Effect of Recent Expert Working Group Recommendations on California Low Carbon Fuels Standard (LCFS) Corn Ethanol Land Use Change Emissions Estimate

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1.0 Introduction and Summary

At the October LCFS Expert Working Group (EWG) meeting, the various EWG subgroups provided their draft recommendations for future CARB efforts and improvements related to land use change (LUC) modeling. In most cases, these recommendations were broken down into shorter-term and longer-term research recommendations. This recognizes the fact that land use modeling is still evolving and still quite uncertain. Modifications to various factors could significantly affect the current estimates.

The purpose of this analysis, which was commissioned by the Renewable Fuels Association (RFA), is to estimate the likely LUC emission impacts of some of the key shorter-term subgroup recommendations. We used the latest version of GTAP to perform this analysis (Tyner et al. 2010). We found that using the Winrock emissions factors and enabling access to CRP in conjunction with the Group 2 modeling runs from Tyner et al. results in corn ethanol ILUC results in the range of 11-12 g CO2e/MJ. This is roughly 60% lower than CARB's current estimate of 30 g CO2e/MJ. The table below summarizes the results of our analysis.

Table 1. Summary of Results, Average LUC from 2001 to 15 bgy	
Scenario	**Emissions, g/MJ**
Tyner et al. Group 2 replicated	17.36
Tyner et al. Group 2 without HWP	20.14
Tyner et al. Group 2 with 25% HWP and with CRP	17.06
Tyner et al. Group 2 with CRP and Winrock EFs	11.97

Other subgroup recommendations (such as the longer-term suggestions to improve modeling of co-products, improve the GTAP model's CET function, and incorporate more robust approaches to modeling yield and demand growth) likely would push the ILUC value even lower, but it was not possible to quantify those impacts for this analysis.

2.0 Subgroup Recommendations

Table 2 below contains a summary of many of the subgroup recommendations. Where we felt qualified to do so, or where information was provided by the subgroups, we have added our preliminary assessment of the likely directional impacts on the current corn ethanol ILUC emissions estimate (30 g CO2e/MJ). Recommendations that are bolded and italicized were considered for our GTAP analysis, which is described in the next section.

TABLE 2. SUMMARY OF SUBGROUP RECOMMENDATIONS	
SUBGROUP NAME AND RECOMMENDATIONS	**POTENTIAL IMPACT ON CARB CORN ETHANOL ILUC VALUE**
TIME ACCOUNTING SUBGROUP	
• No consensus recommendations	
• Alternative Methodologies:	
○ Baseline time accounting	Reduces ILUC emissions to 11-12 g/MJ
○ Time-shift accounting	Results in ILUC emissions of 4-37 g/MJ
○ Fuel warming potential	Results in ILUC emissions of 26-46 g/MJ
COMPARATIVE MODELING SUBGROUP	
• Provided qualitative, longer-term recommendations	
LAND COVER TYPES SUBGROUP	
• "Incorporate estimates of time-dependent yield improvements in all land calculations."	Likely reduces ILUC
• ***"Incorporate TEM (Terrestrial Ecosystem Model) methodology for estimating yield on new land introduced as a result of biofuels."***	***Reduces ILUC***
• "Incorporate more robust approaches to estimating food demand and future yield improvements."	
• "Allow for scenarios of yield improvement reflecting both technology improvement and closing of the yield gap across climate-similar areas of the world"	
• "Update to improved SAGE / M3 cropland and pasture data"	
• "Update to contemporary land cover map"	
• "Reconsider area of inaccessible forest"	
• "Include more unmanaged land"	
• ***"Access CRP classes"***	***Potentially reduces ILUC***
• "Add new land pools including marginal lands and peatlands"	
• "Develop hybridized ecosystem type database"	
• "Develop regional look-up-tables or modifiers that can help adjust CET function results"	
• "Develop CET functions for each region"	
EMISSIONS FACTORS SUBGROUP	
• ***"Evaluate the spatially-explicit Winrock database as a basis for estimating biomass C stock by AEZ"***	***Likely reduces ILUC***
• "Supplement with databases to improve the accuracy of certain regions/eco-system types (such as peatlands), or to include the consideration of certain factors (e.g. forest degradation and fire)"	
• ***"Provide clear justification for the consideration of C stored in harvested wood product (HWP)"***	***No impact. Current CARB value does not include HWP credit.***
• "Provide clear justification for the consideration of other non-land conversion emissions"	No impact. Current CARB value does not include non-land conversion emissions
• "Conduct sensitivity analysis on the effects of non-	

Kyoto climate forcing gases and particles”	
• “Perform uncertainty analysis, including uncertainty propagation and uncertainty importance analysis”	
CO-PRODUCTS SUBGROUP	
• “ARB should re-evaluate its use of a 1:1 displacement of feed corn by DGS to include other components (e.g., SBM and urea) and available data on displacement ratios as a function of animal type and region.”	Potentially reduces ILUC
• “Effort should be made to ensure consistency in co-product treatment between GTAP and GREET.”	Potentially reduces ILUC
• “ARB should re-evaluate the iLUC estimates for soy biodiesel based on the most recent GTAP model.”	Likely reduces ILUC for soy biodiesel
• “ARB needs to be mindful that if biofuels produced from oilseeds beyond soy are introduced into California, work will be needed to properly assess co-product credits.”	
ELASTICITY SUBGROUP	
• ***“Adopt the value of [the elasticity of yield with respect to area expansion] parameter by region as documented in Tyner et al. (2010).”***	***Reduces ILUC***
• ***“Keep the yield elasticity with respect to price at 0.25.”***	***No impact or slight increase to ILUC***
• “Adopt the same combination of elasticities for all biofuel pathways.”	
• “Develop a better method to increase flexibility in the function that determines own and cross-price substitution elasticities across land cover types.”	Reduces ILUC
INDIRECT EFFECTS OF OTHER FUELS SUBGROUP	
• Provided qualitative, longer-term recommendations	

Time Accounting Subgroup

The recommendations coming out of this subgroup could increase or reduce corn ethanol LUC emissions. Both CARB and EPA have so far modeled land use emissions on a 30-year basis with no discounting. For our analysis, described in the next section, we have continued this practice.

Comparative Modeling Subgroup

These recommendations were more general and intended for longer-term implementation. Their impact on corn ethanol LUC emissions is unknown.

Land Cover Types Subgroup

This subgroup’s recommendation to include TEM methodology has already been demonstrated in Tyner et al. (2010). The ability to include Conservation Reserve

Program (CRP) lands was also included in the version of the GTAP model used for the Tyner et al. paper, but the feature that allows the model to access CRP land was turned off.

Emission Factors Subgroup

Among this subgroup's recommendations was to examine the impact of using the Winrock emissions data in conjunction with GTAP. Using the Winrock data with GTAP is something that has not been done yet. The GTAP model used by CARB uses the Woods Hole data for both forest and pasture conversion to crops. CARB assumes all of the above-ground forest and grassland carbon is released, and 25% of the below-ground carbon is released. Generally, the Woods Hole data estimated forest and grassland carbon for undisturbed systems.

EPA used the Winrock data in its LUC analysis for the RFS2. Conversion emissions are estimated for forest, grassland, savannah, brushland, and other land cover types. The Winrock data also includes the use of the CENTURY and DAYCENT model to estimate soil carbon changes upon conversion.

The Tyner et al. (2010) paper assumed that 25% of the above ground forest carbon from the Woods Hole data was converted to hardwood products (HWP) and stored indefinitely in those products or eventually in landfills. The modeling performed by CARB utilizes the Woods Hole data without the adjustment for HWP. The Winrock data also assumes no conversion of above-ground forest to HWP.

Neither the CARB modeling nor the Tyner et al. (2010) paper include non-land use emissions (for example, reduced rice methane emissions or reduced methane emissions from smaller livestock herds brought about by slightly higher feed prices).

Co-Products Subgroup

This subgroup recommended that CARB should revisit its assumption that 1 lb. of DDGS simply replaces 1 lb. of corn in livestock rations. There has been an ongoing debate regarding the economic modeling of co-products use versus displacement modeling. The two methods should provide about the same "answer" in terms of LUC effects, but they currently do not. The economic assumptions contained in GTAP for both the CARB and Tyner et al. work provide less land use benefit than displacement modeling. That being said, incorporating co-products in the manner undertaken by Tyner et al. still reduces land use by corn ethanol by over 30%.

The consistency, or lack thereof, between the GREET model and GTAP land use modeling is still being discussed. Improving consistency between these two models will not likely reduce the land use credit of the co-products--if anything it could increase it.

The Tyner et al. paper only evaluated the LUC impacts of corn ethanol. We believe this analysis needs to be expanded to soybean biodiesel, sugarcane ethanol, and other feedstocks as well.

Elasticity Subgroup

The first recommendation from this subgroup (i.e., to adopt the TEM approach for estimating yields on newly converted lands) is the same as a recommendation from the land cover types subgroup. Keeping the price-yield elasticity at 0.25 was followed in Tyner et al. (2010), so this has already been done and the impacts are understood. This subgroup's recommendation to adopt the same elasticities for all biofuel pathways is a reference to the manner in which CARB changed elasticity assumptions between its corn ethanol, sugarcane ethanol, and soybean biodiesel modeling.

Summary

It is clear that most of the short-term recommendations from the subgroups are embodied in Tyner et al. (2010) prepared for Argonne National Laboratory. More specifically, they are embodied in the "Group 2" modeling of the Tyner 2010 paper. The two items discussed here that were not included in the Tyner work are: 1) Access to the CRP land; and 2) Use of the Winrock emissions data.

It should also be noted that Tyner et al. (2010) assumed 25% of above-ground forest carbon goes to HWP. This was an issue that was considered, but rejected by CARB in the LCFS rulemaking. The original CARB ISOR indicated CARB's intent to include a 10% factor for HWP, but this credit ultimately was not reflected in the final corn ethanol LUC estimate.

AIR has replicated all of the corn ethanol modeling in the Tyner et al. (2010) paper (Group 1 - Group 3, see Attachment 1 for results of this analysis). In this analysis, we also evaluate the use of CRP land, the impacts of using the Winrock data, and the impact of the 25% HWP assumption.

There are several EWG recommendations that deserve attention and likely will have impacts on the LUC value for corn ethanol (and other biofuels as well), but we have not analyzed these in this paper because a simple method for integrating these other recommendations into GTAP was not readily apparent. Some of these issues are discussed below:

- It is clear from the Argonne corn ethanol co-product analyses that distillers' grains replace some soybean meal (in addition to corn) in dairy, poultry, and swine rations. But because of the manner in which the GTAP model is programmed, there is virtually no substitution of DDGs for soybean meal inside the model. If DDGs were substituted for some soybean meal, the land use credit for DDGs, already at about 30%, would be higher. This is an area for future research.

- The report from the elasticity subgroup recommends work on GTAP with regard to the CET function. As the report indicates, "the numbers in the GTAP version used by CARB are too high in the case of forestland, since they should be lower than the module of -0.05 even under a 100-year time frame." The upshot of the current CET function is too much forest is converted. So, with a revised function, the forest converted would be less, leading to lower overall emissions.

- The Land Cover Types subgroup recommended "incorporating more robust approaches to estimating food demand and future yield improvements". The Group 3 results in the 2010 Tyner paper did just that, by estimating demand increases, and incorporating in the model a very modest 1% yield increase. This resulted in lower emissions than the Group 2 results.

- The Emission Factors subgroup also recommended performing sensitivity analysis of impacts on other GHGs. This would also reduce emissions, as EPA has shown in its analysis that incorporated these factors (e.g., reduced methane emissions from less rice cultivation and smaller livestock herds).

3.0 Analysis

Tyner et al. (2010) Modeling

The Group 2 modeling results (average emissions) for corn ethanol performed by AIR are shown in the table below. For more information on these scenarios, please see the Tyner et al. paper. These values include the 25% HWP effect. We show both the marginal emissions and average emissions. The marginal emissions are slightly higher than the average emissions. The average emissions from 2001 to 15 bgy is 17.36 g/MJ. By comparison, the ILUC emissions used for corn ethanol in the CARB LCFS are 30 g/MJ.

Group 2, GTAP-Argonne EFs

Marginal Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.86	1.43	4.29	926	465	1,391	11.27	5.66	16.93
2006 level to 7 B gal	2.145	2.19	0.86	3.04	1,019	399	1,418	12.40	4.86	17.26
7 B to 9 B gal	2.000	2.04	0.81	2.85	1,020	406	1,426	12.42	4.94	17.36
9 B to 11 B gal	2.000	2.03	0.82	2.85	1,017	409	1,426	12.38	4.98	17.36
11 B to 13 B gal	2.000	2.05	0.84	2.89	1,027	418	1,445	12.50	5.09	17.60
13 B to 15 B gal	2.000	2.08	0.85	2.93	1,041	427	1,467	12.67	5.20	17.86

Average Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.86	1.43	4.29	926	465	1,391	11.27	5.66	16.93
2001 to 7 b gal	5.230	5.04	2.29	7.33	964	438	1,402	11.73	5.33	17.07
2001 to 9 b gal	7.230	7.08	3.10	10.18	979	429	1,409	11.92	5.22	17.15
2001 to 11 b gal	9.230	9.12	3.92	13.04	988	425	1,412	12.02	5.17	17.19
2001 to 13 b gal	11.230	11.17	4.76	15.93	995	424	1,418	12.11	5.16	17.27
2001 to 15 b gal	13.230	13.25	5.61	18.86	1,002	424	1,426	12.19	5.16	17.36

2010 Tyner et al results without HWP Effect

Because the Emissions Factors subgroup suggested examining ILUC emissions without a credit for HWP, we used the data presented in Appendix E of the 2010 Tyner et al. report to estimate the impacts of removing the HWP effect. While we generally think these emissions estimates should include some effect for HWP, the CARB land use emissions for corn ethanol currently do not include a HWP effect. EPA's analysis of LUC emissions for various biofuels includes a HWP effect in the U.S., but not outside the U.S. For further details on how this effect was removed, see Attachment 2. The impacts of removing the HWP effect are shown in the table below.

Group 2, Without HWP EFs

Marginal Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	3.49	1.43	4.93	1,133	465	1,598	13.79	5.66	19.45
2006 level to 7 B gal	2.145	2.69	0.86	3.54	1,254	399	1,653	15.26	4.86	20.12
7 B to 9 B gal	2.000	2.51	0.81	3.32	1,255	406	1,660	15.27	4.94	20.21
9 B to 11 B gal	2.000	2.50	0.82	3.32	1,249	409	1,659	15.21	4.98	20.20
11 B to 13 B gal	2.000	2.52	0.84	3.36	1,262	418	1,680	15.36	5.09	20.45
13 B to 15 B gal	2.000	2.56	0.85	3.41	1,278	427	1,705	15.56	5.20	20.75

Average Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	3.49	1.43	4.93	1,133	465	1,598	13.79	5.66	19.45
2001 to 7 b gal	5.230	6.18	2.29	8.47	1,182	438	1,620	14.40	5.33	19.73
2001 to 9 b gal	7.230	8.69	3.10	11.80	1,202	429	1,631	14.64	5.22	19.86
2001 to 11 b gal	9.230	11.19	3.92	15.11	1,213	425	1,637	14.76	5.17	19.93
2001 to 13 b gal	11.230	13.72	4.76	18.47	1,221	424	1,645	14.87	5.16	20.03
2001 to 15 b gal	13.230	16.27	5.61	21.88	1,230	424	1,654	14.97	5.16	20.14

<u>Conservation Resource Program Effect</u>

CRP effects are shown in the next table. In this analysis, we allowed the Tyner GTAP model to utilize CRP land.[1] Detailed output for this analysis is shown in Attachment 3. Emissions for the 2001 to 2006 modeling are the same as without utilizing CRP land. The remainder of the modeling shows slightly lower emissions than without utilizing CRP land. The average emissions from 2001 to 15 bgy is 17.06 g/MJ, or about 2% lower than without CRP included.

[1] There has been some confusion as to whether this option gives stable results. The author emailed Professor Tyner on this issue, and his response is that it should give stable results when modeling one biofuel like corn ethanol.

Group 2 with US CRP Land

Marginal Emissions										
Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.86	1.43	4.29	926	465	1,391	11.27	5.66	16.93
2006 level to 7 B gal	2.145	2.15	0.81	2.97	1,004	379	1,383	12.23	4.61	16.84
7 B to 9 B gal	2.000	2.01	0.77	2.79	1,007	386	1,393	12.26	4.70	16.96
9 B to 11 B gal	2.000	2.01	0.78	2.79	1,004	389	1,394	12.23	4.74	16.97
11 B to 13 B gal	2.000	2.03	0.80	2.83	1,017	398	1,415	12.38	4.85	17.22
13 B to 15 B gal	2.000	2.06	0.81	2.88	1,031	406	1,438	12.55	4.95	17.50

Average Emissions										
Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.86	1.43	4.29	926	465	1,391	11.27	5.66	16.93
2001 to 7 b gal	5.230	5.01	2.25	7.26	958	430	1,388	11.66	5.23	16.89
2001 to 9 b gal	7.230	7.02	3.02	10.04	972	418	1,389	11.83	5.09	16.91
2001 to 11 b gal	9.230	9.03	3.80	12.83	979	412	1,390	11.91	5.01	16.93
2001 to 13 b gal	11.230	11.07	4.60	15.66	985	409	1,395	12.00	4.98	16.98
2001 to 15 b gal	13.230	13.13	5.41	18.54	992	409	1,401	12.08	4.98	17.06

Winrock Emissions + CRP Effect

The next table incorporates the combined effects of utilizing the Winrock emissions data and the CRP effect. Using the Winrock data required estimating forest and pasture emissions for every country, and computing the weighted-average forest and pasture emissions for the GTAP regions. This is a fairly intensive process, because the regions and the land types differ significantly between the Woods Hole and Winrock data. The methodology used in this analysis is described in Attachment 4. The average emissions from 2001 to 15 bgy is 11.97 g/MJ, or about 30% lower than the Group 2 results with CRP land added.

Group 2, Winrock EFs and CRP Land

Marginal Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.34	0.64	2.98	757	209	966	9.22	2.54	11.76
2006 level to 7 B gal	2.145	1.67	0.42	2.09	777	196	972	9.46	2.38	11.84
7 B to 9 B gal	2.000	1.56	0.40	1.96	781	199	980	9.51	2.42	11.94
9 B to 11 B gal	2.000	1.56	0.40	1.96	781	200	981	9.51	2.44	11.94
11 B to 13 B gal	2.000	1.58	0.41	1.99	792	204	996	9.64	2.49	12.12
13 B to 15 B gal	2.000	1.61	0.42	2.02	804	208	1,012	9.79	2.53	12.32

Average Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.34	0.64	2.98	757	209	966	9.22	2.54	11.76
2001 to 7 b gal	5.230	4.00	1.06	5.07	765	204	969	9.32	2.48	11.79
2001 to 9 b gal	7.230	5.56	1.46	7.03	770	202	972	9.37	2.46	11.83
2001 to 11 b gal	9.230	7.13	1.86	8.99	772	202	974	9.40	2.46	11.86
2001 to 13 b gal	11.230	8.71	2.27	10.98	776	202	978	9.44	2.46	11.90
2001 to 15 b gal	13.230	10.32	2.69	13.01	780	203	983	9.49	2.47	11.97

Attachment 1

Replication of 2010 Tyner, et al GTAP Results

The following tables give the detailed emissions results for the three Groups. The first and second table in each group gives the Tyner and AIR results, respectively. The third table gives the differences between the two runs.

Group 1

Group 1, Tyner

Marginal Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.73	1.82	4.56	886	590	1,477	10.79	7.19	17.98
2006 level to 7 B gal	2.145	2.12	1.35	3.47	990	628	1,619	12.06	7.65	19.70
7 B to 9 B gal	2.000	2.07	1.31	3.37	1,033	654	1,687	12.58	7.96	20.54
9 B to 11 B gal	2.000	2.13	1.35	3.49	1,067	677	1,745	12.99	8.25	21.24
11 B to 13 B gal	2.000	2.19	1.40	3.59	1,097	701	1,797	13.35	8.53	21.88
13 B to 15 B gal	2.000	2.24	1.45	3.69	1,122	724	1,846	13.66	8.81	22.48

Average Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.73	1.82	4.56	886	590	1,477	10.79	7.19	17.98
2001 to 7 b gal	5.230	4.86	3.17	8.03	929	606	1,535	11.31	7.38	18.69
2001 to 9 b gal	7.230	6.93	4.48	11.40	958	619	1,577	11.66	7.54	19.20
2001 to 11 b gal	9.230	9.06	5.83	14.89	982	632	1,613	11.95	7.69	19.64
2001 to 13 b gal	11.230	11.25	7.23	18.49	1,002	644	1,646	12.20	7.84	20.04
2001 to 15 b gal	13.230	13.50	8.68	22.18	1,020	656	1,676	12.42	7.99	20.41

Group 1, AIR

Marginal Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.74	1.82	4.56	887	590	1,477	10.79	7.19	17.98
2006 level to 7 B gal	2.145	2.13	1.35	3.47	991	628	1,619	12.06	7.64	19.71
7 B to 9 B gal	2.000	2.07	1.31	3.37	1,033	654	1,687	12.58	7.96	20.54
9 B to 11 B gal	2.000	2.14	1.35	3.49	1,068	677	1,745	13.00	8.25	21.25
11 B to 13 B gal	2.000	2.19	1.40	3.60	1,097	701	1,798	13.36	8.53	21.89
13 B to 15 B gal	2.000	2.24	1.45	3.69	1,122	724	1,846	13.66	8.81	22.47

Average Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.74	1.82	4.56	887	590	1,477	10.79	7.19	17.98
2001 to 7 b gal	5.230	4.86	3.17	8.03	929	606	1,535	11.31	7.37	18.69
2001 to 9 b gal	7.230	6.93	4.48	11.40	958	619	1,577	11.66	7.54	19.20
2001 to 11 b gal	9.230	9.06	5.83	14.89	982	632	1,614	11.95	7.69	19.64
2001 to 13 b gal	11.230	11.26	7.23	18.49	1,002	644	1,646	12.20	7.84	20.04
2001 to 15 b gal	13.230	13.50	8.68	22.18	1,021	656	1,677	12.42	7.99	20.41

Group 1, Difference (AIR-Tyner)

Marginal Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	0.01	0.00	0.00	1	0	0	0.00	0.00	0.00
2006 level to 7 B gal	2.145	0.01	0.00	0.00	1	0	0	0.00	-0.01	0.01
7 B to 9 B gal	2.000	0.00	0.00	0.00	0	0	0	0.00	0.00	0.00
9 B to 11 B gal	2.000	0.01	0.00	0.00	1	0	0	0.01	0.00	0.01
11 B to 13 B gal	2.000	0.00	0.00	0.01	0	0	1	0.01	0.00	0.01
13 B to 15 B gal	2.000	0.00	0.00	0.00	0	0	0	0.00	0.00	-0.01

Average Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	0.01	0.00	0.00	1	0	0	0.00	0.00	0.00
2001 to 7 b gal	5.230	0.00	0.00	0.00	0	0	0	0.00	-0.01	0.00
2001 to 9 b gal	7.230	0.00	0.00	0.00	0	0	0	0.00	0.00	0.00
2001 to 11 b gal	9.230	0.00	0.00	0.00	0	0	1	0.00	0.00	0.00
2001 to 13 b gal	11.230	0.01	0.00	0.00	0	0	0	0.00	0.00	0.00
2001 to 15 b gal	13.230	0.00	0.00	0.00	1	0	1	0.00	0.00	0.00

Group 2

Group 2, Tyner

Marginal Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.85	1.44	4.29	925	465	1,390	11.26	5.67	16.93
2006 level to 7 B gal	2.145	2.19	0.86	3.04	1,019	399	1,418	12.40	4.86	17.26
7 B to 9 B gal	2.000	2.04	0.81	2.85	1,020	406	1,427	12.42	4.95	17.37
9 B to 11 B gal	2.000	2.03	0.82	2.85	1,017	409	1,426	12.38	4.98	17.36
11 B to 13 B gal	2.000	2.05	0.84	2.89	1,027	419	1,446	12.51	5.10	17.60
13 B to 15 B gal	2.000	2.08	0.85	2.93	1,040	427	1,467	12.66	5.20	17.86

Average Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.85	1.44	4.29	925	465	1,390	11.26	5.67	16.93
2001 to 7 b gal	5.230	5.04	2.29	7.33	963	438	1,402	11.73	5.33	17.06
2001 to 9 b gal	7.230	7.08	3.10	10.18	979	429	1,409	11.92	5.23	17.15
2001 to 11 b gal	9.230	9.11	3.92	13.04	987	425	1,412	12.02	5.17	17.19
2001 to 13 b gal	11.230	11.17	4.76	15.93	994	424	1,418	12.11	5.16	17.27
2001 to 15 b gal	13.230	13.25	5.61	18.86	1,001	424	1,426	12.19	5.17	17.36

Group 2, AIR

Marginal Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.86	1.43	4.29	926	465	1,391	11.27	5.66	16.93
2006 level to 7 B gal	2.145	2.19	0.86	3.04	1,019	399	1,418	12.40	4.86	17.26
7 B to 9 B gal	2.000	2.04	0.81	2.85	1,020	406	1,426	12.42	4.94	17.36
9 B to 11 B gal	2.000	2.03	0.82	2.85	1,017	409	1,426	12.38	4.98	17.36
11 B to 13 B gal	2.000	2.05	0.84	2.89	1,027	418	1,445	12.50	5.09	17.60
13 B to 15 B gal	2.000	2.08	0.85	2.93	1,041	427	1,467	12.67	5.20	17.86

Average Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.86	1.43	4.29	926	465	1,391	11.27	5.66	16.93
2001 to 7 b gal	5.230	5.04	2.29	7.33	964	438	1,402	11.73	5.33	17.07
2001 to 9 b gal	7.230	7.08	3.10	10.18	979	429	1,409	11.92	5.22	17.15
2001 to 11 b gal	9.230	9.12	3.92	13.04	988	425	1,412	12.02	5.17	17.19
2001 to 13 b gal	11.230	11.17	4.76	15.93	995	424	1,418	12.11	5.16	17.27
2001 to 15 b gal	13.230	13.25	5.61	18.86	1,002	424	1,426	12.19	5.16	17.36

Group 2, Difference (AIR-Tyner)

Marginal Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	0.01	-0.01	0.00	1	0	1	0.01	-0.01	0.00
2006 level to 7 B gal	2.145	0.00	0.00	0.00	0	0	0	0.00	0.00	0.00
7 B to 9 B gal	2.000	0.00	0.00	0.00	0	0	-1	0.00	-0.01	-0.01
9 B to 11 B gal	2.000	0.00	0.00	0.00	0	0	0	0.00	0.00	0.00
11 B to 13 B gal	2.000	0.00	0.00	0.00	0	-1	-1	-0.01	-0.01	0.00
13 B to 15 B gal	2.000	0.00	0.00	0.00	1	0	0	0.01	0.00	0.00

Average Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	0.01	-0.01	0.00	1	0	1	0.01	-0.01	0.00
2001 to 7 b gal	5.230	0.00	0.00	0.00	1	0	0	0.00	0.00	0.01
2001 to 9 b gal	7.230	0.00	0.00	0.00	0	0	0	0.00	-0.01	0.00
2001 to 11 b gal	9.230	0.01	0.00	0.00	1	0	0	0.00	0.00	0.00
2001 to 13 b gal	11.230	0.00	0.00	0.00	1	0	0	0.00	0.00	0.00
2001 to 15 b gal	13.230	0.00	0.00	0.00	1	0	0	0.00	-0.01	0.00

Group 3

Group 3, Tyner

Marginal Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.85	1.44	4.29	925	465	1,390	11.26	5.67	16.93
2006 level to 7 B gal	2.145	1.54	0.68	2.21	716	317	1,032	8.71	3.86	12.57
7 B to 9 B gal	2.000	1.44	0.70	2.14	721	351	1,072	8.78	4.27	13.04
9 B to 11 B gal	2.000	1.40	0.78	2.18	698	391	1,089	8.50	4.76	13.26
11 B to 13 B gal	2.000	1.39	0.90	2.30	697	452	1,149	8.48	5.50	13.99
13 B to 15 B gal	2.000	1.32	1.00	2.32	659	501	1,159	8.02	6.09	14.11

Average Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.85	1.44	4.29	925	465	1,390	11.26	5.67	16.93
2001 to 7 b gal	5.230	4.39	2.12	6.50	839	404	1,244	10.22	4.92	15.14
2001 to 9 b gal	7.230	5.83	2.82	8.65	806	390	1,196	9.82	4.74	14.56
2001 to 11 b gal	9.230	7.23	3.60	10.83	783	390	1,173	9.53	4.75	14.28
2001 to 13 b gal	11.230	8.62	4.50	13.12	768	401	1,169	9.35	4.88	14.23
2001 to 15 b gal	13.230	9.94	5.50	15.44	751	416	1,167	9.15	5.07	14.21

Group 3, AIR

Marginal Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.86	1.43	4.29	926	465	1,391	11.27	5.66	16.93
2006 level to 7 B gal	2.145	1.54	0.68	2.21	716	317	1,033	8.71	3.86	12.57
7 B to 9 B gal	2.000	1.44	0.70	2.14	722	350	1,072	8.78	4.27	13.05
9 B to 11 B gal	2.000	1.40	0.78	2.18	698	391	1,089	8.50	4.77	13.26
11 B to 13 B gal	2.000	1.39	0.90	2.30	696	452	1,148	8.48	5.50	13.98
13 B to 15 B gal	2.000	1.31	1.00	2.31	657	501	1,157	7.99	6.10	14.09

Average Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	2.86	1.43	4.29	926	465	1,391	11.27	5.66	16.93
2001 to 7 b gal	5.230	4.39	2.11	6.51	840	404	1,244	10.22	4.92	15.14
2001 to 9 b gal	7.230	5.83	2.82	8.65	807	389	1,196	9.82	4.74	14.56
2001 to 11 b gal	9.230	7.23	3.60	10.83	783	390	1,173	9.54	4.75	14.28
2001 to 13 b gal	11.230	8.62	4.50	13.12	768	401	1,169	9.35	4.88	14.23
2001 to 15 b gal	13.230	9.94	5.50	15.44	751	416	1,167	9.14	5.06	14.21

Group 3, Difference (AIR-Tyner)

Marginal Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	0.01	-0.01	0.00	1	0	1	0.01	-0.01	0.00
2006 level to 7 B gal	2.145	0.00	0.00	0.00	0	0	1	0.00	0.00	0.00
7 B to 9 B gal	2.000	0.00	0.00	0.00	1	-1	0	0.00	0.00	0.01
9 B to 11 B gal	2.000	0.00	0.00	0.00	0	0	0	0.00	0.01	0.00
11 B to 13 B gal	2.000	0.00	0.00	0.00	-1	0	-1	0.00	0.00	-0.01
13 B to 15 B gal	2.000	-0.01	0.00	-0.01	-2	0	-2	-0.03	0.01	-0.02

Average Emissions

Simulations	Increase in Etahnol Production (BG)	Annual LUC Emissions (million metric ton C02 equivalent)			Annual LUC Emissions (grams of CO2 equivalent per gallon of ethanol)			Annual LUC Emissions (grams of CO2 equivalent per MJ of ethanol)		
		Forest	Grassland	Total	Forest	Grassland	Total	Forest	Grassland	Total
2001 to 2006 level	3.085	0.01	-0.01	0.00	1	0	1	0.01	-0.01	0.00
2001 to 7 b gal	5.230	0.00	-0.01	0.01	1	0	0	0.00	0.00	0.00
2001 to 9 b gal	7.230	0.00	0.00	0.00	1	-1	0	0.00	0.00	0.00
2001 to 11 b gal	9.230	0.00	0.00	0.00	0	0	0	0.01	0.00	0.00
2001 to 13 b gal	11.230	0.00	0.00	0.00	0	0	0	0.00	0.00	0.00
2001 to 15 b gal	13.230	0.00	0.00	0.00	0	0	0	-0.01	-0.01	0.00

Discussion

The differences between the two runs are always small (varying only in the last decimal place) and not biased (random negative and positive signs). We believe that these differences arise due to GEMPACK version differences (Tyner et al. uses Version 9 while AIR uses Version 10.002) and the data exporting software (Tyner's version appears to capture more decimal places than AIR (which is always limited to 7)).

Attachment 2

Method for Removing HWP Effect from 2010 Tyner et al Results

The impacts of HWP effect on the GTAP-Argonne land use emissions factors are given below.

Emissions (tonnes CO2 equivalent/ha)

GTAP Region	Forest with HWP	HWP Effect	Forest without HWP
1 USA	586.84	138.51	725.35
2 EU27	557.55	100.31	657.85
3 BRAZIL	482.15	125.07	607.23
4 CAN	458.23	90.47	548.70
5 JAPAN	397.05	91.49	488.54
6 CHIHKG	690.59	169.56	860.15
7 INDIA	690.59	169.56	860.15
8 C_C_Amer	482.15	125.07	607.23
9 S_o_Amer	482.15	125.07	607.23
10 E_Asia	397.05	91.49	488.54
11 Mala_Indo	690.59	169.56	860.15
12 R_SE_Asia	690.59	169.56	860.15
13 R_S_Asia	690.59	169.56	860.15
14 Russia	422.10	79.53	501.63
15 Oth_CEE_CIS	557.55	100.31	657.85
16 Oth_Europe	557.55	100.31	657.85
17 MEAS_NAfr	365.93	67.22	433.15
18 S_S_AFR	313.35	63.53	376.88
19 Oceania	397.05	91.49	488.54

These impacts were computed from values found in Tables C-1 through C-9 of Appendix E of the Tyner et al report. The table below shows these values organized into a common format as well as the following calculations:

1. Obtain the Forested Area, C Above Ground, and C In Soil from the Tyner report
2. Compute the percent contribution for each Forest Area ecosystem
3. Compute 25% of the C in Soil
4. Compute the Direct C with HWP Effect: (C Above Ground) * 0.75 + (25% of C In Soil)
5. Compute the Direct C without HWP Effect: (C Above Ground) + (25% of C In Soil)
6. Compute the C HWP Effect by subtracting Step 4 from Step 5
7. Convert the C HWP Effect to CO2 Equivalent by multiplying by 3.67 (~44/12)
8. Weight the emissions from each ecosystem by the percentages found in Step 2

Appendix E. Woods Hole Land Use Emissions Data

Region	Description	Temperate Evergreen Forest	Temperate Woodland	Temperate Seasonal Forest	Temperate Deciduous Forest	Boreal Forest	Tropical Evergreen Forest	Tropical Seasonal Forest	Tropical Open Forest	Tropical Rain Forest	Tropical Moist Forest	Tropical Dry Forest	Tropical Woodland	Broadleaf Forest	Mixed Forest	Woodland	Coniferous/ Moutain Forest	Coniferous Pacific Forest	Chapararral	Wt. Total
USA	Forested Area (M ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	54.60	88.20	38.50	24.10	29.20	6.20	240.80
(Table C-1)	Forested Area (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.67	36.63	15.99	10.01	12.13	2.57	100.00
	C Above Ground (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	150.00	170.00	90.00	150.00	200.00	40.00	150.96
	C In Soil (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	150.00	160.00	90.00	100.00	160.00	80.00	138.48
	25% of C In Soil (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.50	40.00	22.50	25.00	40.00	20.00	34.62
	Direct C with HWP Effect (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	150.00	167.50	90.00	137.50	190.00	50.00	147.84
	Direct C w/o HWP Effect (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	187.50	210.00	112.50	175.00	240.00	60.00	185.58
	C HWP Effect (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.50	42.50	22.50	37.50	50.00	10.00	37.74
	CO2 Eqivalent HWP Effect (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	137.63	155.98	82.58	137.63	183.50	36.70	138.51
North	Forested Area (M ha)	6.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.10	0.00	18.50	0.00	0.00	0.00	0.00	0.00	0.00	27.40
Africa	Forested Area (%)	24.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.66	0.00	67.52	0.00	0.00	0.00	0.00	0.00	0.00	100.00
and	C Above Ground (tonnes/ha)	160.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	200.00	0.00	27.00	0.00	0.00	0.00	0.00	0.00	0.00	73.27
Middle	C In Soil (tonnes/ha)	134.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	117.00	0.00	69.00	0.00	0.00	0.00	0.00	0.00	0.00	88.81
East	25% of C In Soil (tonnes/ha)	33.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.25	0.00	17.25	0.00	0.00	0.00	0.00	0.00	0.00	22.20
(Table C-2)	Direct C with HWP Effect (tonnes/ha)	153.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	179.25	0.00	37.50	0.00	0.00	0.00	0.00	0.00	0.00	77.15
	Direct C w/o HWP Effect (tonnes/ha)	193.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	229.25	0.00	44.25	0.00	0.00	0.00	0.00	0.00	0.00	95.47
	C HWP Effect (tonnes/ha)	40.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00	0.00	6.75	0.00	0.00	0.00	0.00	0.00	0.00	18.32
	CO2 Eqivalent HWP Effect (tonnes/ha)	146.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	183.50	0.00	24.77	0.00	0.00	0.00	0.00	0.00	0.00	67.22
Canada	Forested Area (M ha)	37.30	0.00	0.00	46.10	461.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	544.40
(Table C-3)	Forested Area (%)	6.85	0.00	0.00	8.47	84.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
	C Above Ground (tonnes/ha)	160.00	0.00	0.00	135.00	90.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	98.61
	C In Soil (tonnes/ha)	134.00	0.00	0.00	134.00	206.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	194.97
	25% of C In Soil (tonnes/ha)	33.50	0.00	0.00	33.50	51.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	48.74
	Direct C with HWP Effect (tonnes/ha)	153.50	0.00	0.00	134.75	119.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	122.70
	Direct C w/o HWP Effect (tonnes/ha)	193.50	0.00	0.00	168.50	141.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	147.35
	C HWP Effect (tonnes/ha)	40.00	0.00	0.00	33.75	22.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.65
	CO2 Eqivalent HWP Effect (tonnes/ha)	146.80	0.00	0.00	123.86	82.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	90.47
Latin	Forested Area (M ha)	53.60	0.00	55.40	0.00	0.00	296.30	537.30	252.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,195.10
America	Forested Area (%)	4.48	0.00	4.64	0.00	0.00	24.79	44.96	21.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
(Table C-4)	C Above Ground (tonnes/ha)	168.00	0.00	100.00	0.00	0.00	200.00	140.00	55.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	136.32
	C In Soil (tonnes/ha)	134.00	0.00	134.00	0.00	0.00	98.00	98.00	69.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	95.16
	25% of C In Soil (tonnes/ha)	33.50	0.00	33.50	0.00	0.00	24.50	24.50	17.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.79
	Direct C with HWP Effect (tonnes/ha)	159.50	0.00	108.50	0.00	0.00	174.50	129.50	58.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	126.03
	Direct C w/o HWP Effect (tonnes/ha)	201.50	0.00	133.50	0.00	0.00	224.50	164.50	72.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	160.11
	C HWP Effect (tonnes/ha)	42.00	0.00	25.00	0.00	0.00	50.00	35.00	13.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34.08
	CO2 Eqivalent HWP Effect (tonnes/ha)	154.14	0.00	91.75	0.00	0.00	183.50	128.45	50.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	125.07
Pacific	Forested Area (M ha)	14.00	0.00	0.00	14.00	0.00	0.00	0.00	0.00	0.00	63.60	0.00	106.10	0.00	0.00	0.00	0.00	0.00	0.00	197.70
Developed	Forested Area (%)	7.08	0.00	0.00	7.08	0.00	0.00	0.00	0.00	0.00	32.17	0.00	53.67	0.00	0.00	0.00	0.00	0.00	0.00	100.00
(Table C-5)	C Above Ground (tonnes/ha)	160.00	0.00	0.00	135.00	0.00	0.00	0.00	0.00	0.00	200.00	0.00	27.00	0.00	0.00	0.00	0.00	0.00	0.00	99.72
	C In Soil (tonnes/ha)	134.00	0.00	0.00	134.00	0.00	0.00	0.00	0.00	0.00	117.00	0.00	69.00	0.00	0.00	0.00	0.00	0.00	0.00	93.65
	25% of C In Soil (tonnes/ha)	33.50	0.00	0.00	33.50	0.00	0.00	0.00	0.00	0.00	29.25	0.00	17.25	0.00	0.00	0.00	0.00	0.00	0.00	23.41
	Direct C with HWP Effect (tonnes/ha)	153.50	0.00	0.00	134.75	0.00	0.00	0.00	0.00	0.00	179.25	0.00	37.50	0.00	0.00	0.00	0.00	0.00	0.00	98.20
	Direct C w/o HWP Effect (tonnes/ha)	193.50	0.00	0.00	168.50	0.00	0.00	0.00	0.00	0.00	229.25	0.00	44.25	0.00	0.00	0.00	0.00	0.00	0.00	123.13
	C HWP Effect (tonnes/ha)	40.00	0.00	0.00	33.75	0.00	0.00	0.00	0.00	0.00	50.00	0.00	6.75	0.00	0.00	0.00	0.00	0.00	0.00	24.93
	CO2 Eqivalent HWP Effect (tonnes/ha)	146.80	0.00	0.00	123.86	0.00	0.00	0.00	0.00	0.00	183.50	0.00	24.77	0.00	0.00	0.00	0.00	0.00	0.00	91.49
South	Forested Area (M ha)	0.00	0.00	0.00	0.00	0.00	0.00	137.60	44.90	0.00	159.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	341.90
and	Forested Area (%)	0.00	0.00	0.00	0.00	0.00	0.00	40.25	13.13	0.00	46.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
Southeast	C Above Ground (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	150.00	60.00	0.00	250.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	184.80
Asia	C In Soil (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	80.00	50.00	0.00	120.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	94.71
(Table C-6)	25% of C In Soil (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	20.00	12.50	0.00	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.68
	Direct C with HWP Effect (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	132.50	57.50	0.00	217.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	162.28
	Direct C w/o HWP Effect (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	170.00	72.50	0.00	280.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	208.48
	C HWP Effect (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	37.50	15.00	0.00	62.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	46.20
	CO2 Eqivalent HWP Effect (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	137.63	55.05	0.00	229.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	169.56
Africa	Forested Area (M ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	222.00	190.20	200.10	0.00	0.00	0.00	0.00	27.70	0.00	0.00	640.00
(Table C-7)	Forested Area (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34.69	29.72	31.27	0.00	0.00	0.00	0.00	4.33	0.00	0.00	100.00
	C Above Ground (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	126.70	60.20	12.60	0.00	0.00	0.00	0.00	79.90	0.00	0.00	69.24
	C In Soil (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	190.00	115.00	70.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	126.30
	25% of C In Soil (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	47.50	28.75	17.50	0.00	0.00	0.00	0.00	25.00	0.00	0.00	31.57
	Direct C with HWP Effect (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	142.53	73.90	26.95	0.00	0.00	0.00	0.00	84.93	0.00	0.00	83.50
	Direct C w/o HWP Effect (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	174.20	88.95	30.10	0.00	0.00	0.00	0.00	104.90	0.00	0.00	100.81
	C HWP Effect (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.68	15.05	3.15	0.00	0.00	0.00	0.00	19.98	0.00	0.00	17.31
	CO2 Eqivalent HWP Effect (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	116.25	55.23	11.56	0.00	0.00	0.00	0.00	73.31	0.00	0.00	63.53
Europe	Forested Area (M ha)	71.90	45.00	0.00	55.50	27.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	199.90
(Table C-8)	Forested Area (%)	35.97	22.51	0.00	27.76	13.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
	C Above Ground (tonnes/ha)	160.00	27.00	0.00	120.00	90.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	109.32
	C In Soil (tonnes/ha)	134.00	69.00	0.00	134.00	206.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	129.27
	25% of C In Soil (tonnes/ha)	33.50	17.25	0.00	33.50	51.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.32
	Direct C with HWP Effect (tonnes/ha)	153.50	37.50	0.00	123.50	119.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	114.31
	Direct C w/o HWP Effect (tonnes/ha)	193.50	44.25	0.00	153.50	141.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	141.64
	C HWP Effect (tonnes/ha)	40.00	6.75	0.00	30.00	22.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.33
	CO2 Eqivalent HWP Effect (tonnes/ha)	146.80	24.77	0.00	110.10	82.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.31
Former	Forested Area (M ha)	88.30	186.00	0.00	53.60	612.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	940.80
Soviet	Forested Area (%)	9.39	19.77	0.00	5.70	65.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
Union	C Above Ground (tonnes/ha)	160.00	27.00	0.00	135.00	90.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	86.68
(Table C-9)	C In Soil (tonnes/ha)	134.00	69.00	0.00	134.00	206.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	168.05
	25% of C In Soil (tonnes/ha)	33.50	17.25	0.00	33.50	51.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	42.01
	Direct C with HWP Effect (tonnes/ha)	153.50	37.50	0.00	134.75	119.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	107.02
	Direct C w/o HWP Effect (tonnes/ha)	193.50	44.25	0.00	168.50	141.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	128.69
	C HWP Effect (tonnes/ha)	40.00	6.75	0.00	33.75	22.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.67
	CO2 Eqivalent HWP Effect (tonnes/ha)	146.80	24.77	0.00	123.86	82.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	79.53

Attachment 3
Detailed Output for CRP Effect

The tables below provide a detailed breakdown of the US CRP Effect. Table 1A shows the land use without and with CRP and the associated land use changes. Table 1B shows the resulting emissions due to the land use changes. Since CRP land also impacts harvested area, Tables 2A, 2B and 2C show the associated values without CRP, with CRP, and the differences between the two, respectively.

Table 1A

Area	Land Use Changes (ha), 13.23 BG Ethanol								
	Without CRP			With CRP			Difference (With-Without)		
	Forestry	Cropland	Pastureland	Forestry	Cropland	Pastureland	Forestry	Cropland	Pastureland
USA	-257,568	482,352	-224,704	-245,856	458,432	-212,576	11,712	-23,920	12,128
EU27	-132,784	168,472	-35,720	-130,320	164,504	-34,212	2,464	-3,968	1,508
BRAZIL	-125,072	99,032	26,128	-126,032	95,972	30,112	-960	-3,060	3,984
CAN	-48,296	78,136	-29,834	-48,528	76,672	-28,120	-232	-1,464	1,714
JAPAN	-2,422	4,292	-1,862	-2,435	4,247	-1,806	-13	-45	56
CHIHKG	-7,984	80,192	-72,256	-11,232	80,432	-69,216	-3,248	240	3,040
INDIA	-51,514	92,608	-41,080	-51,123	91,232	-40,067	391	-1,376	1,013
C_C_Amer	-21,456	70,384	-48,920	-19,864	68,576	-48,688	1,592	-1,808	232
S_o_Amer	28,768	98,664	-127,376	26,832	96,208	-123,008	-1,936	-2,456	4,368
E_Asia	7,760	5,598	-13,256	7,430	5,528	-12,880	-330	-70	376
Mala_Indo	-36,536	41,132	-4,627	-36,404	40,780	-4,426	132	-352	201
R_SE_Asia	-25,416	26,456	-1,044	-25,368	26,224	-826	48	-232	218
R_S_Asia	-15,630	61,708	-46,068	-15,401	60,580	-45,184	229	-1,128	884
Russia	71,968	85,952	-157,936	67,488	85,552	-153,080	-4,480	-400	4,856
Oth_CEE_CIS	-65,164	199,408	-134,176	-64,996	194,600	-129,632	168	-4,808	4,544
Oth_Europe	-3,192	4,663	-1,465	-3,162	4,565	-1,397	30	-98	68
MEAS_NAfr	1,093	53,476	-54,528	1,066	52,796	-53,808	-27	-680	720
S_S_AFR	24,640	318,240	-343,104	24,064	312,752	-336,960	-576	-5,488	6,144
Oceania	-3,139	66,560	-63,360	-3,318	65,184	-61,856	-179	-1,376	1,504
Total	-661,943	2,037,324	-1,375,188	-657,159	1,984,836	-1,327,630	4,784	-52,488	47,558

Table 1B

Area	Land Use Change Emissions (Tonnes CO2 Equivalent), 13.23 BG Ethanol								
	Without CRP			With CRP			Difference (With-Without)		
	Forestry	Cropland	Pastureland	Forestry	Cropland	Pastureland	Forestry	Cropland	Pastureland
USA	151,150,698	24,739,910	175,890,608	144,277,651	23,404,618	167,682,268	-6,873,047	-1,335,293	-8,208,340
EU27	74,033,465	7,111,763	81,145,228	72,659,667	6,811,524	79,471,191	-1,373,798	-300,239	-1,674,038
BRAZIL	60,304,066	-1,965,740	58,338,326	60,766,935	-2,265,476	58,501,459	462,869	-299,736	163,132
CAN	22,130,566	5,092,568	27,223,134	22,236,874	4,799,994	27,036,869	106,309	-292,574	-186,265
JAPAN	961,645	194,725	1,156,370	966,807	188,919	1,155,726	5,162	-5,805	-643
CHIHKG	5,513,701	14,385,989	19,899,690	7,756,750	13,780,733	21,537,483	2,243,049	-605,256	1,637,792
INDIA	35,575,252	8,178,925	43,754,177	35,305,229	7,977,240	43,282,469	-270,022	-201,686	-471,708
C_C_Amer	10,345,114	3,680,496	14,025,610	9,577,523	3,663,042	13,240,565	-767,590	-17,455	-785,045
S_o_Amer	-13,870,630	9,583,133	-4,287,496	-12,937,178	9,254,507	-3,682,671	933,452	-328,626	604,825
E_Asia	-3,081,076	1,386,511	-1,694,565	-2,950,051	1,347,184	-1,602,868	131,025	-39,328	91,697
Mala_Indo	25,231,537	921,224	26,152,761	25,140,379	881,206	26,021,584	-91,158	-40,019	-131,177
R_SE_Asia	17,552,133	207,858	17,759,991	17,518,985	164,455	17,683,439	-33,149	-43,403	-76,552
R_S_Asia	10,793,982	9,172,024	19,966,006	10,635,836	8,996,021	19,631,857	-158,146	-176,002	-334,148
Russia	-30,377,674	33,183,538	2,805,864	-28,486,667	32,163,256	3,676,589	1,891,007	-1,020,282	870,725
Oth_CEE_CIS	36,332,064	26,714,106	63,046,170	36,238,396	25,809,407	62,047,803	-93,668	-904,699	-998,367
Oth_Europe	1,779,694	291,678	2,071,371	1,762,967	278,139	2,041,106	-16,726	-13,539	-30,265
MEAS_NAfr	-399,810	3,618,264	3,218,455	-390,113	3,570,488	3,180,375	9,697	-47,776	-38,079
S_S_AFR	-7,720,987	15,236,219	7,515,232	-7,540,497	14,963,383	7,422,886	180,491	-272,837	-92,346
Oceania	1,246,327	6,627,139	7,873,466	1,317,398	6,469,828	7,787,227	71,071	-157,311	-86,240
Total	397,500,066	168,360,332	565,860,398	393,856,891	162,258,466	556,115,357	-3,643,175	-6,101,866	-9,745,041

Table 2A

Area	Harvested Area Changes (ha), 13.23 BG Ethanol, Without CRP								
	Paddy_Rice	Wheat	CrGrains	Oilseeds	Sugar_Crop	OthAgri	CRP Land	Pasturecrop	Total
USA	-44,287	-872,316	4,828,556	-1,158,650	-11,210	-1,284,948	-782	-974,038	482,326
EU27	2,717	-33,464	72,034	106,424	-830	21,560	0	0	168,440
BRAZIL	-1,410	-5,609	244,639	126,286	526	18,720	0	-284,124	99,027
CAN	0	-43,653	45,425	76,354	-10	6	0	0	78,122
JAPAN	-1,316	911	3,524	351	-105	925	0	0	4,289
CHIHKG	-18,484	27,412	-9,576	82,322	-686	-764	0	0	80,224
INDIA	9,056	11,036	4,840	6,048	1,661	59,956	0	0	92,597
C_C_Amer	-3,545	-6,004	180,094	1,486	-20,506	-81,138	0	0	70,386
S_o_Amer	-115	272	25,257	66,181	-2,991	10,054	0	0	98,657
E_Asia	-5,584	632	12,359	3,408	0	-5,219	0	0	5,597
Mala_Indo	-23,210	0	9,005	43,682	-605	12,316	0	0	41,189
R_SE_Asia	-62,560	1,420	18,356	59,843	-2,924	12,313	0	0	26,449
R_S_Asia	4,557	38,589	4,103	2,428	95	11,930	0	0	61,702
Russia	487	23,886	34,468	25,388	-1,144	2,906	0	0	85,991
Oth_CEE_CIS	63	62,800	70,850	32,873	1,372	31,450	0	0	199,408
Oth_Europe	4	121	2,874	153	-9	1,519	0	0	4,662
MEAS_NAfr	-7,732	26,541	78,986	7,880	-2,335	-49,850	0	0	53,490
S_S_AFR	607	17,875	-49,264	95,328	-715	254,456	0	0	318,287
Oceania	77	1,587	42,830	6,878	85	15,104	0	0	66,561
Total	-150,676	-747,965	5,619,360	-415,336	-40,328	-968,705	-782	-1,258,162	2,037,406

Table 2B

Area	Harvested Area Changes (ha), 13.23 BG Ethanol, With CRP								
	Paddy_Rice	Wheat	CrGrains	Oilseeds	Sugar_Crop	OthAgri	CRP Land	Pasturecrop	Total
USA	-40,346	-795,504	4,939,112	-1,048,354	-9,234	-1,158,840	-519,570	-908,832	458,432
EU27	2,637	-31,984	70,268	101,171	-627	23,024	0	0	164,489
BRAZIL	-1,339	-5,548	240,731	118,927	572	17,591	0	-274,950	95,983
CAN	0	-41,285	44,286	72,672	-9	1,003	0	0	76,668
JAPAN	-1,188	832	3,480	314	-96	903	0	0	4,244
CHIHKG	-16,150	28,056	-12,176	78,832	-582	2,452	0	0	80,432
INDIA	9,920	11,466	5,490	5,962	1,842	56,520	0	0	91,200
C_C_Amer	-3,641	-5,992	178,201	974	-19,916	-81,045	0	0	68,580
S_o_Amer	122	615	23,024	64,371	-2,736	10,818	0	0	96,213
E_Asia	-5,315	621	12,139	3,180	1	-5,099	0	0	5,527
Mala_Indo	-21,175	0	9,073	41,557	-551	11,902	0	0	40,806
R_SE_Asia	-58,760	1,318	18,318	56,266	-2,615	11,667	0	0	26,195
R_S_Asia	4,986	37,022	4,219	2,365	236	11,747	0	0	60,574
Russia	479	23,434	34,626	24,404	-1,106	3,806	0	0	85,643
Oth_CEE_CIS	104	60,362	69,514	31,662	1,487	31,496	0	0	194,625
Oth_Europe	3	115	2,839	146	-8	1,469	0	0	4,564
MEAS_NAfr	-7,501	25,122	78,039	7,393	-2,234	-48,008	0	0	52,810
S_S_AFR	1,498	17,332	-48,820	92,474	-579	250,940	0	0	312,846
Oceania	80	844	42,337	6,466	130	15,342	0	0	65,198
Total	-135,587	-673,174	5,714,699	-339,219	-36,024	-842,312	-519,570	-1,183,782	1,985,031

Table 2C

Area	Differences in Harvested Area Changes (ha), 13.23 BG Ethanol, (With CRP-Without CRP)								
	Paddy_Rice	Wheat	CrGrains	Oilseeds	Sugar_Crop	OthAgri	CRP Land	Pasturecrop	Total
USA	3,941	76,812	110,556	110,296	1,976	126,108	-518,788	65,206	-23,894
EU27	-80	1,480	-1,766	-5,253	203	1,464	0	0	-3,951
BRAZIL	71	61	-3,908	-7,359	46	-1,129	0	9,174	-3,044
CAN	0	2,368	-1,139	-3,682	1	997	0	0	-1,454
JAPAN	128	-79	-44	-38	9	-22	0	0	-45
CHIHKG	2,334	644	-2,600	-3,490	104	3,216	0	0	208
INDIA	864	430	650	-86	181	-3,436	0	0	-1,397
C_C_Amer	-96	12	-1,893	-513	590	93	0	0	-1,806
S_o_Amer	237	343	-2,233	-1,810	255	764	0	0	-2,444
E_Asia	269	-11	-220	-228	0	120	0	0	-70
Mala_Indo	2,035	0	68	-2,125	54	-414	0	0	-383
R_SE_Asia	3,800	-102	-38	-3,577	309	-646	0	0	-254
R_S_Asia	429	-1,567	116	-63	141	-183	0	0	-1,128
Russia	-8	-452	158	-984	37	900	0	0	-348
Oth_CEE_CIS	40	-2,438	-1,336	-1,211	115	46	0	0	-4,783
Oth_Europe	0	-6	-35	-7	1	-50	0	0	-98
MEAS_NAfr	231	-1,419	-947	-487	100	1,842	0	0	-680
S_S_AFR	891	-543	444	-2,854	136	-3,516	0	0	-5,441
Oceania	3	-743	-493	-412	44	238	0	0	-1,363
Total	15,089	74,791	95,339	76,117	4,304	126,393	-518,788	74,380	-52,375

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Attachment 4

Method of Estimating Winrock Emissions in GTAP Regions

The CARB methodology (coupled with GTAP) estimates forest and pasture changes (above ground and below ground) in 19 different regions around the world, and multiplies the forest and pasture converted by their respective emission factors, which incorporate above and below ground losses upon conversion and lost sequestration. The Winrock data is available for many more regions, and for more land types. Therefore, the challenge in utilizing Winrock data with GTAP output, is to reduce the Winrock data to the land types and regions used by GTAP. This should be considered a first-cut and performing this analysis, we intend to refine this analysis in the future.

AIR used data from an EPA study to generate the Winrock emissions for the GTAP-Argonne model. The study, entitled "Stochastic Analysis of Biofuel-Induced Land Use Change GHG Emissions Impacts", and its associated spreadsheet, were released in January 2009 as part of the EPA's LCF analysis (EPA Docket References EPA-HQ-OAR-2005-0161-3152.1.doc and EPA-HQ-OAR-2005-0161-3152.2.xls.xla).

The detailed Winrock Emission Factors are located in the "EmisFac" worksheet in the spreadsheet. A total of 160 countries, many broken down into numerous administrative units, have emission factors. These factors cover 9 land types (Forestland, Shrubland, Wetland, Barren Land, Savanna Land, Grasslands, Mixed Lands, Croplands, Perennial) and are grouped into 42 different land conversion paths. AIR obtained all the Winrock factors for the 30-year period as well as the associated land use share value, LU Shr 1.

AIR next mapped the 160 Winrock countries into the 19 GTAP-Argonne countries. This was performed by initially using the abbreviated country listings found in Table B-2 of the Tyner report. However, in many instances, combined countries were given in the Table (names beginning with an X). These combined areas were decoded via the GTAP 6 and GTAP 7 database documentation manuals. The final mapping is shown in the table below.

Mapping of Winrock Countries into GTAP-Argonne Regions

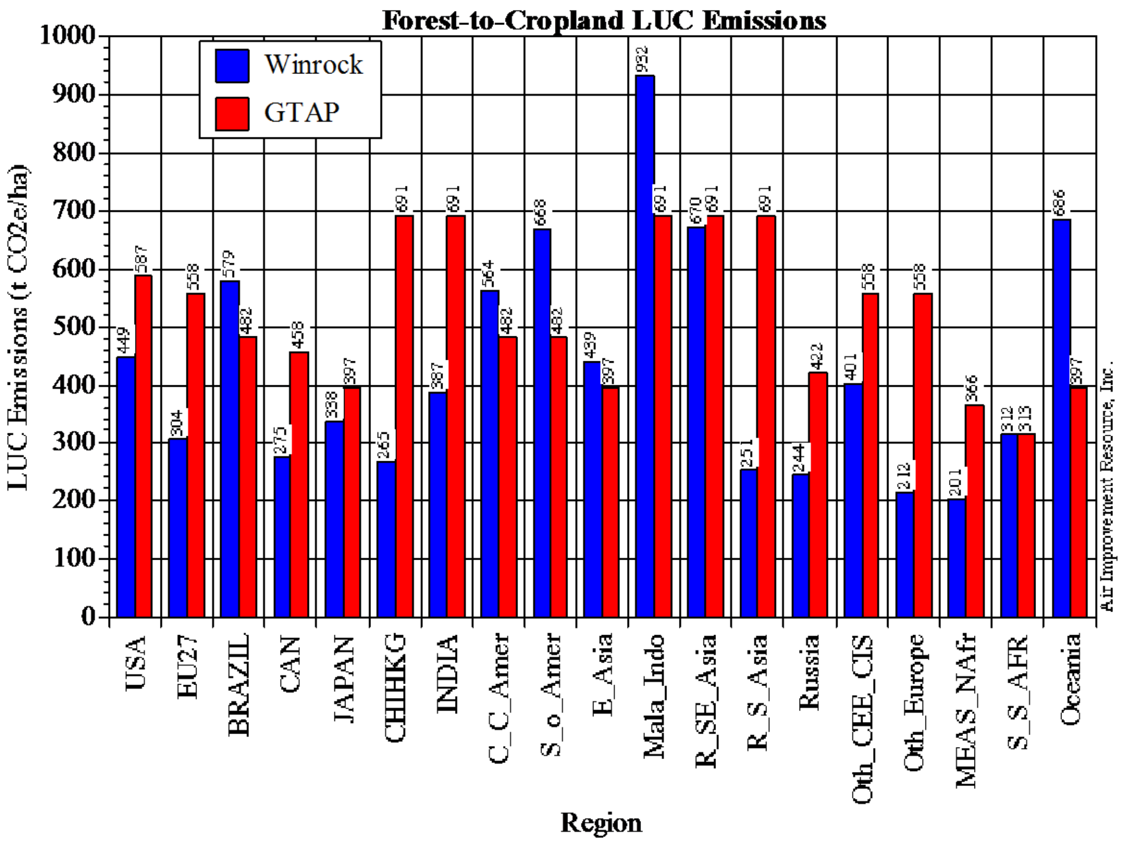
GTAP-Argonne Region	Winrock Country
01 USA	US
02 EU27	Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom
03 BRAZIL	Brazil
04 CAN	Canada
05 JAPAN	Japan
06 CHIHKG	China
07 INDIA	India
08 C_C_Amer	Belize, Costa Rica, Cuba, Dominican Republic, El Salvador,

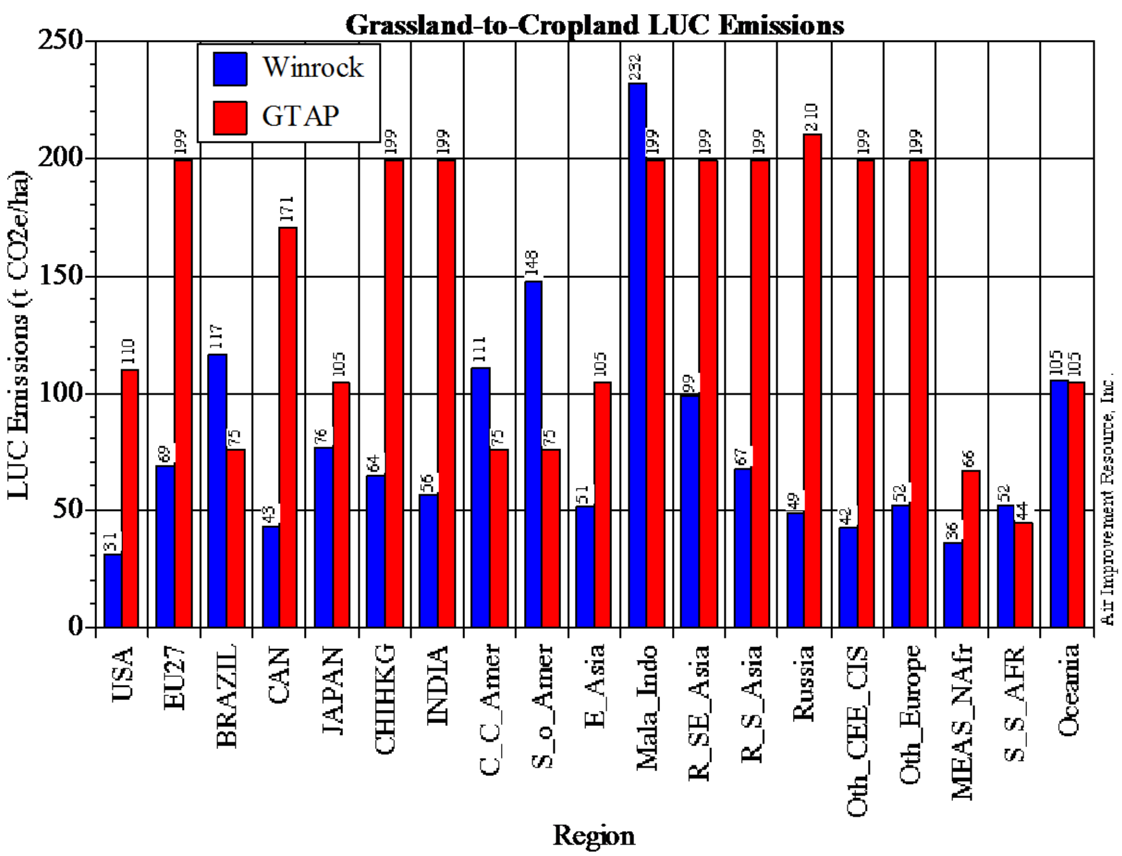
	Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Trinidad and Tobago
09 S_o_Amer	Argentina, Bolivia, Chile, Colombia, Ecuador, Guyana, Guyane, Paraguay, Peru, Suriname, Uruguay, Venezuela
10 E_Asia	Mongolia, North Korea, South Korea, Taiwan
11 Mala_Indo	Indonesia, Malaysia
12 R_SE_Asia	Brunei Darussalam, Cambodia, Laos, Myanmar, Philippines, Singapore, Thailand, Timor-Leste, Vietnam
13 R_S_Asia	Afghanistan, Bangladesh, Bhutan, Nepal, Pakistan, Sri Lanka
14 Russia	Russia
15 Oth_CEE_CIS	Albania, Andorra, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Croatia, Kazakhstan, Kosova, Kyrgyzstan, Macedonia, Moldova, Montenegro, Serbia, Tajikistan, Turkey, Turkmenistan, Ukraine, Uzbekistan
16 Oth_Europe	Iceland, Liechtenstein, Norway, Switzerland
17 MEAS_NAfr	Algeria, Egypt, Iran, Iraq, Israel, Lebanon, Libya, Morocco, Oman, Saudi Arabia, Syria, Tunisia, United Arab Emirates, Yemen
18 S_S_AFR	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Cote d'Ivoire, Democratic Republic of the Congo, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Republic of Congo, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe
19 Oceania	Australia, New Zealand, Papua New Guinea

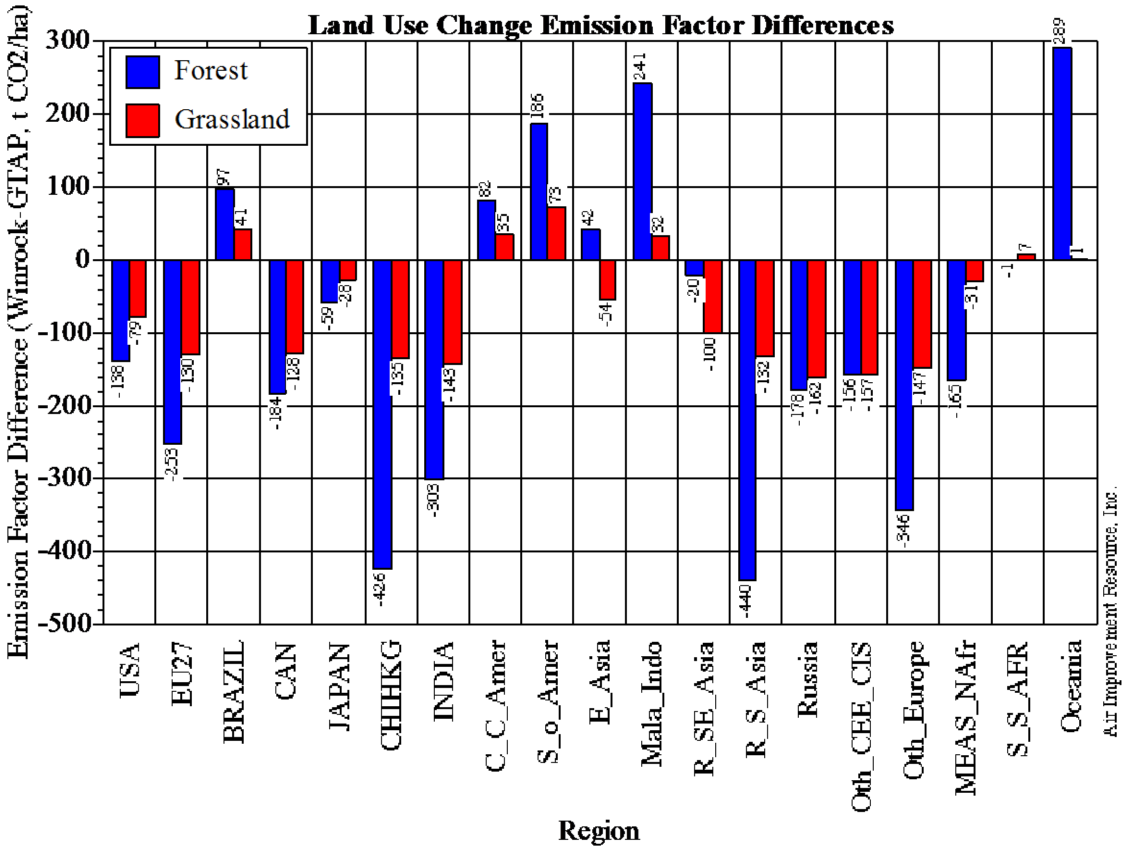
AIR then calculated the product of the emission factor and the land use share. The summations of these values, plus the summations of the land use shares, were then computed for each of the 19 GTAP-Argonne region and all 42 land conversions paths. By dividing the sum of the products by the sum of the land use shares, a weighted Winrock factor was computed for each GTAP-Argonne region and land use change path. The final Winrock factors for the Forest to Cropland and Grassland to Cropland paths are compared to the corresponding GTAP-Argonne in the table and graphics below.

As shown in the table and figures, 13 regions have a Winrock Forest-to-Cropland emission factor that is less than the GTAP factor. Similarly, 13 regions have a Winrock Grassland-to-Cropland that is less than the corresponding GTAP factor. Interestingly, not all regions that have a lower Forest-to-Cropland have a lower Grassland-to-Cropland Winrock value.

Comparison of Land Use Change Emissions (tonnes/hectare)						
	Forest-to-Cropland			Grassland-to-Cropland		
GTAP Region	GTAP	Winrock	Difference	GTAP	Winrock	Difference
01 USA	586.838	448.608	-138.230	110.100	31.100	-79.000
02 EU27	557.548	304.465	-253.083	199.098	68.699	-130.399
03 BRAZIL	482.155	579.247	97.092	75.235	116.641	41.406
04 CAN	458.228	274.586	-183.642	170.697	42.942	-127.755
05 JAPAN	397.046	338.335	-58.711	104.595	76.298	-28.297
06 CHIHKG	690.594	264.953	-425.641	199.098	64.145	-134.953
07 INDIA	690.594	387.453	-303.141	199.098	56.182	-142.916
08 C_C_Amer	482.155	563.738	81.583	75.235	110.604	35.369
09 S_o_Amer	482.155	668.148	185.994	75.235	147.936	72.701
10 E_Asia	397.046	439.312	42.266	104.595	51.037	-53.558
11 Mala_Indo	690.594	931.730	241.136	199.098	231.537	32.440
12 R_SE_Asia	690.594	670.203	-20.391	199.098	99.016	-100.081
13 R_S_Asia	690.594	250.793	-439.801	199.098	67.286	-131.812
14 Russia	422.100	243.774	-178.325	210.108	48.592	-161.516
15 Oth_CEE_CIS	557.548	401.219	-156.330	199.098	41.938	-157.159
16 Oth_Europe	557.548	212.030	-345.518	199.098	51.769	-147.329
17 MEAS_NAfr	365.925	201.123	-164.803	66.356	35.545	-30.811
18 S_S_AFR	313.352	311.988	-1.364	44.407	51.563	7.156
19 Oceania	397.046	686.441	289.395	104.595	105.287	0.692


Forest-to-Cropland LUC Emissions
LUC Emissions (t CO2e/ha)
Winrock
GTAP
1000
900
800
700
600
500
400
300
200
100
0
449
587
304
558
579
482
275
458
338
397
265
691
387
691
564
482
668
482
439
397
932
691
670
691
251
691
244
422
401
558
212
558
201
366
312
313
686
397
USA
EU27
BRAZIL
CAN
JAPAN
CHIHKG
INDIA
C_C_Amer
S_o_Amer
E_Asia
Mala_Indo
R_SE_Asia
R_S_Asia
Russia
Oth_CEE_CIS
Oth_Europe
MEAS_NAfr
S_S_AFR
Oceania
Region
Air Improvement Resource, Inc.


Grassland-to-Cropland LUC Emissions
LUC Emissions (t CO2e/ha)
Winrock
GTAP
250
200
150
100
50
0
31
110
69
199
117
75
43
171
76
105
64
199
56
199
111
75
148
75
51
105
232
199
99
199
67
199
49
210
42
199
52
199
36
66
52
44
105
105
USA
EU27
BRAZIL
CAN
JAPAN
CHIHKG
INDIA
C_C_Amer
S_o_Amer
E_Asia
Mala_Indo
R_SE_Asia
R_S_Asia
Russia
Oth_CEE_CIS
Oth_Europe
MEAS_NAfr
S_S_AFR
Oceania
Region
Air Improvement Resource, Inc.


Land Use Change Emission Factor Differences
Emission Factor Difference (Winrock-GTAP, t CO2/ha)
Forest
Grassland
300
200
100
0
-100
-200
-300
-400
-500
USA
EU27
BRAZIL
CAN
JAPAN
CHIHKG
INDIA
C_C_Amer
S_o_Amer
E_Asia
Mala_Indo
R_SE_Asia
R_S_Asia
Russia
Oth_CEE_CIS
Oth_Europe
MEAS_NAfr
S_S_AFR
Oceania
Region
-138
-79
-253
-130
97
41
-184
-128
-59
-28
-426
-135
-303
-143
82
35
186
73
42
-54
241
32
-20
-100
-440
-132
-178
-162
-156
-157
-346
-147
-165
-31
-1
7
289
1
Air Improvement Resource, Inc.