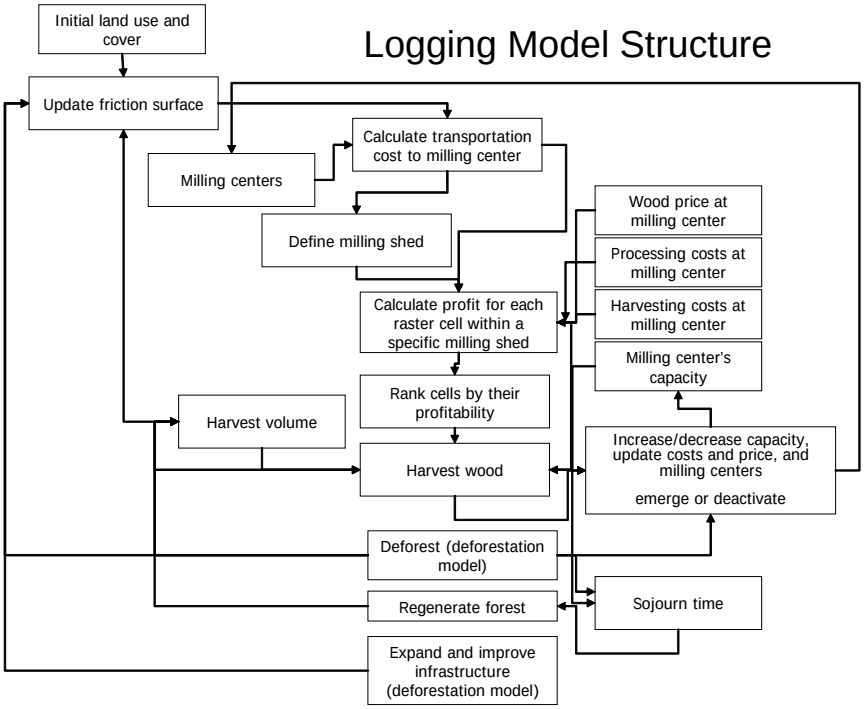
Supplementary material for "The costs and benefits of carbon emissions reductions from deforestation and forest degradation in the Brazilian Amazon"

The logging rent model

The model used is a 30-year partial equilibrium dynamic spatial simulation model of the Amazon timber industry – which calculates a residual stumpage value on forest lands, an annual harvest volume and value, potential tax revenues, and forecasts industrial capacity – we examine several future forest sector scenarios. For this research, a 30-year partial equilibrium model of timber harvesting in the Brazilian Amazon was developed. A residual analysis is used to calculate standing tree value or forest rent in each land unit (a raster cell of 2 by 2 km). Commercial volume is estimated for each available land unit using available geographical data and an initial demand corresponding to current logging capacity of processing centers. Processing centers are chosen to match municipal seats. A sawnwood price at the mill gate is specified for each processing center, and the model works backward to each land unit deducting relevant costs expended to transport wood from the land unit to the mill gate. The resulting value is the potential net rent from harvesting a particular forest land unit in a given location at a given point in time. This is known in economics as a residual or stumpage price. This stumpage price is multiplied by commercial volume at each land unit to arrive at an estimate of forest rent for the land unit. Our results from this modeling effort are now in review in the *Proceedings of the National Academy of Sciences*. In addition, the model had now been integrated into the Opportunity Cost model.



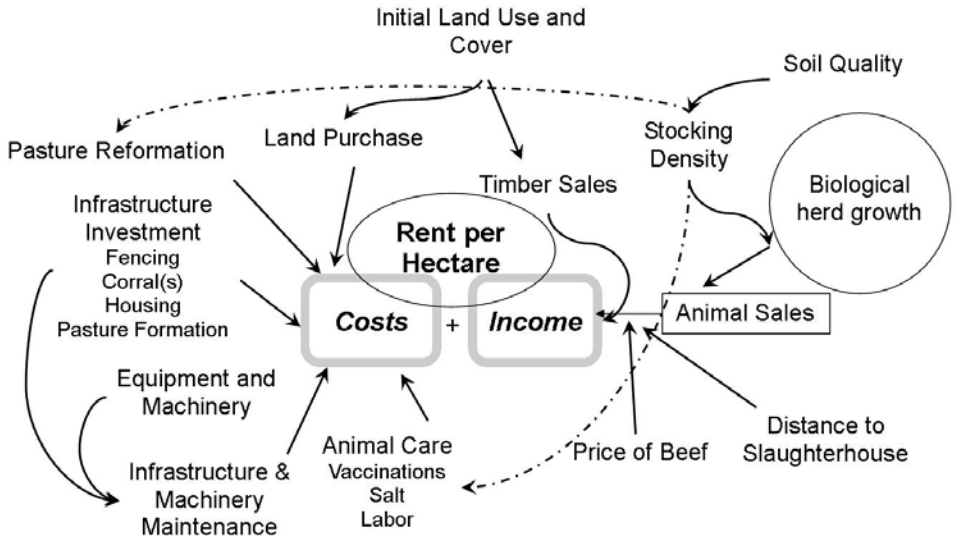
Source: Merry, F., B. Soares, D. Nepstad, G. Amacher and H. Rodrigues. A sustainable future for the Amazon timber industry. In review *Proceedings of the National Academy of Science*

The cattle rent model

For the cattle model we use a series of interconnected models to analyze returns to cattle production over a 30 year period. This model provides rent estimates based on a standard 500 hectare ranch. The model includes estimates of land prices in the Amazon, costs of conversion to pasture, a dynamic herd growth model, and spatial models of input prices. The combination of these underlying estimates allow us to calculate returns to beef production over a 30 year time horizon for any piece of land in the Amazon. We begin by identifying initial land cover, because each will have different costs of conversion. We calculate a price of land based on data from the Brazilian Institute of Geography and Statistics (IBGE) agricultural production values and area harvest. We use data from the logging model to estimate timber sales from conversion. The land owner then begins improving the land by investing in infrastructure and equipment. Simultaneously herd growth and costs are modeled with a biological herd growth model. As the breeding and fattening herd matures, animals are sold in the closet abattoir. Prices for beef are collected from various secondary sources.

Cattle Model Structure

Source: Merry et al. in prep**.**



The soy rent model

We used an interdisciplinary model to estimate soybean yields based on climate, soils, and economic determinants (Vera-Diaz *et a*l., 2007). We then adapted this model to simulate soybean profitability over a 30 year time-period based on variation in transportation costs due to road expansion and paving throughout the Amazon region (Soares-Filho *et al.*, 2006). We then constrained the soy rent model to produce positive rents only on suitable land for mechanized agriculture. The suitability map for mechanized agriculture takes into account four factors: the availability of flat land, appropriate soils, inundation free areas, and regions without climatic restrictions. The first was obtained using the SRTM topography dataset to produce an altitude deviance map and then setting visually, using published maps of soy field occurrence (Morton et al. 2006) a threshold to identify the flat lands. As a last step, a mode filter was applied to eliminate small areas, as mechanized agriculture need large tracts of land. Soil criteria excluded soils with strong edaphic restrictions, e.g.: ultisols with impeding soil clay horizons, lithosols, dysthropic podzols, sands, and hydromorphic soils. Flooding plains were mapped by expanding the altitudes on the major river channels to the surrounding regions and then defining a flooding threshold equal to the river altitudes plus 10 meters. Finally, regions with average annual precipitation above 2250 mm or above 0.5 mm per day during the four driest months were masked from the combined map, since they are too rainy to develop large-scale crops.

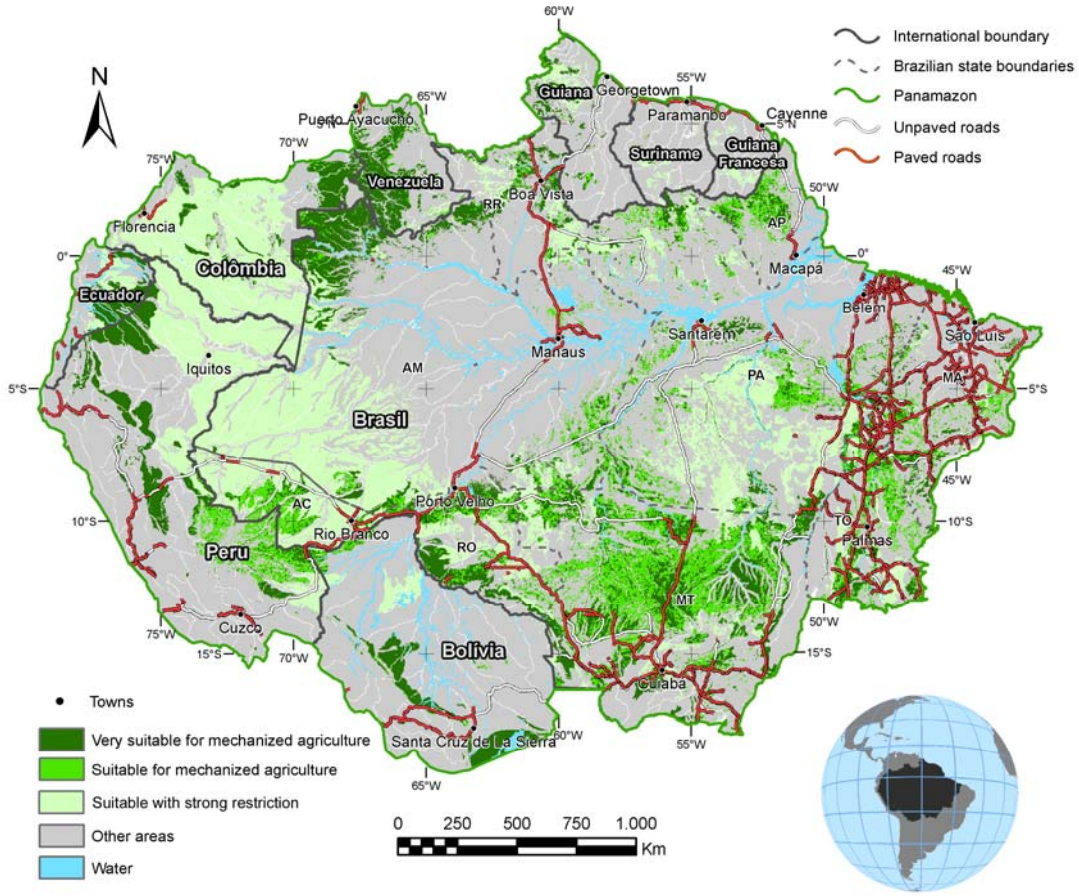


Figure 1. Map of soil and climate suitability for soybean production. This map was used as a filter to restrict the areas in the Amazon where positive soy rents are possible. Source: Nepstad e*t al.* (in press)

Forest Family Compensation:

The forest family compensation of one half of a minimum salary ($100 per month per family) used in this report was selected through analysis of existing programs in the Brazilian Amazon designed to provide incentives to those farmers who are shifting away from their dependence on slash-and-burn agriculture. The first of these programs is the *Programa de Desenvolvimento Sustentável para a Produção Familiar Rural da Amazônia* (Sustainable Development Program for Family Agriculture in the Amazon) (GTA 2007), which was initiated by organizations of smallholder farmers along the Transamazon highway in collaboration with the Instituto de Pesquisa Ambiental da Amazônia (IPAM) in 2001. The purpose of this program was to compensate smallholder families, organized in regional centers called “polos”, for their role in protecting or recovering ecosystem services. The program evolved through meetings among smallholder organizations, IPAM, and other institutions, developing organizational structures and systems for self monitoring. The program was adopted by the federal

government of Brazil in 2003, which allocated funds to initiate some of the first compensations to forest families. In the case of the Transamazon "polo", involving the municípios of Anapu, Pacajá, and Senador José Porfírio, 340 forest families received compensation of R$100 per month ($57 at current exchange rates) for six months and an additional R$126 per family ($72) for the purchase of agricultural tools, 9 community agents received minimum salary payments of R$380 ($217) for eight months, and 9 tree crop nurseries were constructed at a total cost of R$45.000 ($25,714). Although the compensation of the Transamazon Proambiente farmers was short-lived, it appears to have influenced farmer behavior, with most farmers establishing fruit trees and other crops to fulfill the legal requirement that 80% of each property in the Brazilian Amazon support forest cover (Kalif and Almeida, unpublished report). Twenty-eight percent of the income of 22 farm families evaluated was derived from perennial tree crops (primarily of cacau planted prior to 2006) and most of these families had expanded their area of tree crops through financial incentives and technical support that lasted less than a year.

The second program evaluated as a basis for establishing the per family compensation rate is the "bolsa florestal" (forest stipend) program of the State of Amazonas government. In March of 2007, the Amazonas goverment announced the creation of a fund for the compensation of forest-based farmers who defend their forests. The fund is now providing R$50 ($29) monthly payments to families, with the requirement that these families are taking steps towards reducing deforestation on their properties to zero, maintaining the children in school, and participating in community activities (Government of Amazonas 2007).

Perimeter Defense on Indigenous Lands

Interviews with indigenous leaders from the Kayapó and Panará tribes indicate that the average cost for patrolling indigenous reserve borders by truck or boat ranges from $7.00 to $8.40 per square kilometer (S. Schwartzman, unpublished data). We assume in the report that indigenous groups and other public forest stewards should receive $10 per square kilometer of forest reserve in support of perimeter defense.

Perimeter Defense in Protected Areas

We draw on analyses conducted in support of Brazil's protected area expansion program, called "Amazon Region Protected Areas" (ARPA, Ministerio de Meio Ambiente 2007) to estimate the costs of monitoring/patrolling existing public forests. We assume that an additional $20 per square kilometer will be needed for the government to effectively protect these areas and an additional $50 per square kilometer to establish new protected areas and develop management plans for these areas.

Increase in government services for forest people:

We based our estimates of the increase in services to forest families that would be necessary to increase the viability of these families as forest guardians using two methods using government statistics of current public outlays per family for public schools (primary education), the "family stipend" program ("bolsa família"), and the federal health system ("Sistema Única de Saúde"—SUS). These per family costs are summarized in Table 1. The "bolsa família" provides payments to families with children attending school as an incentive to keep them in school instead of sending them to the work force. The $700 per family increase in services represents a 45% in these three government outlays.

Table 1. Proposed REDD-financed increase in services to forest families in comparison with current government outlays for education, school stipend, and health.	
Annual Government Outlays per Family, Legal Amazon	
Primary education (assumes 2 students per family)[a]	$907
"Bolsa familiar" (pays families with school children)[b]	$426
Health (Sistema Unica de Saude, SUS)[c]	$232
Total	**$1,565**
Proposed REDD-financed increase in public services per family	**$700**
REDD funding as percent of current total	**45%**
Sources:	
[a]Instituto Nacional de Educacao Publica, www.inep.gov.br	
b contasabertas.uol.com.br/noticias/detalhes_noticias.asp?auto=1407	
[c]Datasus, 2007, www.datasus.gov.br	

Government payments for services in support of indigenous groups are divided between the Fundação Nacional do Índio (FUNAI), responsible for the administration of indigenous lands, and the Fundação Nacional de Saúde (FUNASA), responsible for indigenous health services, at a rate of $600 per individual per year, or approximately $3600 per family per year. The $700 REDD supplement would represent a 19% increase above this current level of government investment.

Literature Cited

Government of Amazonas State. 2007. http://www.sds.am.gov.br/programas_02.php?cod=1858

Kalif, K and O. T. Almeida. Unpublished. O potencial dos Sistemas Agroflorestais na recuperação de Áreas de Reserva Legal e Áreas de Preservação Permanente na região da Transamazônica, Pará. Relatório técnico de bolsa DTI, processo Nº: 38144520070. 2007.

Mattos, L., A. Faleiro, C. Pereira. 2001. PROAMBIENTE: Uma proposta dos produtores familiares rurais para criação de um programa de crédito ambiental na Amazônia. In:

IV Encontro Nacional da Sociedade Brasileira de Economia Ecológica (ECOECO). Belém/PA. 2001.

Ministério de Meio Ambiente. 2007. www.mma.gov.br

Nepstad, D., Stickler, C., Soares-Filho, B. S, Merry, F. Interactions among Amazon land use, forests, and climate: prospects for a near-term forest tipping point. Philosophical Transactions of the Royal Society B. (in press).

Soares-Filho, B. S., D. C. Nepstad, L. M. Curran, G. C. Cerqueira, R. A. Garcia, C. A. Ramos, E. Voll, A.McDonald, P. Lefebvre, and P. Schlesinger (2006), Modelling conservation in the Amazon basin, *Nature*,*440* (7083), 520-523.

Vera-Diaz, M. del C., R. K. Kaufmann, D. C. Nepstad, P. Schlesinger. 2007. An interdisciplinary model of soybean yield in the Amazon Basin: the climatic, edaphic, and economic determinants. *Ecological Economics* doi:10.1016/j.ecolecon.2007.07.015.