Induced Land Use Change Associated with US Soy Biodiesel

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The objective of this paper is to present the results of a new analysis of the induced land use change associated with US soy biodiesel. A specialized version of the GTAP-BIO model was used for this analysis. The new version of the model incorporates some new parameters and a new nesting structure for land cover. The full description of the changes in the model is contained in a paper by these same authors entitled "Biofuels and Land Use Change: Applying Recent Evidence to Model Estimates."

The research reported in that paper was motivated by recent changes in global land use. Earlier in the development of biofuels, there was little global land use change because the size of the biofuels programs was relatively small. However, in the past decade, there have been substantial changes in global land use induced partly by higher commodity prices. Global harvested area has increased 72 million hectares (173 million acres) between 2002 and 2010 (see Figure 1), after having been essentially constant for the proceeding decade. Thus, we now have evidence that was not available before on how much change has occurred globally. We also have evidence on where land use change has been occurring (see Figure 2). The evidence indicates that Sub-Saharan Africa, China, South America, and Southeast Asia are the regions with the most land use change. The evidence also shows that the US, EU, and Canada have had little change in total crop acreage.

The previous work we and others have done using GTAP reflects a very different global distribution of land use change. Previous model results have more of the land cover change occurring in the US, for example, yet the reality is that total crop acreage has changed very little. This discrepancy suggested to us that we needed to recalibrate the parameters in GTAP that partially govern land cover change. In the previous version of the model the CET (constant elasticity of transformation) parameter was -0.2 for all regions of the world. Thus, there was no regional differentiation. The evidence suggests otherwise, so we recalibrated the CET parameters and grouped the GTAP regions into four groups with very low, low, high, and very high land cover transformation. Specific parameters will be presented below.

The second issue motivating the model changes has to do with land transformation between forest or pasture and cropland. In the standard version of GTAP, the land cover nest has forest, pasture, and cropland in one nest implying, everything else being equal, that the ease of transformation between forest and cropland and pasture and cropland is the same. Yet, we expect that it is much easier and less costly to transform pasture to cropland than forest to cropland. The remedy we chose is to change the nesting structure for land cover as shown in Figure 3. In the new nesting structure, cropland and pasture substitute directly, and that composite substitutes with forest. We then tested new CET parameters for the two levels of transformation.

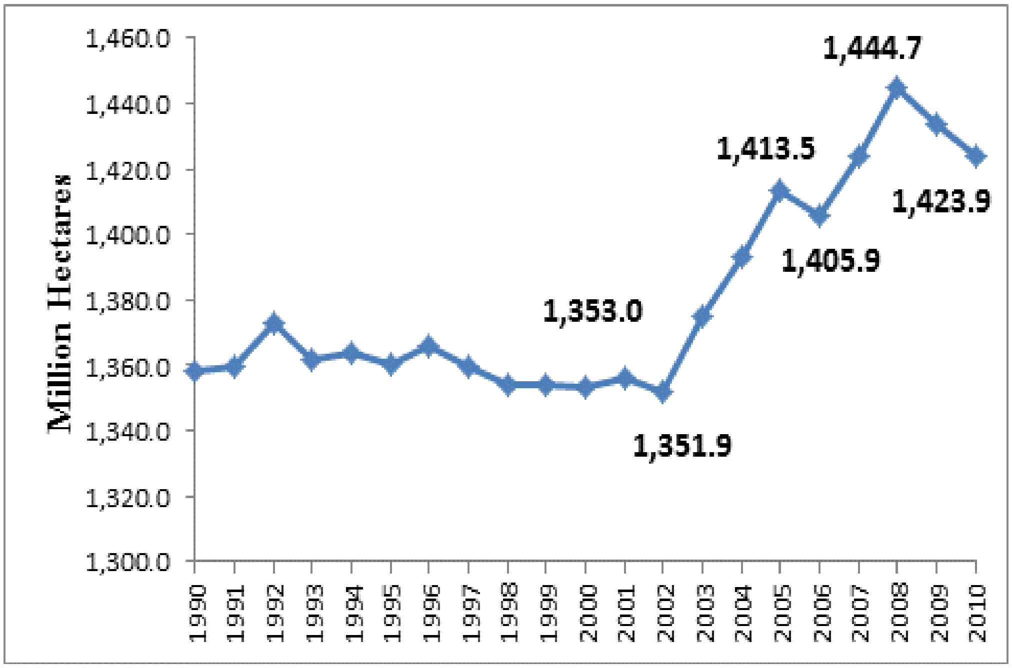

Figure 1. Global Harvested Area, 1990 – 2010

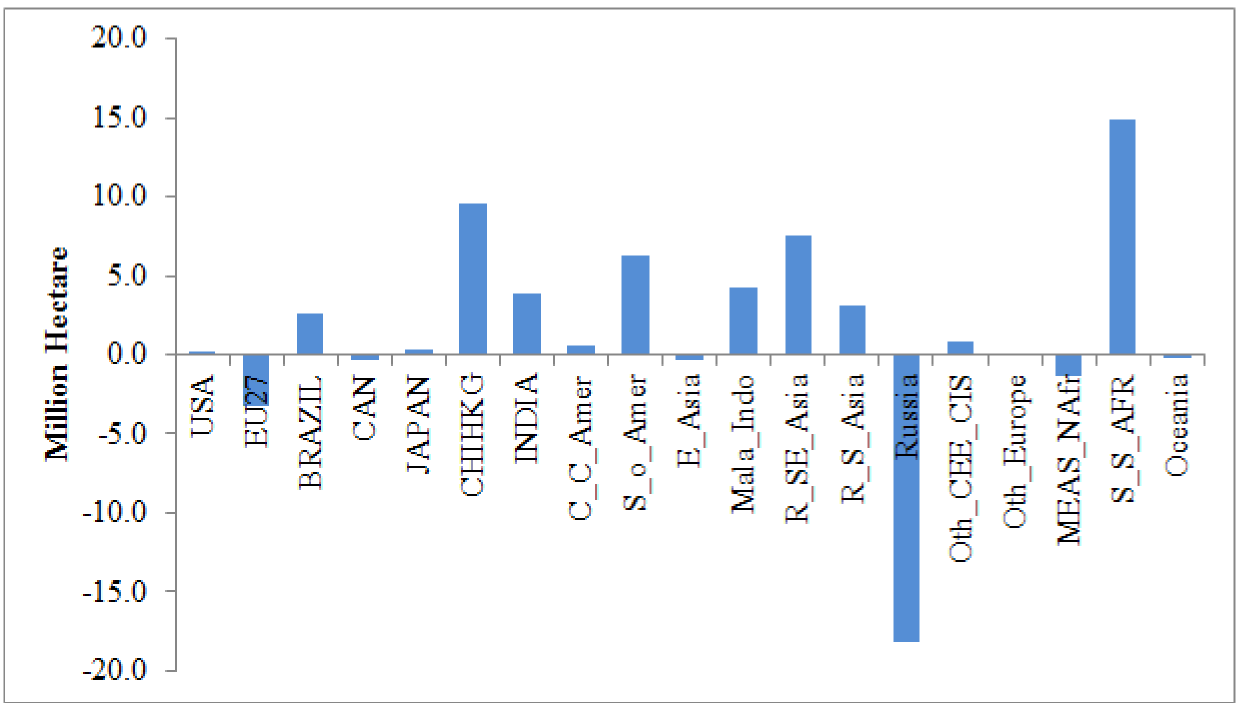

Figure 2. Change in Harvested Area by Region, 2004 -2010

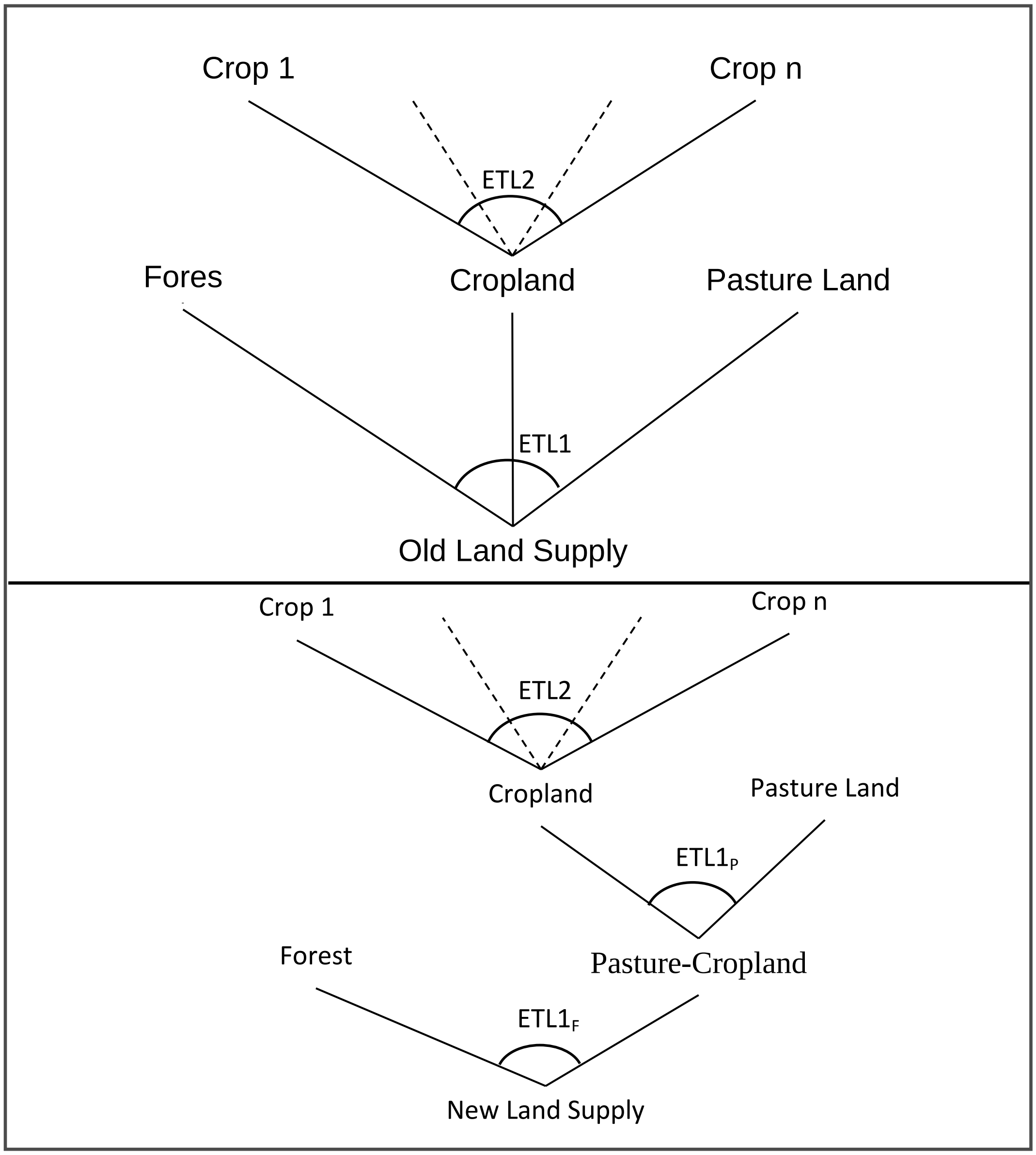

Figure 3. New and Old Land Supply Trees in the GTAP-BIO Model

Finally, we observed that substitution among crops appears stronger in some regions than others, so we also adjusted the cropland CET parameter by region. All of the new parameters are shown in Table 1. The ETL1 parameter in Table 1 is the parameter from the regional analysis described above. To adapt that parameter to the new nesting structure, we created ETL_F and ETL_P reflecting a somewhat greater east of transforming pasture to cropland than forest to cropland. The ETL2 parameter is the CET for the cropland nest, which now also varies by region.

For this paper, we used the modified model as described above to simulate the land use change impacts of the US soy biodiesel program. The simulations were done with a shock of 812 million gallons of soy biodiesel, assuming the rest of the biodiesel component of the RFS would come from other sources.

Table 1. Tuned Regional Land Cover Transformation Elasticities

Regions	Rank in land cover change	Tuned ETL1	Tuned $ETL1_F$	Tuned $ETL1_P$	Tuned ETL2
Oth_Europe	Very Low	-0.02	-0.018	-0.0218	-0.25
Oceania		-0.02	-0.018	-0.0218	-0.25
CAN		-0.02	-0.018	-0.0218	-0.25
USA		-0.02	-0.018	-0.0218	-0.75
MEAS_NAfr		-0.02	-0.018	-0.0218	-0.25
Oth_CEE_CIS		-0.02	-0.018	-0.0218	-0.75
C_C_Amer		-0.02	-0.018	-0.0218	-0.25
EU27		-0.02	-0.018	-0.0218	-0.75
INDIA	Low	-0.1	-0.0909	-0.1091	-0.25
R_S_Asia		-0.1	-0.0909	-0.1091	-0.25
Russia	High	-0.2	-0.1818	-0.2182	-0.75
JAPAN		-0.2	-0.1818	-0.2182	-0.5
CHIHKG		-0.2	-0.1818	-0.2182	-0.25
E_Asia		-0.2	-0.1818	-0.2182	-0.5
BRAZIL	Very High	-0.3	-0.2727	-0.3273	-0.5
R_SE_Asia		-0.3	-0.2727	-0.3273	-0.5
Mala_Indo		-0.3	-0.2727	-0.3273	-0.25
S_o_Amer		-0.3	-0.2727	-0.3273	-0.25
S_S_AFR		-0.3	-0.2727	-0.3273	-0.5

The simulation results are presented in Table 2. The simulation was done with the original GTAP CET values and nesting structure and the revised parameters and nesting structure. With the original parameters and structure, the land requirement per 1000 gallons of biodiesel is 0.33. With the revised CET parameters and nesting structure, the land requirement is 0.18 hectares per 1000 gallons. Globally, 270,000 hectares of cropland is added with the old parameters and model, and 142,000 in the new version. In the US, 150,000 hectares is added with the old version, and 23,000 in the new version. As expected, most of the land use change is outside the US, which better matches what has been happening in the real world. A bit over a million hectares of soybeans are added globally in both versions with almost all of it in the US. However, most of that land for soybeans comes from switching from other crops rather than land conversion, which also better reflects what has been happening in the real world.

The bottom line is that the new model and parameters do a much better job of representing land use change than the old version. Also, and not by design, the land use requirement for soy biodiesel falls substantially from 0.33 to 0.18 hectares per 1000 gallons of biodiesel.

Table 2. Global Land Use Implications of US Soy Biodiesel (1000 hectares)

	Land cover	US	EU	Brazil	Others	Total
Original parameters and land cover nest	Forest	-70	-5	7	50	-17
	Crop	150	14	7	99	270
	Pasture	-80	-9	-14	-150	-252
	Cropland Pasture	-198	0	-17	0	-215
	Soybeans	1064	-1	-2	-64	997
Revised parameters with regional ETL1&2, and new land cover nest	Land cover	US	EU	Brazil	Others	Total
	Forest	-13	-1	13	20	19
	Crop	23	4	13	103	142
	Pasture	-10	-3	-26	-123	-162
	Cropland Pasture	-273	0	-13	0	-287
	Soybeans	1,045	-1	0	-38	1,007

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