A Note[1]
Updating Carbon Density and Opportunity Cost Parameters in Deforesting Regions in the GCOMAP Model

Jayant Sathaye, Peter Chan, Helcio Blum, Larry Dale, and Willy Makundi

1 Introduction

In recent years several models have estimated the cost of reducing deforestation and forestation globally. The IPCC Fourth Assessment Report (AR4) reported the results of these models in Chapter 9 of its WGIII report on climate mitigation (Nabuurs et al. 2007). Under a carbon price of $20/t CO2, these models show that reducing deforestation in four tropical regions would account for more than half of the mitigation potential from global forestry activities. Reducing deforestation is the preferred option in the short term compared to forestation since the carbon sequestration from the latter option occurs primarily at the rate of growth of the forest vegetation.

The cost and carbon mitigation potential estimates from these models are sensitive to several key parameters that are not well documented. These include the (1) carbon density of forests, (2) opportunity costs of deforested areas, (3) transaction costs of implementing projects or programs, (4) proportion of forest area that would be replanted or allowed to regenerate, and (5) future baseline deforestation estimates. Carbon emissions from deforestation are sensitive to the proportion of forest that is harvested for timber and its carbon density, and also to the proportion of area that regenerates or is planted with perennial crops and/or forest vegetation. Models use a wide range of estimates of the above parameters because they are not well documented in the literature (Nabuurs et al. 2007).

The purpose of this project was two fold: (1) Gather information from the literature on the above parameters with particular emphasis on carbon density and opportunity costs, and (2) run the GCOMAP model using these estimates for 1200 carbon price scenarios. This note describes the data that was gathered for the estimation of carbon density and

[1] 'This paper was commissioned by the Office of Climate Change as background work to its report 'Climate Change: Financing Global Forests' (the Eliasch Review). Further information about the Eliasch Review is available at: www.occ.gov.uk

opportunity costs, which were used in the generation of the 1200 runs, and relevance of transaction costs in above analysis.

2 Background

The Generalized Comprehensive Mitigation Assessment Process (GCOMAP) (Sathaye et al., 2005, Sathaye et al. 2006) is a dynamic partial equilibrium model that analyzes the carbon and social welfare benefits of forestation globally in 10 regions, and of reducing deforestation in four tropical rainforest regions. It establishes a reference case level of land use, absent carbon prices, for 2000 to 2100 before simulating the response of forest land users (i.e. farmers) to changes in prices in forest land and products, and prices emerging in carbon markets. The model's objective is to estimate the land area that land users would plant above the reference case level, or prevent from being deforested, in response to carbon prices. As a result, GCOMAP estimates the net changes in carbon stocks while meeting the annual demand for timber and non-timber products. It models the reduction of deforestation in four tropical rainforest regions: Africa, South-East Asia, Central America and South America. GCOMAP model has recently been combined with the POLES model to estimate the impact of deforestation reduction for post-Kyoto CDM-type projects on the global value of carbon credits (Anger and Sathaye, 2008).

For the data on the key deforestation parameters noted in the introduction above, GCOMAP used the following sources of information.

- <u>Carbon density</u> was derived from the biomass and carbon density values published in the FAO 2005 Global Assessment of Forests.
- <u>The baseline</u> was estimated on the basis of FAO historical deforestation rates for each region. These baseline values are described in Sathaye et al. (2006).
- <u>The opportunity cost</u> of deforested land consists of two components, net present value (NPV) of timber harvested prior to deforestation, and net present value of the revenue stream from agricultural crops or cattle ranching over a period of 10 years. These values are presented in Table 1

We describe the project activities and the data that were collected for the new GCOMAP runs, which were used in the 1200 new carbon price scenarios that were analyzed in the GCOMAP model.

3 Carbon Density

Data for the carbon density parameter were acquired from the 2005 FAO Global Forest Assessment. The carbon density values of forest stock include above and below ground living biomass, dead wood and litter, which vary by country. These average values were assumed to apply to deforested areas of the forests of each region. For Africa, an average value weighted by the deforested area of three sub-regions, Eastern and Southern, Northern, and Western and Central Africa was calculated. For South East Asia, an average value was estimated by weighing country-specific data for forest cover and carbon density available from the 2005 FAO report. For other regions, average values were available for the three modelled regions in the FAO report.

The resulting carbon densities were higher than calculated earlier using the 2000 biomass values for the three regions by the following margins, Africa – 33%, Central America – 75%, and SE Asia – 48%, and carbon density was lower for South America by 13% (Table 2). The particularly high figure for Central America is based on the assumption that deforestation primarily occurs in tropical forests in that region, and carbon densities tend to be high there. Higher carbon density values increase the total emissions in the base year and vice versa. The global 2000 emissions estimates increased by about 25% to 996 Mt C. This value may be compared with the range of mean value estimates from De Fries at 0.9 Gt C and Houghton at 2.1 Gt C as reported in Table 9.2 of the IPCC WG III AR4 report (Nabuurs et al. 2007). A significant consequence of the higher emissions is that at the same opportunity cost per ha, the carbon price required to reduce emissions is lower compared to earlier GCOMAP runs (Sathaye et al. 2006).

4 Opportunity Cost

In our estimation of the opportunity cost of reducing deforestation we include the cost of timber that might be harvested prior to removal or burning of the live and dead wood from the forested area, and the planting of annual or perennial crops, timber plantations, and cattle ranching. Roads constructed by logging trucks open access to parts of the forest. Open access permits deforesters to migrate to other parts of the forest that would otherwise be difficult to reach.

Typically, the soil is rich enough to grow crops for the first couple of years and in Central and South America this is followed by ranching. Ranching offers a stable source of income that carries relatively lower weather and economic risk than growing crops (Figure 1). Subsistence agriculture and shifting cultivation is practiced in some regions, which allow the deforested land to regenerate over time. Elsewhere, due to poor soil conditions land may not regenerate leaving waste land behind.

The proportion of deforested area that is harvested for timber varies by region. The values shown in Table 1 range from a high of 35% for South East Asia to 10% for Africa. The value was assumed to be high for SE Asia because of the substantial illegal logging of harvested timber (Smith et al. 2003). Illegal logging of prime species such as mahogany opens access to the illegal logging of other species and for broader deforestation of the neighbouring regions. By its very nature, illegal logging is difficult to pin a value on. One study reports illegal logging to have ranged from 70-80% of forest production in Indonesia, up to 90% in the Brazilian Amazon, and between 34% to 70% in West Africa (Rhodes, Allen, and Callahan 2006, Contreras-Hermosilla 2001). Many countries are taking regulatory actions to enforce existing laws to reduce illegal logging. Despite these actions, illegal logging driven by the domestic and international demand for timber continues to be a major impediment to reducing deforestation. While the illegal logging percentage is high in these regions, the extent to which this leads to deforestation is not known. Merchantable timber fetches a substantial value that can range from $160-200/m^3$ in the domestic market to $700/m^3$ or more at the point of export to the international market. Such high returns can significantly affect the carbon price needed to reduce deforestation. We have assumed relatively conservative percentage values in our analysis, which are shown in Table 1. However, should these percentages be higher, the investment and carbon price needed to reduce deforestation would rise significantly.

We describe the data and information that was gathered for each region below.

4.1 Africa

African forest area and change-in-forest cover statistics are reported separately for North Africa, Eastern and Southern Africa and Western and Central Africa. In North Africa, Sudan lost 589,000 ha of forest cover annually between 1990 and 2000, but the change in carbon stock was only about 13.5 Mt C/yr (FAO, 2007, Tables 2 and 3). On the other hand, the Democratic Republic of Congo lost 530,000 ha annually from 1990-2000, with an estimated change in carbon stock of about 92 Mt C/yr. The other countries with significant forest and carbon loss in the region were Zambia, Nigeria, Code D'Ivoire and Cameroon.

The reasons for deforestation and the use of deforested lands vary across the continent and over time. Agricultural products (cocoa, palm, corn and rubber) have played a major role in fostering deforestation, and indeed exports of cocoa and coffee supported whole economies such as those in Cameroon and Ghana. Furthermore, the lowering of export prices for these products in the late 1980s and 1990s caused a severe economic downturn in these economies leading to increased deforestation to support food crops. There are many studies that report on the opportunity cost to reduce deforestation for the continent particularly for Cameroon (Tomich et al. (2005, Loggerheads (2006), Price et al. (2005)), Ghana, Uganda (Naidoo and Adamovicz (2005)); (2006), Kenya (Griffiths and Southey (1995)), and Tanzania (Makundi et al. (2001)). The Global Environment Facility (GEF) has conducted a study that reports on the net returns on African dry and irrigated croplands for several countries (Kurukulasuriya and Mendelsohn 2006). Based on these studies, we estimate the cost of clearing forests, the average return from crop plantations, and the value of harvested timber (Table 1). These are used in GCOMAP to calculate the total opportunity cost of deforested land.

Data on the fraction of merchantable timber that is harvested from deforested areas in Africa is not readily available and may vary by forest type and the mode of deforestation. In this analysis we assume that the fraction for Africa is about 10%.

4.2 Central America

In Central America, Mexico has the largest rate of forest cover change about 348,000 ha/yr from 1990 to 2000, which is almost an order of magnitude higher than that in any other country in the region (FAO 2007). We focus on the opportunity cost in the Yucatan region of the country, which is subject to severe deforestation. Busch (2006) describes the situation in that region and estimates the opportunity costs from agricultural cropping and cattle ranching in his thesis. Maize, chili pepper, and cattle ranching are the primary activities. Maize and chili pepper yield a net present value of 10 year returns of $650 and $150 per ha respectively. Cattle ranching has a much lower NPV of about $49 per ha., yet, this is the preferred option among farmers. As Busch (2006) cites in his thesis, both higher weather and economic risks (fluctuating market prices, transportation risk, lack of storage facilities) make growing crops an unsustainable proposition and farmers prefer ranching over other options. It provides a stable income at minimal risk to the farmer. We estimate a net present value per ha assuming that a farmer plants maize for the first two years after deforestation, and then switches to cattle ranching. This yields the NPV shown in Table 1.

The cost of harvesting and revenue derived from deforested timber is assumed to be the same as for long-rotation forestry in GCOMAP. We use the same values for the deforestation analysis. The critical factor has to do with the fraction of timber that is harvested from the deforested area. Busch (2006) reports this fraction to be negligible since secondary forest that have limited or negligible timber value were deforested.

The fact that the fraction is negligible raises an important issue about the process and timing of deforestation. One possibility is that the road access and timber harvest occurs months or years in advance. Where this is the case, opportunity cost may not need to include the cost of harvesting timber since post-harvest farmers would be the only ones who need to be compensated and the NPV of their land use is relatively low (Table 1).

We assume that about 10% of the timber is harvested for domestic and international markets in Central America.

4.3 South America

South America accounted for 3.8 Mha/year of forest cover change between 1990 and 2000. The Legal Amazon region of Brazil accounted for 70% of this change and its share increased to 73% in the subsequent five years. As in the case of Mexico this is an order of magnitude higher than any other country in the region. We therefore focus on Brazil to understand the dynamics of the forest cover change and opportunity costs.

A few salient points are worth noting about deforestation in Brazil:

- Deforestation rate varies sharply from year to year by as much as a factor of two, and since 1990 there have been several periods when deforestation appeared to be going up or going down only to reverse sharply. Deforestation was on the decline in 2005 and 2006 but has surged again in late 2007 due to high commodity (soy) prices.

- As in the case of Mexico, annual crops, soy in particular, are a major driver for deforestation, but cattle-ranching continues to occupy the major share (60%) of the deforested area.

- Opportunity costs for deforested land are a combination of soy and other crop (corn and rice) planting and cattle ranching. Soy accounted for 50%, corn and rice for 30% and other crops for 20% of the planted area in 2006 (Figures 2a and 2b). The share of soy has increased from 37% in 2000 because of higher international prices for the crop. The area planted under different crops can change rapidly depending on market prices, and we make no attempt to capture these fluctuations in the model. Instead, we rely on decadal averages to understand the impact of crop costs and revenues. Net revenue from crop planting was positive from 1998 to 2005 but turned negative in 2006, and the cash flow from soy mirrored this situation (Figure 1).[2] While it is difficult to know for sure, it is possible that the negative soy revenue may have been a reason for the reduced deforestation in the last few years. On the other hand, net revenue from cattle and beef has varied to a much lesser extent from 32% to 43% over the same period demonstrating its stability relative to that of the cash flow from annual crops.

- A cash flow stream over 10 years for cattle ranching in the state of Para' is provided by EMBRAPA (2006). We use this 10-year cash flow to estimate the net present value and internal rate of return for South America in the GCOMAP

[2] Values estimated from: production and revenues (IBGE, 2008); production costs and productivity (CONAB, 2008).

model for 60% of the deforested area. For the remaining area we use the cash flow for soy, cotton and rice estimated from crop budgets in the state of Mato Grosso in the year 2000 (CONAB, 2008), and discount it over a 10 year life. The internal rate of return (IRR) is 20% and 24% respectively for the two types of land uses. The averaged over NPV value is shown in Table 1.

With respect to South America, we assume that 15% of the timber in deforested areas is harvested and sold in domestic and international markets at prices commensurate with those for timber from long-rotation plantations (Table 1).

4.4 South East Asia

Indonesia accounted for about 1.9 Mha per year or about 68% of the forest cover change in South East Asia from 1990 to 2005. Myanmar, Philippines and Cambodia are the other major deforesting countries in the region. We focus our accounting on Indonesia because of its large contribution to forest cover change.

Unlike other regions, deforestation in Indonesia is driven by a combination of causes. These include small holder conversions, illegal logging, government-supported resettlement of vast regions such as in Sumatra and Kalimantan, large-holder oil palm plantations, etc. As reported by Rizaldi et al. (2007) for the Jambi province in Sumatra the proportion of lands being converted for these reasons varies across the landscape. Tomich et al. (2005) confirm this with an assessment of costs and causes of deforestation that are as varied as those reported by Rizaldi et al. (2007).

For Sumatra, Rizaldi et al. (2007) report the establishment cost, and net present value for 11 different types of planting options. These include tree planting for timber, fruits and nut trees, rice, rubber, oil palm, etc. Tomich et al. (2005) and Rizaldi et al. (2007) both report that perennial crops sequester carbon, and these values are reported in the papers as well. We use a weighted average of the values reported in the Rizaldi et al. (2007) paper to estimate the opportunity cost for a hectare of deforested land. Data on the share of land used for various uses across South East Asia or for that matter across Indonesia has not been collected to date. We assume that it follows the baseline pattern of land use that is reported in this paper, which includes illegal logging of trees for supply to neighboring timber mills, rubber, oil palm and timber plantations, and rice planting. The average NPV value weighted for a combination of these uses is reported in Table 1

With respect to South East Asia, we calculate that about 35% of the timber in deforested areas is harvested and sold in domestic and international markets at prices commensurate with those for timber from long-rotation plantations. The calculated percentage is based on the Jambi study reported by Rizaldi et al. (2007).

4.5 Choke Prices

The relevance of the values described above on GCOMAP results may be illustrated by examining the impact on choke prices in the earlier (Sathaye et al. 2006) and GCOMAP runs for this current report. Choke price refers to a constant carbon price that is high enough to completely halt deforestation. This price varies by region since the opportunity costs and carbon densities are different for each region.

In the earlier carbon price scenario analysis, the choke price ranged from $39/t C for Africa to about $281 for SE Asia. In the current runs, the choke price is typically lower or the same for each region (Table 3). This occurs because of the higher carbon density values for each region, and because the opportunity cost estimates are lower than earlier ones. The earlier estimates were based on relatively higher crop revenue.

The regional variation in crop revenue averaged over time and across crops is not as significant as that in the proportion of timber that is harvested from deforested area. Much of the difference in choke prices is accounted for by this variation. If we assume that timber is harvested from the same fraction of deforested area, say 20%, in each region then the choke prices are as shown in the last column in the table. Africa choke price is marginally higher than in Americas because of the planting of high cash value crops, coffee, cocoa, palm, and rubber, and subsistence agriculture, but little or no cattle ranching.

5 Transaction Costs

In order to assess the role of institutional barriers for crediting carbon abatement from reducing deforestation, we have investigated the magnitude of transaction costs of forestry projects arising for example from the associated project identification search, negotiation, feasibility studies, monitoring and verification, regulatory approval, and insurance costs (Antinori and Sathaye, 2007). The transaction costs are based on four data sets that covered project and programmatic data for a variety of energy supply- and demand-side, forestry, methane reduction, and other types of projects globally. Forestry projects were located in Brazil, Bolivia, Ecuador, Eritrea, India, and the US. The main conclusion for forestry projects was that

- Transaction costs varied from $0.1/t C for large projects to as high as $3.4/t C for small projects.
- Transaction costs ranged from less than one percent up to 20% of smaller projects.

One way to factor these costs in the GCOMAP analysis is to assume that the carbon price that farmers might benefit from would be reduced by the level of transaction costs noted above. Accounting for transaction costs, a carbon market price of $100/tC would translate into virtually the full $100 worth of carbon revenue reaching the farmer or in case of high transaction costs the revenue would be reduced to $97/tC revenue depending on the way the project is designed and implemented. This analysis was not conducted as part of the project, but it shows the relative magnitude of the impact of transaction costs on gross carbon revenue. The impact will be higher if the carbon price is lower and vice versa. Another element of the impact of transaction costs has to do with its effect on the speed with which carbon market rules are set up and implemented for market participants. The CDM market for instance has been slow to take off and its impact has been lower than desired by many industrialized countries. The rapidity with which markets can function and accommodate programs and projects is likely to have a much larger impact on carbon mitigation potential than the transaction costs.

References

Anger N. and Sathaye J. (2008). Reducing Deforestation and Trading Emissions: Economic Implications for the post-Kyoto Carbon Market. LBNL- and ZEW-Discussion Paper No. 08-016.

Antinori C. and Sathaye J (2007). Assessing Transaction Costs of Project-Based Greenhouse Gas Emissions Trading (Lawrence Berkeley National Laboratory, Berkeley, CA), LBNL Report 57315.

Busch, C. (2006). “Deforestation in the Southern Yucatán: Recent trends, their causes, and policy implications,” PhD diss., University of California, Berkeley.

Chomitz K., P. Buys, G. deLuca, T. Thomas and S. Wertz-Kanounnikoff. (2006). At Loggerheads? Agricultural Expansion, Poverty Reduction, and Environment in the Tropical Forests. IBRD / World Bank Policy Research Report. Washington D.C., USA

CONAB (2008). Datasets with annual crop budgets, available at www.conab.gov.br, “Central de Informacoes Agropecuarias” >> “Indicadores Agropecuarios” >> “Custos de Producao” >> “Safra de Verao – Serie Historica”.

Contreras-Hermosilla, A. (2001). Forest law enforcement—an overview. Working Papers Series, World Bank Institute. Washington, D.C (http://www.worldbank.org/wbi/)

EMBRAPA (2006). “Criação de Bovinos de Corte no Estado do Pará: Coeficientes técnicos, custos, rendimentos e rentabilidade.” Embrapa Amazonia Oriental, Sistemas de Producao, 3.

FAO (1993). Forest Resource Assessment (1990). UN Food and Agricultural Organization, Rome.

FAO (2001). Global Forest Resources Assessment 2000, Main report; UN FAO Forestry Paper 140, Rome.

FAO (2004). Yearbook of Forest Products. UN Food and Agricultural Organization, Rome.

FAO (2005): State of the World's Forests, Food and Agriculture Organization of the United Nations, Rome.

FAO (2007): State of the World's Forests, Food and Agriculture Organization of the United Nations, Rome.

Greenpeace (2003). Partners in Crime: A Greenpeace Investigation of the links between the UK and Indonesia’s timber Barons. http://www.saveordelete.com; http://www.greenpeace.org.uk/tags/illegal-timber

IBGE (2008). “Producao Agricola Municipal 1990-2006: Series Historicas.” IBGE Instituto Brasileiro de Geografia e Estatistica.

ITTO (2003). Annual Review and Assessment of World Timber Situation. Yokohama, Japan

Kazianga, H, and W. Masters. (2005). "Property Rights, Production Technology and Deforestation: Cocoa in Cameroon." [http://
www.columbia.edu/~hk2252/KaziangaMasters.pdf].

Kotto-Same, J et al (2000) Summary Report and Synthesis of Phase II in Cameroon. Alternatives to Slash and Burn ICRAF, Nairobi.

Kurukulasuriya P. and R. Mendelsohn 2006. A Ricardian analysis of the impact of climate change on African cropland. The Centre for Environmental Economics and Policy in Africa (CEEPA) Discussion Paper No. 8. University of Pretoria.

Makundi, W.R. (2001), 'Carbon mitigation potential and costs in the forest sector in Tanzania', *Mitigation and Adaptation Strategies for Global Change* **6**, 335–353.

Nabuurs, G.J., O. Masera, K. Andrasko, P. Benitez-Ponce, R. Boer, M. Dutschke, E. Elsiddig, J. Ford-Robertson, P. Frumhoff, T.Karjalainen, O. Krankina, W.A. Kurz, M. Matsumoto, W. Oyhantcabal, N.H. Ravindranath, M.J. Sanz Sanchez, X. Zhang, (2007): Forestry. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Naidoo, Robin, and Wiktor L. Adamowicz. (2005). "Economic Benefits of Bio-diversity Exceed Costs of Conservation at an African rainforest reserve." Proceedings of the National Academy of Sciences 102 (46): 16712-16.

Naidoo, Robin, and Wiktor L. Adamowicz . (2006). "Modeling opportunity Costs of Conservation in Transitional Landscapes." *Conservation Biology* 20 (2): 490-500.

Nepstad D. Stcikler C, and Almeida (2006). Conservation Biology, pp.1595-1603.

Norton-Griffiths, Michael, and Clive Southey. (1995). "The opportunity Costs of Biodiversity Conservation in Kenya." *Ecological Economics* 12 (2): 125-39.

Rizaldi et al. (2007). Assessment of carbon leakage in multiple carbon sink projects: a case study in Jambi province, Indonesia. *Mitigation and Adaptation Strategies Journal* 2007. 1169-1188.

Rhodes W., Allen E., and Callahan M. (2006), Illegal logging: A market-based analysis of trafficking in illegal timber. Unpublished Report. US Dept. of Justice. http://www.illegal-logging.info/uploads/traffiking_analysis.pdf

S.A., Sanchez, P.A., Ericksen, P.J. and Juo, A.S.R., eds. Slash and Burn: The search for alternatives. *(2005)*Columbia University Press, New York, USA
http://www.worldagroforestry.org/sea/Publications/searchpub.asp?publishid=1311

Sathaye, J., Makundi, W., Dale, L., Chan, P., and K. Andrasko (2005): "Estimating Global Forestry GHG Mitigation Potential and Costs: A Dynamic Partial Equilibrium Approach", *Lawrence Berkeley National Laboratory* Formal Report LBNL-55743.

Sathaye, J., Makundi, W., Dale, L., Chan, P., and K. Andrasko (2006): "GHG Mitigation Potential, Costs and Benefits in Global Forests: A Dynamic Partial Equilibrium Approach", *The Energy Journal*, Multi-Greenhouse Gas Mitigation and Climate Policy Special Issue, 95-124

Smith, J., J. Obidzinki, Subarudi and Suramenggala. (2003). Illegal logging, collusive corruption and fragmented governments in Kalimantan, Indonesia. *International Forestry Review* 5(3) pg 293-302.

Stern, N. (2007): *The Economics of Climate Change: The Stern Review*. Cambridge University Press, Cambridge

Tomich, T. P., Cattaneo, A., Chater, S., Geist, H.J., Gockowski, J., Kaimowitz, D., Lambin, E.F., Lewis, J, Ndoye, O., Palm, C., Stolle, F., Sunderlin, W., Valentim, J.F., van Noordwijk, M. and Vosti, S.A. (2005) "Balancing agricultural development and environmental objectives: Assessing tradeoffs in the humid tropics". In Palm, C.A, Vosti, S.A., Sanchez, P.A., Ericksen, P.J. and Juo, A.S.R., eds. *Slash and Burn: The search for alternatives* Columbia University Press, New York, USA http://www.worldagroforestry.org/sea/Publications/searchpub.asp?publishid=1311

WWF International (2002), The timber footprint of G8 and China.

Yaron, G. 2001. "Forest, Plantation Crops or Small-scale Agriculture? An Economic Analysis of Alternative Land Use Options in the Mount Cameroon Area." *Journal of Environmental Planning and Management* 44 (1): 85-108.

Figure 1: Profit margins based on variable costs only: Cattle revenue is stable over time compared to crop revenue in Legal Amazon in Brazil

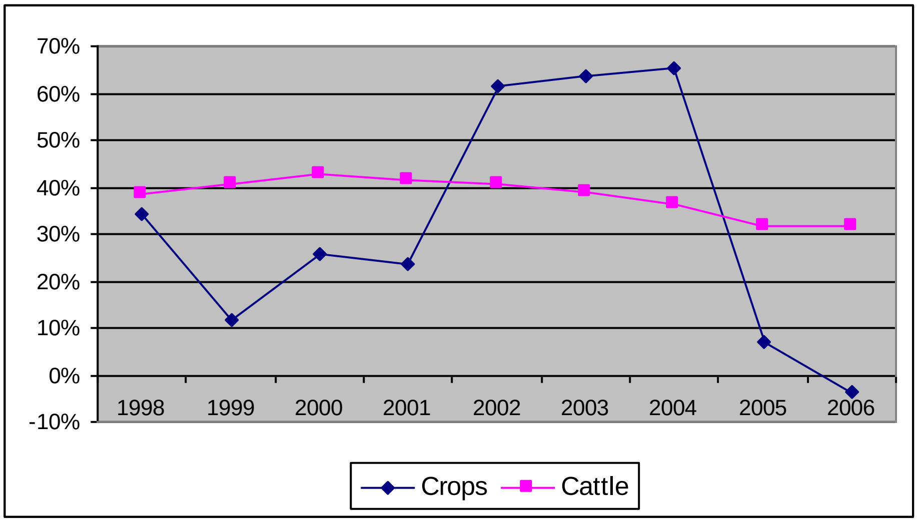

Figure 2a: Proportion of planted area in Brazil: Soy share has increased from 2000 onwards

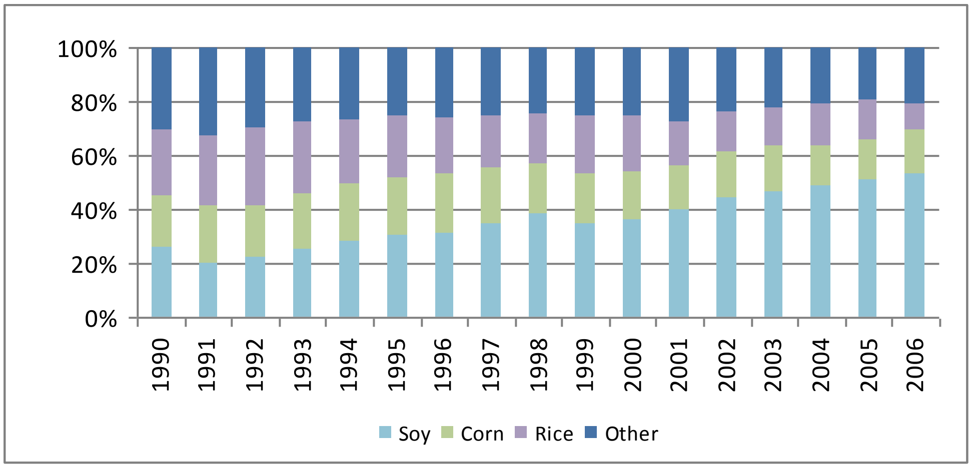

Figure 2b: Soy planted area and production

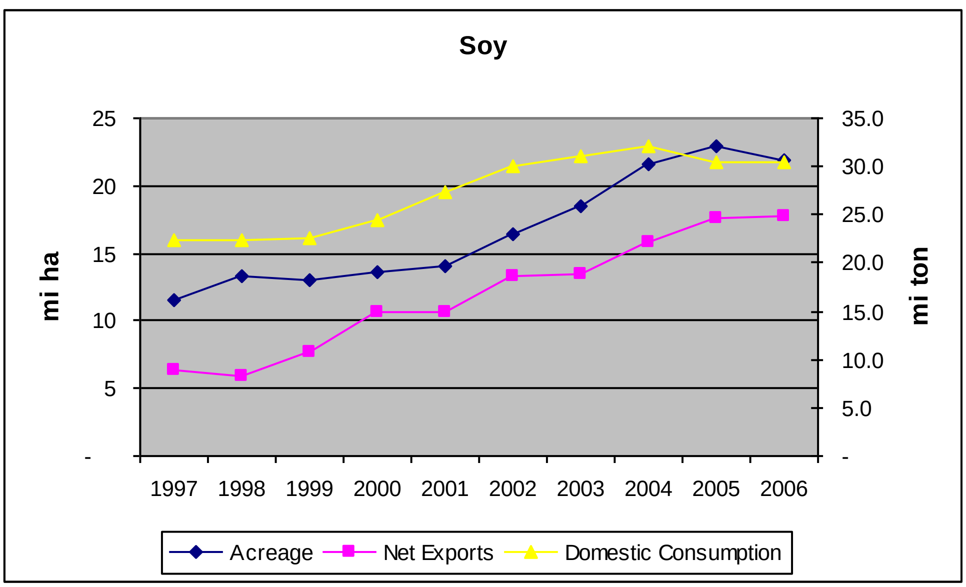

Table 1: Opportunity cost of land: Net Present Value (Includes cost and revenue streams of products noted for each region)

Region	NPV[1]	Included items	NPV[2]	% of Deforested Area Harvested
Africa	$169	Cocoa, palm, corn and rubber	$1258	10%
Central America	$158	Maize, chili pepper, cattle ranching	$300	15%
South America	$184	Soy, rice, cotton, cattle	$825	27.5%
South-east Asia	$143	Timber, oil palm, rubber, and upland rice	$897	35%

NPV[1]: Net Present Value (2000 US$ @20% over 10 years) per ha
NPV[2]: Net Revenue (2000 US$) from timber harvesting per ha

Table 2: Carbon density values in GCOMAP (2006) and GCOMAP (2008)

	Carbon Density (t C/ha)		
Region	GCOMAP (2006)	GCOMAP (2008)	% Change
Africa	74	98.4	33%
Central America	71	124	75%
South America	142	124	-13%
South-east Asia	68	101	48%

Table 3: Carbon Choke Prices

Region	Sathaye et al. 2006	Current	20% area- timber harvest
Africa	$39	$39	$115
C America	$127	$85	$105
S America	$147	$132	$100
SE Asia	$281	$250	$145