Agricultural impacts of reduced tropical deforestation

Steven Rose (EPRI)

Alla Golub (Purdue University)

Brent Sohngen (Ohio State University)

Tom Hertel (Purdue University)

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Introduction

Reducing carbon emissions by avoiding deforestation (RED) has been estimated to have large greenhouse gas (GHG) abatement potential (e.g., Kinderman et al., 2008, Wise et al., 2009, Busch et al., 2009), and could be especially valuable as a near-term abatement strategy in managing the long-run costs of attaining climate change objectives (e.g., USEPA, 2010). International negotiations regarding land-use, and land-use change related emissions have increasingly focused attention on RED, and in particular countries with high rates of deforestation.

However, RED will be challenging to implement—both programmatically as well as due to the complexity of interactions that complicate assuring net environmental integrity (e.g., Rose and Sohngen, in press). Much of this complexity derives from the fact that agricultural production is a primary driver for tropical deforestation, and the implementation of RED in one region, may transmit to other areas of the world through endogenous impacts on agricultural prices and land returns. However, there has been little discussion, and next to no analysis, of this issue in the policy debate. Agricultural implications of RED are not well understood. This paper estimates the implications of efforts to reduce GHG emissions through reduced deforestation, and seeks to quantify the associated uncertainties.

Approach

For this study, we employ two models—a dynamic global forest and land-use model (Choi et al., 2010; Sohngen and Mendelsohn, 2007) and a dynamic computable general equilibrium (CGE) model (Golub et al., 2009). With this approach we exploit the comparative strengths of both models as well as their complementary land allocation structures which have been designed to facilitate the transfer of information from one framework to the other. The forest and land-use model intertemporally optimizes the management (age, species, and intensity), extent, and protection of global regional forests for timber and carbon. By offering a fully intertemporal optimization of these factors, the model captures important forest investment responses to expectations about timber prices and carbon policies decades in the future, which are relevant to timber rotations and land cover decisions. In addition, the detailed modeling of forest decisions allows us to identify the unique impacts of regional tropical forest protection for prices and land rents. The dynamic, global CGE model takes RED-induced shifts in the forest access cost functions as exogenous inputs. It has been extended to include explicit land allocation and managed land expansion, as well as agricultural production input choice decisions across various agricultural (crop and livestock) sectors. With the CGE model, we can evaluate agricultural expansion and intensification responses, as well as impacts on global regional production, price, and consumption implications. With multiple crop and livestock sectors, heterogenous land types, input substitution opportunities, and bilateral trade, the dynamic CGE framework is ideal for estimating the array of market affects, including the responses of agricultural producers and national consumers.

In this analysis, we estimate the effects of reduced deforestation policies on the cost of tropical forest access using the forest and land-use model. Specifically, we estimate the implied changes in inaccessible forest access costs and acreage levels in response to RED policies with varying reduced deforestation outcomes. We also translate the deforestation response into land endowment elasticities. Specifically, we estimate the percentage change in regional land endowments (i.e., the managed cropland, pasture, and timber land) relative to the percentage change in weighted land rents. We estimate the elasticities for the baseline and RED policy cases and for each region and agro-ecological zone within each region (AEZ, Figure 1). The endowment elasticity provides a measure of responsiveness on how readily tropical forests are accessed for agricultural production when returns to agricultural land increase with and without RED incentives.

We can then introduce the estimated access costs or elasticities into the CGE model. Tropical forests are accessed only when value of land in a region is high enough to cover the cost of access; the later increases as less forest land is left unmanaged. Following Gouel and Hertel (2006), the marginal access cost function that we use is convex in the share of accessed forest such that, as the share of accessed forest increases, the cost of accessing an additional hectare rises. The costs of access become infinite as the last hectare of inaccessible forest is approached.

We adjust the cost function by the implied access cost response from the forest model. Before doing so, we first calibrate the CGE model's baseline access costs to the forest and land-use model's reference case. We then estimate the change in regional access costs in the forest and land-use model owing to the RED policies. These are then introduced into the global CGE model via shifts in that model's regional access cost functions, thereby permitting us to estimate the implications for tropical country agricultural expansion and intensification.

We also evaluate the implications for non-tropical country land-use, as well as the implications for agricultural sector income, the regional distribution of production and trade, consumer prices, and household welfare. In addition, we consider uncertainties in key economic parameters, such as the marginal productivity of land, trade elasticities, and the elasticity of substitution between land-using activities.

Results

Tropical forest access costs – baseline

For the moment, we focus on Brazil. In Brazil, deforestation occurs primarily in AEZs 5 and 6 (Figure 2). These AEZs contain sizable tropical forest area and lie closest to the agriculture frontier in Brazil. They also offer high productivity agricultural opportunities with growing periods up to 180 and 240 days per year respectively. On the other hand, AEZs 4 has a shorter growing period. AEZ 12 is similar to AEZ 6.

The average cost of accessing these lands for agricultural purposes is shown in Figure 3. AEZs 4 and 5 are the least expensive to access per hectare. The cost of access is much higher in AEZs 6 and 12. In particular, we see the rapid increase in access cost with cumulative deforestation in AEZ 6.

Avoided deforestation

To model avoided deforestation we introduce a \$50/tC (~\$14/tCO2) incentive to retain tropical forest carbon. An incentive of this size translates into a very strong signal for preserving this carbon, and therefore protecting tropical forests.[1] Figure 4 (vs. Figure 2) illustrates the substantial reduction in Brazilian deforestation. For example, the projected baseline deforestation rates of nearly 800,000 to over million hectares per year in AEZs 3 and 4 respectively are reduced to tens of thousands of hectares per year when the carbon in the forests is valued at \$50/tonne carbon.

Given the quantity of forest carbon protected (relative to the baseline), we can compute the implied increase in the cost of accessing tropical forests (Figure 5 – to be added).

By varying agricultural land rents, we also compute the baseline endowment elasticities (Table 1). From the table, we see that some regions and AEZs are more likely to expand the land endowment via deforestation with increased agricultural returns. For instance, Brazil AEZ5 is relatively responsive with an elasticity of 1.3. This overall elasticity is the result of reductions in managed forest land and cropland, but increases in livestock, which have the largest share of the total endowment land area. AEZ6 on the other hand has a negative elasticity with reductions in managed forest and cropland. However, the difference here is that these land types dominate the existing endowment. The other key difference between Brazil's AEZ5 and AEZ6, is the access costs. Deforestation is far cheaper in AEZ5 (Figure 3). As noted above, a RED policy for all practical purposes increases the cost of expanding the endowment. We would expect to

[1] This analysis does not consider additional costs associated with country and crediting investment uncertainty and transactions costs. These elements could represent substantial economic costs.

this in the endowment elasticity as well as a lower value. In other words, an increase in agricultural land rents results a smaller percentage change in the endowment.

Agricultural implications of reducing deforestation

To be added

- implications for tropical country agricultural expansion and intensification
- implications for non-tropical country land-use
- implications for agricultural sector income, the regional distribution of production and trade, consumer prices, and household welfare.
- We plan to also evaluate uncertainties in key economic parameters, such as the marginal productivity of land, trade elasticities, and the elasticity of substitution between land-using activities.

Conclusion (to be completed)

Policies designed to slow or prevent tropical deforestation will displace deforesting activities. This paper explores the potential implications for these activities locally, as well as the overall global distributional and welfare implications for society…

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Figure 1 – Global agro-ecological zones (maroon = tropical, green = temperate, blue = boreal)

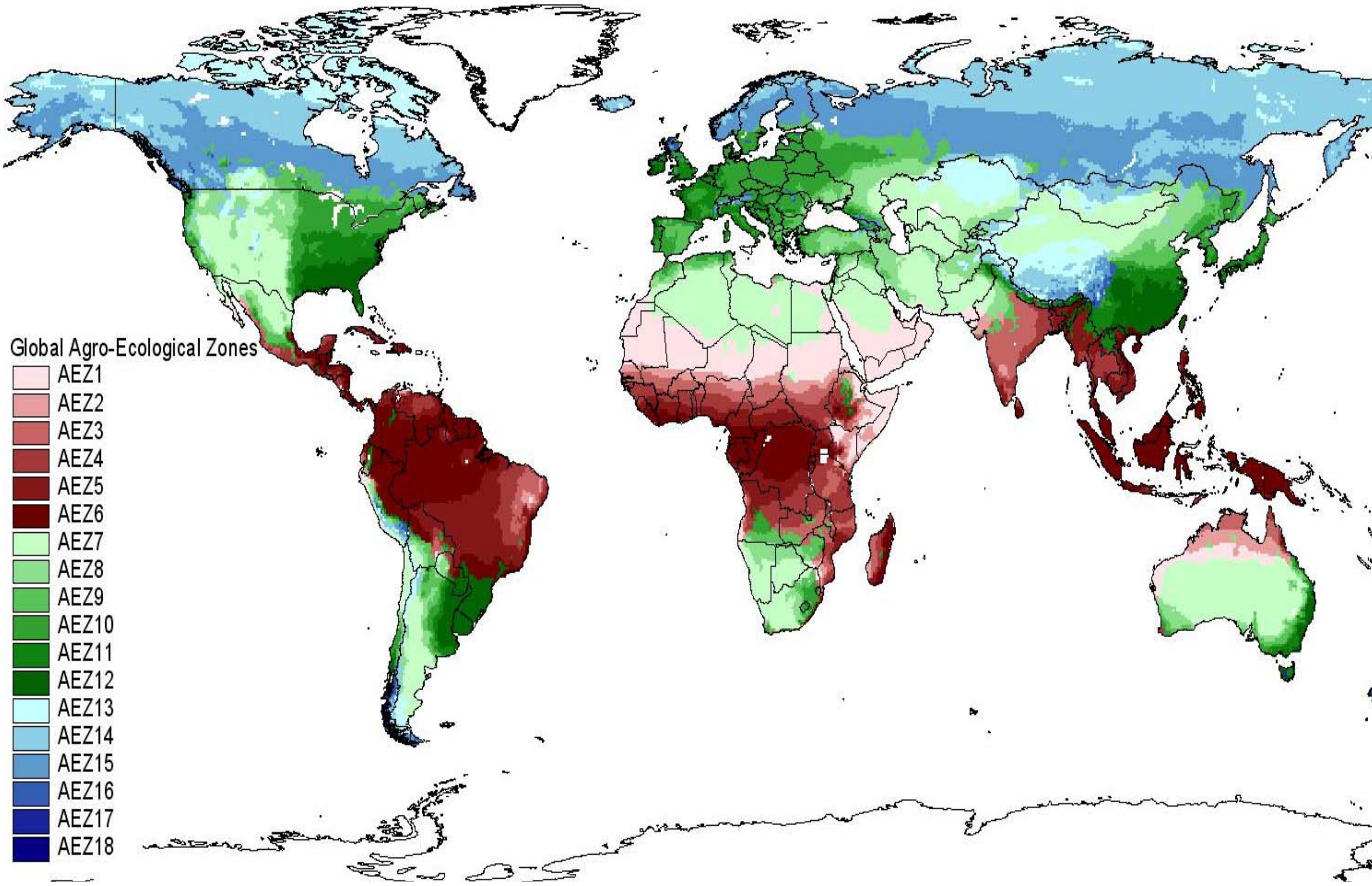

Figure 2

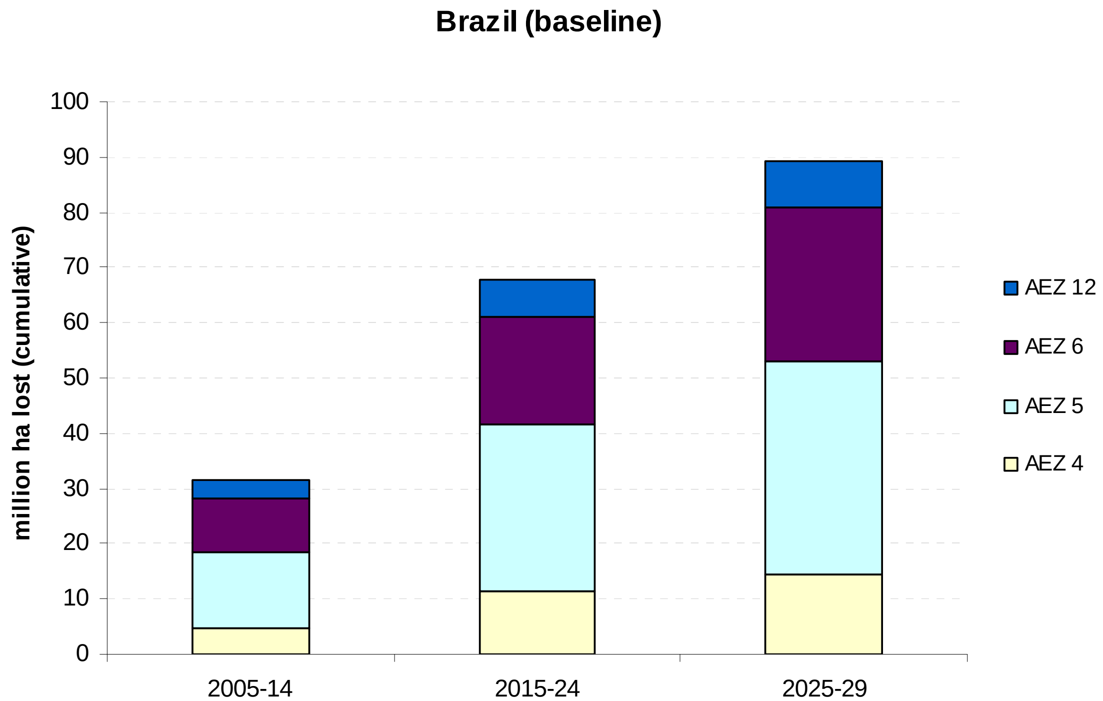

Figure 3

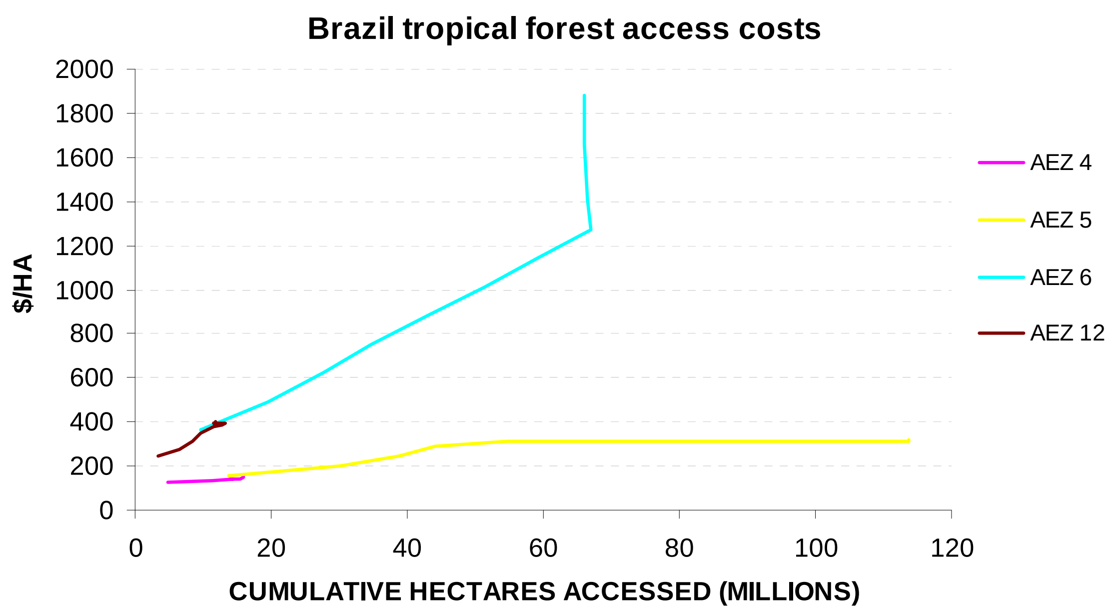

Figure 4

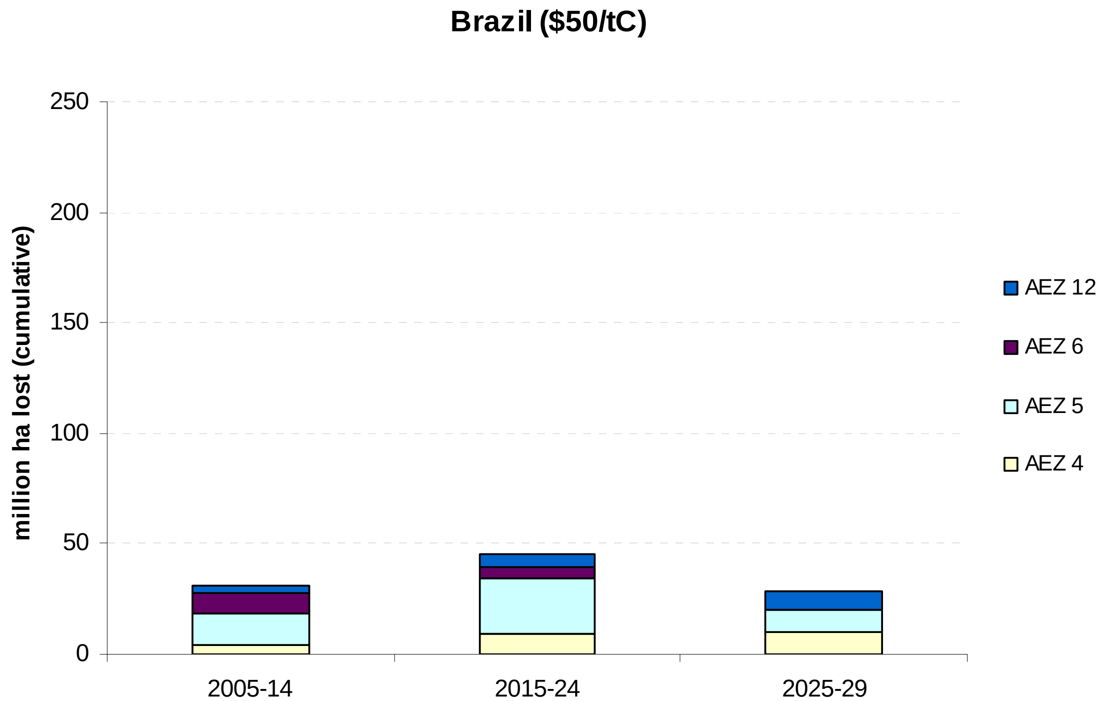
Brazil ($50/tC)
million ha lost (cumulative)
250
200
150
100
50
0
2005-14
2015-24
2025-29
AEZ 12
AEZ 6
AEZ 5
AEZ 4

Table 1 – Land endowment elasticities

		AEZs																	
		Tropical						Temperate						Boreal					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Brazil	forest				-3.5	-1.7	2.1						-1.0						
	crop				4.0	-9.0	-10.9						0.0						
	livestock				0.2	0.2	0.4						0.4						
	total				0.4	1.3	-1.1						-1.4						
C America	forest			-0.8	-0.5	-0.5	-4.6	-7.8	0.0	-0.6	-0.7	-0.9	0.9						
	crop		0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2						
	livestock		-0.1	-2.2	-0.1	-0.6	7.0	-13.9	-0.1	-0.1	0.2	-0.1	0.0						
	total		0.0	-0.1	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0						
Rest of S America	forest	0.0	0.5	-1.2	-43.4	0.6	-0.3	-1.2	-0.7	-156.6	-5.1	-0.9	-1.2	8.9	-2.1	4.3	0.0	-4.3	
	crop	0.8	0.0	0.0	0.6	0.3	0.2	0.3	0.7	0.3	0.4	0.4	0.4	0.4	0.7	0.0	0.0	0.0	
	livestock	0.0	0.6	3.2	2.3	-2.0	4.1	-0.8	0.5	-0.2	-0.8	1.4	2.5	-0.1	1.2	2.3	0.0	7.3	
	total	0.2	-0.4	0.0	0.0	0.0	-0.3	0.2	0.0	0.0	0.1	0.0	0.3	-0.1	0.0	-0.2	0.0	-0.2	
SSA	forest		-1.1	-1.2	-2.0	-2.8	-2.4		-0.7	-0.9									
	crop	0.0	0.4	0.0	0.1	-0.1	-0.2	-0.3	0.4	0.4	0.4	0.4							
	livestock	0.1	0.1	0.1	0.2	0.2	0.5	0.1	0.1	0.1	0.2	0.1							
	total	0.4	0.3	0.5	1.4	0.5	0.4	0.1	0.3	0.3									
SE Asia	forest				-0.7	-0.3	-0.6				-0.3	9.3							
	crop				0.4	0.5	0.4				0.6	0.7							
	livestock				1.2	0.5	-0.1				0.7	0.1							
	total				0.0	0.1	0.2				-0.2	1.6							
Africa ME	forest		-0.4	-0.5															
	crop	0.0	0.0	0.0				0.0	0.0	0.0	-0.1								
	livestock	0.0	0.5	0.3				0.0	0.0	0.0	0.1								
	total	0.1	-0.4	-0.5				0.0	0.0	0.0	0.0								