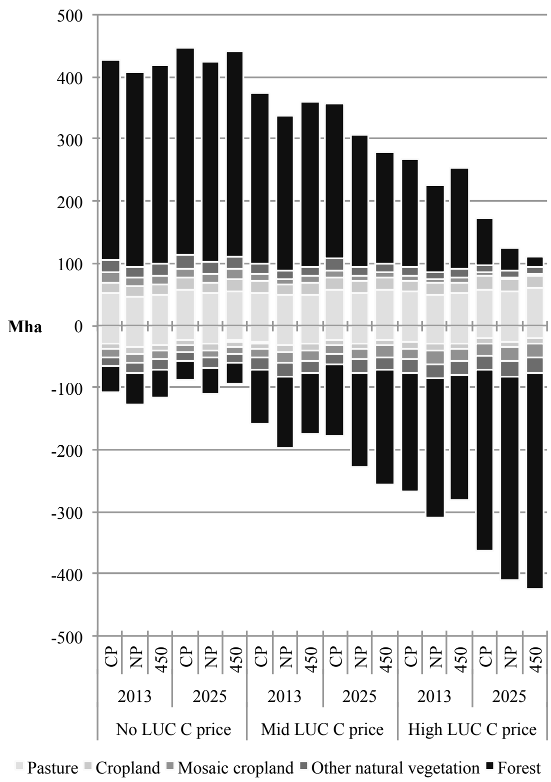

Figure 1: Amount of land in six different land categories where establishment of oil palm plantations for biodiesel production would be profitable (NPV > 0; bars above the x-axis) and unprofitable (NPV < 0; bars below the x-axis), in each of the main 18 scenarios. Land unsuitable for oil palm production is excluded.

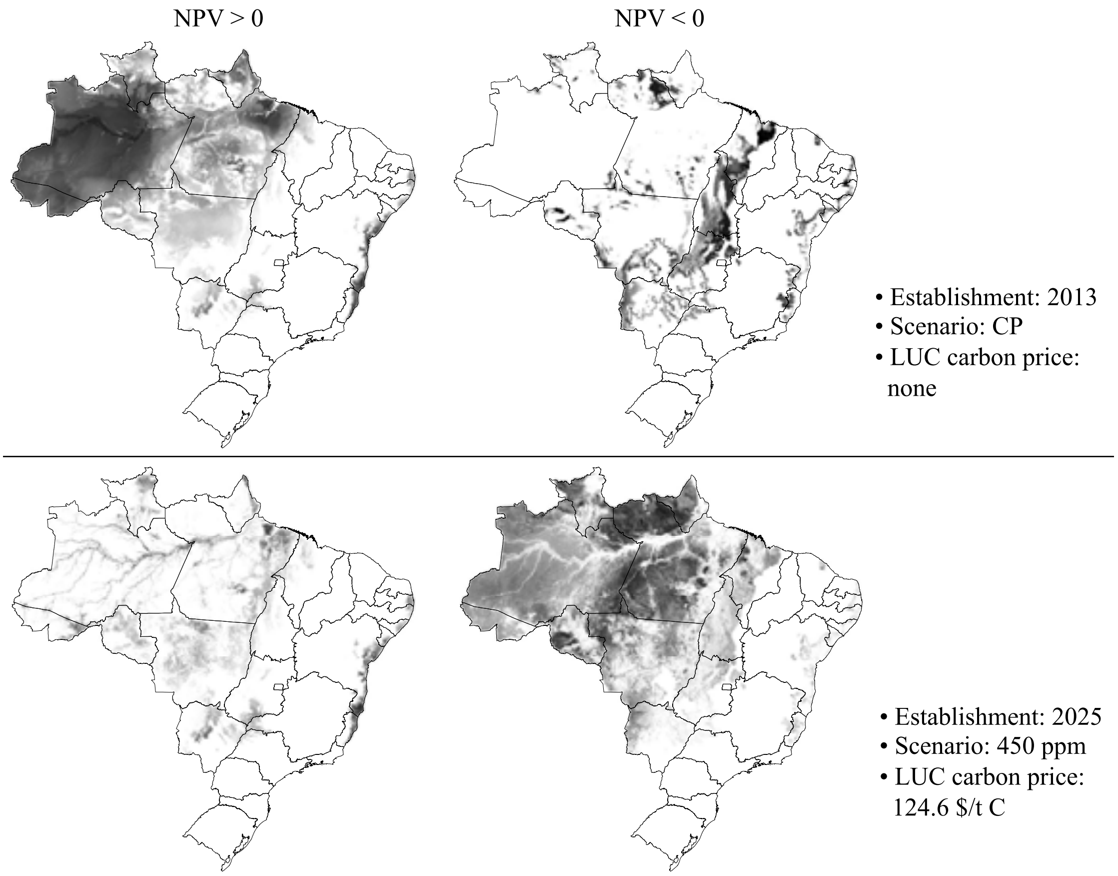

Figure 2: NPV of establishing oil palm plantations in two scenarios, described in the figure to the right. The left maps show where NPV is positive, and the right maps show where it is negative. NPV ranges between -6718 – 26772 in the scenario at the top, and -70871 – 44397 in the scenario at the bottom.

The effectiveness to protect forests by pricing LUC carbon emissions naturally depends on the carbon price (Table 1, Fig. 1). The carbon prices used for 2013, correspond to the current average carbon price on voluntary carbon markets (22 $/t C) and the carbon price on the EU ETS market (64 $/t C). Carbon price levels diverge over time and are assumed to grow faster in the 450 ppm scenarios. By 2025, in the 450 ppm scenario, the highest carbon price used (249 $/t C) resulted in that oil palm establishment has negative NPV in 96% of the forests.

Concerning the profitability of planting oil palm on other land types than forests, there are small variations between the different scenarios. On average, there are about 50 Mha of pastures, 20 Mha of cropland, 10 Mha of mosaic cropland, and 15 Mha of land under natural vegetation, where establishment of oil palm for biodiesel would be profitable, at present (Fig 2). At 2025, the numbers are similar. Palm oil plantations on these lands could support production of roughly 8-10 EJ/a of biodiesel.

3.2 Effects of expanding and upgrading infrastructure

If all existing national and regional infrastructure plans in Brazil were realized by 2025, including the paving of all unpaved roads, the total biodiesel potential would increase just a few percent. Most of the area where additional oil palm planting would be profitable is presently forested (65-95 %) and/or land considered as having high conservation value (50-85 %).

Table 1: Summary of the main 18 scenarios, including the total area in the scenarios where oil palm establishments would have a positive NPV, and the percentages of forest area where conversion to oil palm plantations has negative NPV.

Establish-ment year	IEA scenario	LUC carbon price ($/t C)	Area where conversion to oil palm has positive NPV (Mha)	% of forest area where conversion to oil palm plantations has negative NPV
2013	CP	None	429	11
	NP		408	14
	450 ppm		419	12
	CP	22 (mid)	375	24
	NP		339	31
	450 ppm		360	27
	CP	64 (high)	267	52
	NP		227	61
	450 ppm		254	55
2025	CP	None	447	9
	NP		426	12
	450 ppm		442	10
	CP	43 (mid)	358	31
	NP		306	42
	450 ppm	86 (mid)	278	51
	CP	125 (high)	173	80
	NP		125	90
	450 ppm	249 (high)	110	96

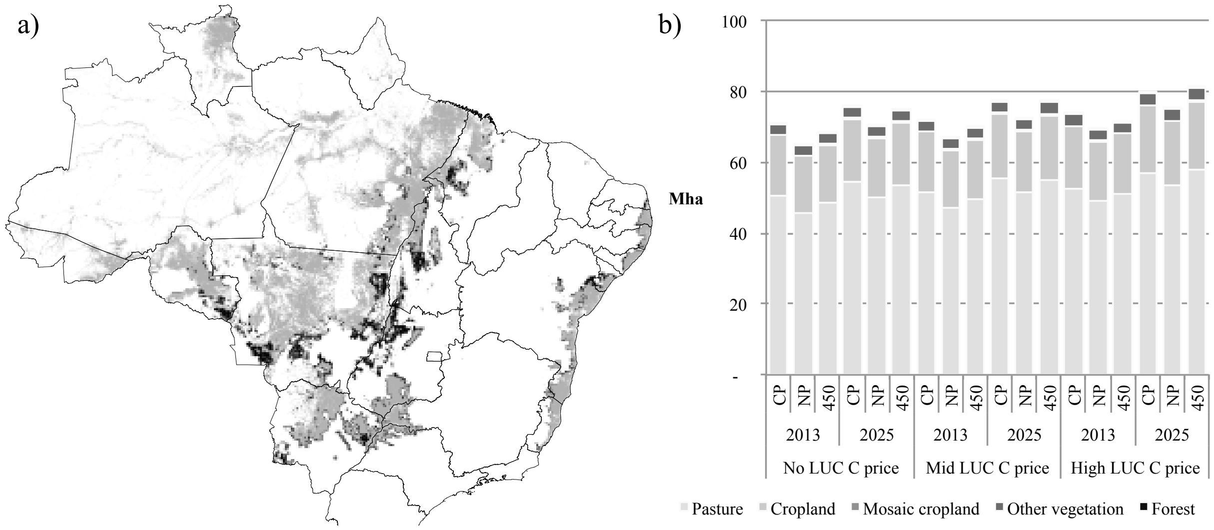

Figure 3: Areas where establishment of new oil palm plantations would (1) be profitable (NPV>0); (2) increase carbon stock; and (3) not infringe on land classified as HCV. a) shows the spatial distribution of this land in the scenario with the lowest potential (grey) and highest (grey+black); b) shows quantified results for all scenarios aggregated in six LULC classes.

The small effect of expanding and upgrading road infrastructure is partly explained by that transportation costs are less critical for palm oil than for some other crops such as soybeans, due to the often higher profitability of palm oil production. Also, river transportation is a competitive alternative in many areas where the road infrastructure is poor. Transportation on rivers is significantly less costly than on unpaved roads, and about the same as on paved roads [12-15]. Since palm oil can be exported through Manaus and Santarém, the transportation cost from land nearby navigable rivers in Amazonas is already relatively low. However, construction or upgrading of roads would increase the present transportation capacity, which may not suffice in case of a large increase in palm oil production upstreams.

3.3 Possibilities of meeting multiple objectives

If oil palm planting is only allowed on land not classified as high conservation value (HCV) land and where C stock losses are avoided, roughly 65-80 Mha of land would be available corresponding to production of some 6-7 EJ/a of biodiesel, or up to about 15% of the global petrodiesel demand (Fig. 3). Almost all (95%) of this land is presently agriculture land, with roughly 3/4 being pasture and 1/4 being cropland. This corresponds to 25-30 % of all pastures and around 15% of all croplands in Brazil.

4 UNCERTAINTIES

In this study, it was assumed to be profitable to plant oil palm on lands where NPV > 0. The profitability of palm oil production was however not compared with that of alternative land uses, due to lack of comparative datasets. Preliminary estimates indicate that oil palm production is more profitable that traditional land uses in the absolute majority of cells, but work is in progress to properly incorporate opportunity costs in the NPV calculations.

The two most critical uncertainties in the model are the discount rate and the oil price projections. The discount rate converts (discounts) the future cost and benefits from investments in oil palm production into present value, and represents the opportunity cost of capital. The discount rate should therefore reflect the (risk-free) expected returns from investments, i.e., market interest rates. Historically, interest rates in Brazil have been very high, but in the latest decade rates have averaged around 10% per year [16]. We therefore use a 10 % discount rate as a baseline assumption as a way to reflect the higher risk involved in making investments in palm oil production capacity, and to not overestimate the profitability of deforestation for biodiesel production (a higher discount rate will put more emphasis of the present carbon cost of clearing vs. the future revenues from biodiesel production).

As seen in Fig. 2-3, the LUC C price level is the most important factor behind the variations in the scenarios. The projections on oil, coal and carbon prices in the IEA WEO study [17] are model-generated and thus interconnected, making it an appropriate source for this study. However, it should be noted that the small differences between the IEA scenarios (at a given LUC carbon price level) are mainly due to small differences in oil price projections, which determine the willingness-to-pay for biodiesel.

5 DISCUSSION AND CONCLUSIONS

The results unveil that palm oil production for biodiesel can be profitable (positive NPV) on very large areas in Brazil, and that such production can conflict with greenhouse gas (GHG) emissions reduction and nature conservation objectives in many places. But it can also be concluded that there are large possibilities to produce substantial biodiesel volumes without impacting on carbon stocks and HCV lands.

The results also show that a LUC carbon pricing scheme can make conversion of forests to oil palm plantations unprofitable, if set sufficiently high. For example, the current average price on voluntary carbon markets (22 \$/t C) would only suffice to protect forests where the potential palm oil yield is moderate. In order to protect most forests, a price of 249 \$/t C would be necessary. However, establishing an effective LUC carbon pricing scheme with sufficiently high carbon prices is a challenge.

Most of the land where oil palm could be planted without impacting on areas with high conservation value, and/or carbon stocks, is already under agriculture. There is a large potential for enhancing the land productivity of especially pasture production in Brazil. For example, Sparovek et al. [8] estimate that modest increases in stocking and slaughter rates could release almost 70 Mha of pasture land for other purposes, i.e. more than the pasture area estimated to be suitable for oil palm, as described in section 3.3. However, agriculture land use may not decrease as a consequence of intensification since the intensification measures potentially also make the agricultural activity more profitable and thus more attractive, resulting in an increase in agricultural land rather than a reduction [18-21] . Thus, unless appropriate policy measures are taken, there is a risk that large scale oil palm expansion could displace existing agricultural land onto natural vegetation. In the case of a LUC carbon pricing scheme, it would have to be applied for all agricultural activities, not just oil palm production, to avoid such indirect land use change effects.

6 REFERENCES

[1] R. A. Butler, “Brazil launches major push for sustainable palm oil in the Amazon,” *Mongabay*, 07-May-2010. [Online]. Available: http://news.mongabay.com/2010/0507-amazon_palm_oil.html. [Accessed: 13-Feb-2014].

[2] H. Schwaiger, N. Pena, A. Mayer, and D. N. Bird, *Technologies to produce liquid biofuels for transportation: An overview*. CIFOR, 2011.

[3] FAO, “FAOSTAT,” Food and Agriculture Organization of the United Nations, Rome, 2013.

[4] R. Butler, “In Brazil, Palm Oil Plantations Could Help Preserve the Amazon,” *Yale Environment 360*, 2011. [Online]. Available: http://e360.yale.edu/feature/in_brazil_palm_oil_plantations_could_help_preserve_amazon/2415/. [Accessed: 06-Feb-2014].

[5] EMBRAPA, “Zoneamento Agroecológico do Dendezeiro para as Áreas Desmatadas da Amazônia Legal,” Brazilian Agricultural Research Corporation - Embrapa, 2010.

[6] G. Sparovek, G. Berndes, I. L. F. Klug, and A. G. O. P. Barretto, “Brazilian Agriculture and Environmental Legislation: Status and Future Challenges,” *Environ. Sci. Technol.*, vol. 44, no. 16, pp. 6046–6053, 2010.

[7] S. Yui and S. Yeh, “Land use change emissions from oil palm expansion in Pará, Brazil depend on proper policy enforcement on deforested lands,” *Environ Res Lett*, 2013.

[8] G. Sparovek, G. Berndes, A. G. de O. P. Barretto, and I. L. F. Klug, “The revision of the Brazilian Forest Act: increased deforestation or a historic step towards balancing agricultural development and nature conservation?,” *Environmental Science & Policy*, vol. 16, pp. 65–72, Feb. 2012.

[9] S. Bontemps, P. Defourny, E. van Bogaert, O. Arino, V. Kalogirou, and J. R. Perez, “GLOBCOVER 2009,” European Space Agency (ESA) and Université catholique de Louvain, 2009.

[10] IIASAFAO, “Global Agro-ecological Zones (GAEZ v3.0).” IIASA/FAO, Laxenburg/Rome.

[11] A. Baccini, S. J. Goetz, W. S. Walker, N. T. Laporte, M. Sun, D. Sulla-Menashe, J. Hackler, P. S. A. Beck, R. Dubayah, M. A. Friedl, S. Samanta, and R. A. Houghton, “Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps,” *Nature Climate Change*, vol. 2, no. 3, pp. 182–185, Mar. 2012.

[12] M. D. C. Vera-Diaz, R. K. Kaufmann, and D. C. Nepstad, “The Environmental Impacts of Soybean Expansion and Infrastructure Development in Brazil's Amazon Basin,” *GLOBAL DEVELOPMENT AND ENVIRONMENT INSTITUTE WORKING PAPER NO. 09-0*, 2009.

[13] A. C. Barros and C. Uhl, “Logging along the Amazon River and estuary: patterns, problems and potential,” *Forest Ecology and Management*, vol. 77, no. 1, pp. 87–105, 1995.

[14] M. Lentini, D. Pereira, D. Celentano, and R. Pereira, *Fatos florestais da Amazônia 2005*. IMAZON, 2005.

[15] D. Salin, “Soybean Transportation Guide,” *USDA*, 2011. [Online]. Available: http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5098677. [Accessed: 21-Feb-2013].

[16] A. Segura-Ubiergo, “The Puzzle of Brazil's High Interest Rates,” International Monetary Fund, Working Paper 12/62, 2012.

[17] IEA, *World Energy Outlook 2012*. OECD Publishing, 2012.

[18] A. Balmford, R. E. Green, and J. Scharlemann, “Sparing land for nature: exploring the potential impact of changes in agricultural yield on the area needed for crop production,” *Glob Chang Biol*, vol. 11, no. 10, pp. 1594–1605, Oct. 2005.

[19] R. M. Ewers, J. P. W. Scharlemann, A. Balmford, and R. E. Green, “Do increases in agricultural yield spare land for nature?,” *Glob Chang Biol*, vol. 15, no. 7, pp. 1716–1726, Jul. 2009.

[20] T. K. Rudel, L. Schneider, M. Uriarte, B. L. I. Turner, R. DeFries, D. Lawrence, J. Geoghegan, S. Hecht, A. Ickowitz, E. F. Lambin, T. Birkenholtz, S. Baptista, and R. Grau, “Agricultural intensification and changes in cultivated areas, 1970-2005,” *Proc. Natl. Acad. Sci. U.S.A.*, vol. 106, no. 49, pp. 20675–20680, 2009.

[21] E. F. Lambin and P. Meyfroidt, “Global land use change, economic globalization, and the looming land scarcity,” *Proc. Natl. Acad. Sci. U.S.A.*, vol. 108, no. 9, pp. 3465–3472, 2011.