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October 5, 2011

Mr. Floyd Vergara
Chief, Alternative Fuels Branch
California Air Resources Board
Headquarters Building
1001 I Street
Sacramento, CA 95812

RE: Comments of the Renewable Fuels Association in regard to proposed changes to the LCFS indirect land use change analysis as outlined at September 14, 2011 public workshop

Dear Mr. Vergara,

The Renewable Fuels Association (RFA) appreciates the opportunity to provide comments regarding the proposed changes to the indirect land use change (ILUC) analysis conducted for the Low Carbon Fuels Standard (LCFS) regulation. The new analysis and the proposed changes were discussed during the California Air Resources Board (CARB) public workshop held September 14, 2011.

RFA is the leading trade association for America's ethanol industry. Its mission is to advance the development, production, and use of ethanol fuel by strengthening America's ethanol industry and raising awareness about the benefits of renewable fuels. Founded in 1981, RFA represents the majority of the U.S. ethanol industry and serves as the premier meeting ground for industry leaders and supporters.

While we continue to have concerns with the selective application of indirect greenhouse gas emissions penalties only to crop-based biofuels in the LCFS, RFA believes GTAP7 represents a significant improvement in land use modeling for biofuels over the previous version of the model. However, while the new GTAP model is a major advancement over earlier versions used by CARB, we believe a number of key enhancements are still needed (both to the model structure and to the input parameters used) before the model can be reasonably used to estimate ILUC for the purposes of regulatory enforcement. Further, we believe the new AEZ-Emissions Factor (EF) model and many of its underlying assumptions need much improvement before they can be used by CARB to estimate the emissions associated with the land use changes projected by GTAP.

The attached report by Air Improvement Resource Inc. (AIR) contains detailed comments and recommendations for further improvements to both the GTAP modeling framework and AEZ-EF model. The AIR report shows that using more reasonable assumptions in the emissions factors model and revising the GTAP parameter governing crop yields on cropland/pasture results in corn ethanol ILUC emissions of **12.4 grams CO2e/megajoule**. It should be noted that this estimate would be even lower if other improvements are considered, such as exogenous crop yield growth after 2004, higher substitution of distillers grains for conventional feed ingredients, higher responsiveness of crop yields to price changes, and inclusion of Conservation Reserve Program (CRP) lands in the GTAP model. RFA will continue to examine additional sensitivity cases that consider these and other factors, and we will share those results with CARB as they become available. Further, we will be providing all of the documents, reports and studies referenced in the AIR report.

Thank you again for the opportunity to comment. Please don't hesitate to contact us with any questions or comments regarding the attached report.

Sincerely,

Geoff Cooper

Geoff Cooper
Vice President, Research

Comments on Proposed Changes to the Corn Ethanol Land Use Change Analysis for the LCFS

For: Renewable Fuels Association

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Executive Summary

On September 14, CARB released its new preliminary analysis of land use change (LUC) emissions for corn ethanol, soybean biodiesel, and sugarcane ethanol. The land use changes utilized an updated GTAP model from Purdue, and the emission changes for different land types used a new agriculture ecological zone emission factor model (AEZ-EF). CARB ran a base case and a number of sensitivity cases. The actual emissions of the different cases were not presented by CARB, but could be estimated from the GTAP and AEZ models released by CARB after the workshop. The base case emissions for corn ethanol were 19.6 g CO2 eq/MJ. Sensitivity case emissions range from 18.9 g/MJ to 25.9 g/MJ.

AIR reviewed both the GTAP model and AEZ-EF model, the accompanying documentation, and the sensitivity cases, and developed a number of major comments on the modeling. Our comments are summarized in the two sections below (GTAP and Emissions).

GTAP

Overall, GTAP7 represents a major improvement in land use modeling for biofuels over the previous version of the model, GTAP6. However, we have several concerns with the current land use modeling that should be addressed in the short term:

- Examination of the impacts of the corn ethanol shock on distillers grains prices for region-to-region shows some regions where the price impacts of this shock are very large, and may indicate that there is not enough trade in DDGs in the model for these regions for 2004. This could lead to overestimating the LUC of corn ethanol in these areas. Purdue should consider fixes to the wide disparity in DDG pricing (i.e., possibly introducing more trade in DDGs in these regions in the base year).

- The previous modeling performed by CARB and Purdue utilized an exogenous yield adjustment for changes in crop yields between the base year (2001 at that time) and current yields. This external adjustment was omitted in the latest modeling, without adequate justification. We still believe the adjustment is still necessary, until Purdue releases a dynamic GTAP model that can account for longer-term yield changes endogenously.

- The cropland/pasture yield adjustment for Brazil should be set to 0.6, instead of 0.4, based on information submitted by UNICA. This change alone reduces the corn ethanol land use emissions from 19.6 g/MJ to 17.8 g/MJ.

- Yield-price sensitivity analyses should be conducted at levels above and below the Purdue central value of 0.25, and not just at levels far below 0.25. CARB's use of levels below 0.25 (0.05 and 0.10) is based on analyses very short-term data of yield-price effects, which Purdue and CARB Expert Work Group considers inappropriate for use with this GTAP parameter.

- The food consumption impacts should be presented as a range from zero to the modeled values, because the impacts depend on how a food constant scenario is implemented. Also, it should be emphasized that the food consumption index impacts are very small on average, in all regions less than one-half of one percent.

- U.S. Conservation Reserve Program lands should be included in the modeling. The code is in the model; all that appears to be needed is for Purdue to validate the modeling.

Our longer-term recommendations are for Purdue to update the Continuous Elasticity of Transformation (CET) Methodology and include cropland/pasture for other developed regions like Canada and the EU27. The CET is the most critical parameter to update, because it governs the amount of forest converted, and forest converted drives most of the emissions impact. The Elasticity Subgroup of the Expert Working group concluded that the CET is greatly overestimating the amount of forest converted by GTAP.

Emissions

In general, it appears that many improvements are needed to the AEZ-EF model and the underlying data and assumptions. We recommend addressing the following issues in the short-term:

- The current emissions model assumes that 20% of the above ground live carbon for forests for the U.S. ends up being stored in hardwood products (HWP). CARB is also evaluating a U.C. Davis model that estimates carbon storage in hardwood products. However, data from the U.S. Forest Service and from Heath et al indicate that 35% of carbon is stored in HWP and in landfills, and that an additional 35% of above ground carbon is burned for energy, replacing fossil fuels. The CARB assumption is currently ignoring the use of above ground carbon for energy, and carbon in various products being stored in U.S. landfills. The HWP factor should be increased to the range of 70% in the U.S. to account for these other carbon sinks in the U.S. Also, it is likely that other developed areas such as Canada and the EU27 follow similar practices.

- The AEZ-EF Model should use the EPA 2010 U.S. GHG Inventory for above ground carbon stocks for forest in the U.S. The U.S. inventory is well developed, includes estimates of above ground live carbon in forests on private land, and uses consistent definitions of the various deadwood, forest floor, and soil carbon pool so as to avoid double-counting.

- CARB currently assumes that when forest is converted to either crops or pasture, that all forest deadwood and litter is converted to GHG immediately and charged to corn ethanol. However, without the forest being cleared, the deadwood and litter would have decayed, either forming CO2 or being part of soil carbon. Thus, deadwood and litter emissions during forest clearing should not be charged to biofuels.

- The foregone carbon sequestration emissions currently in the emissions model are too high, and not at all reflective of average carbon sequestration rates according to the 2010 U.S. Inventory. The average sequestration rates in U.S. forests are on the order of 0.3 Mg C/Ha/year, where the model is currently using 2.5 Mg C/ha/year.

We estimated the impact of these emission model recommendations on the LUC of corn ethanol, using the GTAP modeling with Purdue defaults. Results are shown in Table ES-1 below.

Table ES-1. Effects of Emission Modeling Recommendations on Corn Ethanol LUC Emissions (first 3 changes are independent, not incremental changes)

Case	LUC (g CO2 eq/MJ)
Purdue Base	19.59
Don't include forest litter and deadwood in forest conversion emissions, all areas	18.20
Increase HWP factor for U.S. to 70% to account for carbon stored in landfills and burned for energy	18.01
Reduce U.S. foregone carbon sequestration estimates by 80% to account for data on average sequestration in U.S. forest	17.11
All three of the above	14.14
All three of above, with GTAP cropland/pasture yield improvement at 0.4/0.6	12.37

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1.0 Introduction

In December 2010, the California Air Resources Board (CARB) adopted Resolution 10-49 directing CARB staff to present amendments to the Board that would include "[u]pdates to the land use values for corn ethanol, sugarcane ethanol, and soy biodiesel, and other feedstocks, and other effects using, to the extent appropriate, the draft recommendations of the Expert Workgroup and other available information…"

As part of the amendments process, CARB staff held a workshop Sep. 14, 2011, to discuss planned updates to the indirect land use change (ILUC) analysis conducted for the Low Carbon Fuels Standard (LCFS). Specifically, the workshop addressed 1) revisions to the Global Trade Analysis Project (GTAP) model, and resultant effects on land conversion estimates; 2) revisions to carbon stock estimates; 3) a new emissions factor model; and 4) sensitivity of ILUC carbon intensity values to model structure and parametric changes.

This document contains our comments on the update to the corn ethanol land use emissions, and underlying data and methods. Our comments are organized as follows;

- GTAP Land Use Modeling
- Emissions

2.0 GTAP Land Use Modeling

Purdue's GTAP modeling is discussed in a preliminary paper prepared by Tyner for CARB.[1] The land use change results for the Tyner primary case are summarized in Table 1. Tyner's primary case utilizes the following inputs:

- Yield-price elasticity: 0.25
- Crop transformation elasticity: -0.75
- Cropland/pasture yield adjustment: 0.4 for U.S., 0.2 for Brazil

Table 1. Land Use Changes for Corn Ethanol

Parameter	Area changes	Ha/1000 gal
Forest changes (ha)	-290,637	0.025
Cropland changes (ha)	2,126,261	0.018
Pasture changes (ha)	-1,835,267	0.158
Cropland/pasture changes (ha)	1,438,468	0.122

Using CARB's AEZ Emissions Model with this GTAP output, which currently estimates that 20% of forest carbon is in hardwood products (HWP) in the U.S., and 5% outside of the U.S. are in HWP, we determined that the LUC for corn ethanol is 19.6 g/MJ.[2]

At CARB's request, Purdue also ran some sensitivity cases, varying some of the input parameters. CARB requested that the elasticity with respect to price (hereafter referred to as the yield-price elasticity) be run at 0.10 and 0.05, that the crop transformation elasticity be run at -0.5, that the cropland/pasture (CP) yield adjustment values be run at zero, and that the GTAP model be run with food consumption held constant for the (1) developing world, and (2) for all countries. CARB took the output from GTAP for these cases, and used it with the AEZ Emissions Model to estimate emissions for each of these cases. CARB's emission sensitivity analysis for these cases is shown in Table 2.

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[1] Tyner, Calculation of Indirect Land Use Change (ILUC) Values for Low Carbon Fuel Standard (LCFS) Pathways, Interim Report, September 2011.

[2] Plevin, et al, Agro-ecological Zone Emission Factor Model, September 12, 2011.

Table 2. Sensitivity Cases		
	% Change	Emissions (g/MJ) ***
Food constant – developing	+24	24.4
Yield-price: 0.25 to 0.1	+32	25.9
Crop transformation: -0.75 to -0.5	-4	18.9
CP yield adjustment included	-20*	19.6
CP adjustment excluded	+26**	24.6

* Uses different baseline than first three sensitivity cases
** Uses the same baseline as the first three sensitivity cases
*** Emissions estimated by AIR, Inc utilizing GTAP and AEZ Emissions Model

The first two sensitivity cases increase emissions by 24-32%, and the third sensitivity case reduces emissions by 4%. The percent reduction for the fourth case uses a different baseline than the first three cases. It estimates the percent reduction in emissions from a baseline that *excludes* the CP adjustment (24.6 g/MJ), whereas the first three sensitivity cases use a baseline that includes the CP adjustment. Using a common baseline for all cases would require showing the impact of excluding the CP adjustment, which would increase emissions by 26% (fourth line of Table 1).

One should not attribute too much weight to the absolute land use CI values in Table 2 from these preliminary sensitivity analyses, because they are based on both the GTAP modeling *and* the new AEZ Emissions Model developed for CARB. The new emissions model has not undergone peer review, and we have many comments on this emissions model that are explained in Section 3. Clearly a number of estimates need to be changed in the model that will affect the absolute land use emissions for different GTAP sensitivity cases. In fact, some of the relative effects of the GTAP sensitivity cases could change significantly once the AEZ emissions model is improved. Thus, the focus is on the relative differences in emissions for the sensitivity cases, and not on their absolute values, and these sensitivity cases will need to be repeated once the emissions model is improved.

Using both GTAP and the AEZ Emissions Model, an analysis of the contributions of different land transitions to total emissions was conducted. Results indicate that 74% of the emissions from corn ethanol come from the forest-to-cropland transition. Therefore, factors that affect (1) the total land converted, and in particular (2) the forest fraction converted, are of most importance. As indicated above, the contribution of the forest-to-cropland transition to total emissions could change if the AEZ emissions model is improved.

The remainder of this section reviews the GTAP modeling and sensitivity cases in more detail. The following subjects are presented:

- Exogenous Yield Adjustment

- Distillers Grains Price Impact Concerns
- Cropland/Pasture For Other Regions
- Yield-price elasticity
- Crop transformation elasticity
- Cropland pasture yield adjustment
- Food constant analysis
- Conservation Reserve Program effects
- Modeling Recommendations

2.1 Exogenous Yield Adjustment

In CARB's and Purdue's previous work for the LCFS, an exogenous yield adjustment was included to alter the land use changes in response to longer-term changes in crop yields.[3] This is important because GTAP is a static rather than a dynamic model, in that it uses a very detailed 2004 equilibrium database. In essence, the model is only designed to answer the question: How much land use change occurs if the ethanol expansion that takes place in the real world from 2004 to 2015 is all compressed into 2004? The exogenous yield adjustment was previously utilized by Purdue and CARB to adjust the GTAP-generated land use values for expected increases in crop yields between 2001 and 2009.[4] The best method of dealing with longer-term yield changes is with a dynamic model, rather than a static model, but this exogenous adjustment was thought to be one way to temporarily address the issue of longer term yield changes.

In this newest analysis, there is no mention of an adjustment for exogenous yield changes between 2004 and 2011 or 2004 and 2015. One reason given by CARB staff for this omission is that given the weather-related yield reductions in the U.S. over the past two years, the crop yield growth trend is relatively flat since 2004. While that may be true of the U.S., it is not true of major crop producing regions outside the U.S. and these ex-U.S. yield trends have important implications for the exogenous yield adjustment. Further, the longer-term trend suggests average yields will continue to grow beyond 2004-2011 levels between now and 2015. This factor clearly needs more analysis before it is omitted from CARB's new study of land use changes. This analysis should focus on historical yield changes between 2004 and 2011 and also the expected yield improvements between 2004 and 2015. It is also important to note that in GTAP, corn is one crop in a category called "Coarse Grains", which includes barley and sorghum. The per-acre yields on sorghum and barley are much lower than corn (sorghum and barley are grown in areas with less water than corn), so as more drought-resistant varieties of corn are introduced, one way yields can be improved is by switching from sorghum and barley to corn. Thus, the analysis should not only examine trends in corn yields, but also trends in sorghum and barley yields, and trends in crop switching from barley and sorghum to corn.

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[3] Proposed Regulation to Implement the Low Carbon Fuel Standard, Volume II, Appendices, Appendix C5, March 5, 2009.

[4] Even though the ethanol shock occurs between 2004 and 2015, CARB made the adjustment between 2004 and 2009 based on historical data. The base year for the previous GTAP model, GTAP6, was 2001 instead of 2004.

Further, GTAP modeling conducted by Tyner et al. for the Argonne National Lab introduced a method in which the model can account for global exogenous yield growth *inside the model*, as opposed to CARB’s external adjustment (Group 3 simulation). CARB should justify why it is not enabling this feature in GTAP for this modeling effort.

More analysis on historical and future crop yield growth is warranted. This is a short-term recommendation.

2.2 Distillers Grains Price Impacts Outside of the U.S.

Many improvements were made to methods of handling co-products from biofuels for GTAP7, which are detailed in the Tyner paper. One check we made was the impacts of the ethanol shock on prices of distillers grains (DDGs), both inside and outside the U.S. With the expansion of corn ethanol has come an expansion in DDGs used as animal feed. DDGs are widely used in the U.S. with several animal types, and exports of DDGs have increased significantly in the last few years.

Table 3 shows the price impacts of DDGs due to corn ethanol in various GTAP regions. The increased supply of DDGs reduces its price by 5% in the US. This blunts the increase in feed prices for livestock due to somewhat higher corn prices. But the increases in DDG prices in some countries are far out of line with others; for example, Central America, South America (except Brazil), Malaysia/Indonesia, the Rest of Southeast Asia, the Middle East and North Africa and Sub-Sahara Africa. Since DDG is a globally traded commodity, these large price differences would not exist, because if they did, they would be subject to arbitrage. The reason for the large increases is probably very low exports to these regions in the base year of 2004.

This price discrepancy issue for DDGs is important because with much higher prices for DDGs in these regions, there is more land use conversion than would occur in the real world. These price discrepancies are easily fixed by Purdue by introducing slightly more DDG trade with these regions in the base year. It is worth noting that when we examined this issue for the soybean shock, there were not discrepancies in the prices impacts of this shock on soybean meal in different regions, so evidently Purdue fixed the issue for the soybean expansion.

This is a short-term problem that should be addressed.

Table 3. Price Impacts of Corn Ethanol on DDGs in Various Regions
(% change in GTAP variable "pm", market price of commodity i in region r)

Region (GTAP abbreviation)	% Price Impact
USA	-4.95
EU27	5.52
Brazil	0.53
Can	2.69
Japan	4.34
Chihkg	0.43
India	0.27
CCAmer	**70.78**
SoAmer	**41.47**
EAsia	**40.98**
MalaIndo	**32.25**
RSEAsia	**19.97**
RSAsia	0.62
Russia	0.05
Oth CEE CIS	0.27
Oth Europe	0.43
Meas NAfr	**43.14**
SSAfr	**10.79**
Oceania	1.00

2.3 Cropland/Pasture for Other Countries

> The Tyner GTAP report indicates that two new land categories of cropland pasture and U.S. Conservation Reserve Program lands were added into the model's land supply.

In reference specifically to cropland/pasture, the report goes on to say that "Other regions do not have this category of land." We think what Tyner means by this statement is that Purdue does not specifically have data for other regions with this category of land. Certainly other regions, like Canada and the EU27, do have this category of land (cropland/pasture). Updating these regions to include cropland/pasture will change the mix of forest and pasture converted for corn ethanol and other biofuels.

This is a longer-term recommendation.

2.4 Yield Elasticity with Respect to Price

The land use work that CARB initially performed for the LCFS used a yield-price elasticity range of 0.2 to 0.4. Seven different cases were evaluated with various yield-price elasticities and the average elasticity value was 0.32.[5]

CARB acknowledged that the research available to guide the use of this key parameter was lacking in currency and breadth. Thus, this particular elasticity was identified as a top priority for further analysis by the Expert Work Group (EWG) convened by CARB at the direction of the Board. The EWG formed an Elasticities Subgroup, which focused much of its research effort on improving the understanding of the price/yield elasticity.

After examining the existing literature on this elasticity (which shows a range of 0.15-0.76) and performing empirical data tests, the Elasticities Subgroup's final report recommended that CARB should:

> [k]eep the central value of the yield elasticity with respect to price at 0.25 if only one value can be used for all crops and all countries. If this elasticity can be varied, then it should be increased for crops-country combinations that can be double-cropped and it should be decreased for combinations that cannot.[6]

In addition to examining empirical data, the EWG Elasticities Subgroup justified its recommendation to use a central value of 0.25 by pointing out that:

> "[f]armers have an incentive to adopt higher-yielding seed technologies with higher prices. They have an incentive to control pest damage more thoroughly with higher prices. And they have an incentive to apply additional fertilizer under higher prices. In addition, higher prices give farmers a greater incentive to double crop."

Further, the EWG Elasticities Subgroup suggested, "If differentiation can occur by country, then setting the price-yield elasticity to 0.175 for countries with no double cropping, 0.25 for the U.S., and 0.3 for Brazil and Argentina will provide a more reasonable approximation to reality."[7]

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[5] Proposed Regulation to Implement the Low Carbon Fuel Standard, Volume I, Table IV-10, March 5, 2009.

[6] Babcock, Gurgel, Stowers, and Adili. Final Recommendations from the Elasticity Values Subgroup (no date).

[7] Ibid. To test the subgroup's recommendation, AIR examined the effects of varying the elasticity by region for Brazil (0.3), U.S. (0.25), and the rest of the world (0.175). AIR found the differences between using 0.25 globally and varying factors for Brazil, the U.S., and rest of world were so slight that "…a change is inadvisable until more research can be performed. See http://www.arb.ca.gov/fuels/lcfs/workgroups/ewg/040111ewg-rfa-com.pdf

In its most recent analysis, CARB ignored all of these recommendations by the EWG, and performed one-sided sensitivity modeling on this parameter only at yield-price elasticities below 0.25 (0.10 and 0.05). The lower values are based on research by Berry that was recently commissioned by CARB staff. Berry prepared an initial paper for CARB in November 2010 and co-authored a second paper with Schlenker dated August 5, 2011.[8,9] In his initial analysis of this elasticity, Berry cites a paper by Roberts & Schlenker, which asserts yields are not at all responsive to price changes. However, concerns have been raised about the approach used by Roberts & Schlenker. Specifically, the authors use historical yield shocks as instrumental variables for their price index, and they assume these yield shocks occurred exogenously and were driven by the weather events. Rather than seeking to *quantify* price/yield endogeneity, Roberts & Schlenker simply assume it does not exist.

The Elasticities Subgroup reviewed the initial Berry paper and the Roberts & Schlenker work and outlined concerns at the November 2010 EWG meeting.[10] CARB has not yet responded to the critiques of Berry and Roberts & Schlenker offered by the subgroup.

In their August 2011 paper, Berry and Schlenker develop equations for the change in "net" yields that considers the change in prices, land area converted, and various temperature variables such as heat and humidity. The "net" yield change approach does not hold the land fixed, but also reflects expansion of crops on new land (or perhaps double-cropping, it is not clear), which may be at a different yield levels than the existing cropland, so the "direct" yield-price effect must be "inferred" from the area-yield elasticity and an assumption about the productivity of the new land. The derived direct price/yield value from this approach is 0.08.

Two primary principles have emerged with respect to selecting a price-yield elasticity value. First, the elasticity clearly <u>should reflect a long-run yield-price effect</u>; and second, the elasticity value <u>should account for double cropping</u> as well as other factors, such as higher-yielding seed technologies and other management techniques resulting from higher prices.

The EWG Elasticities subgroup reviewed much of Berry's work and other literature on price-yield effects, and concluded:

> The overall conclusion that one can take from the literature *is that the short-run (one-year) response of U.S. yield to price is quite inelastic with an average value of 0.05 to 0.2* (emphasis added). The long-run responsiveness of yield to price will be greater than the short-run response if there are lags in the adoption or development of new management practices or seed varieties. Hence, to the extent

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[8] Berry, Biofuels Policy and the Empirical Inputs to GTAP Models, January 4, 2011.

[9] Berry and Schlenker, Technical Report for the ICCT: Empirical Evidence on Crop Yield Elasticities, August 5, 2011

[10] Babcock, Gurgel, and Stowers. Presentation to EWG. Nov. 2010

> that existing studies provide reliable one-year estimates, they underestimate the long-run response of yields to price.

With regard to the yield-price elasticity in GTAP, Tyner states in his September 2011 paper:

> There is ample evidence in the literature that research and development (seeds, machinery, infrastructure) follows crop profitability. And certainly crop profit depends in part on crop price. Hence, there is no doubt that there is a yield response to higher crop prices. Estimating the parameter accurately will be very difficult. *We know that a one-year estimate is totally inappropriate* (emphasis added). We also know that a longer time period would have a larger response (elasticity) than a shorter time period. We do not in reality know if the appropriate value for the yield-to-price elasticity is 0.25 or higher or lower. However, CARB has requested that we do sensitivity analysis only for lower values of 0.05 and 0.10, so that is what is reported in this paper.

With regard to double cropping, GTAP does not explicitly account for double cropping. Therefore, the only method to include double cropping is with the yield-price effect. The Elasticity Subgroup paper indicates:

> Babcock and Carriquiry conclude that the incentive to double crop soybeans with corn and cotton in Brazil justifies the use of a yield elasticity of 0.24 all by itself. The smaller share of U.S. double-cropped soybeans supports a smaller yield elasticity increment (for double cropping) than 0.24.

Clearly, CARB is basing its lower elasticities of 0.1 and 0.05 on the short-term yield-price elasticity work by Berry and Schlenker, which Tyner and Babcock indicate is not appropriate for GTAP. Because the time period implied by the GTAP ethanol shock is 2004-2015 (11 years), a longer-term response is clearly justified for this parameter.

Regarding the size of the yield-price effect, the GTAP report indicates that corn prices increase by 7.1% in the US, and 3.1% worldwide, as a result of the corn ethanol volume shock. Using a yield-price elasticity of 0.25, the model would increase coarse grain yields by 1.78% and worldwide by less than 1%. At a 2004 U.S. coarse grain yield of 144 bu//acre, the yield-price elasticity increases U.S. coarse grain yields by 2.6 bu/acre to 146.6 bu/acre.[11] Such an increase in yield, resulting strictly from cultural changes stimulated by higher prices, seems an entirely plausible scenario and a reasonable assumption for CARB's analysis.

We support the EWG's recommendation to set this parameter at 0.25. If sensitivity analyses are to be performed, it should be at levels above and below 0.25. This is

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[11] The 144 bu/acre in GTAP for coarse grains is estimated by summing corn, sorghum, and barley production in the model (corn is 95% of production), and assuming a corn density of 56 lbs/bu.

supported by the Elasticity Subgroup's interim recommendation to analyze a range of values from 0.1 and 0.4. Also, in its final recommendations, the subgroup supported using a central value of 0.25, and a range of something larger than zero to 0.35 for sensitivity work:

> For sensitivity analysis, the central value of a single parameter setting should be 0.25. The lower bound on this elasticity should not be zero because of strong theoretical considerations (input use responds to crop price) and the reality of double cropping. But there is no empirical basis to choose either a lower limit or an upper limit for sensitivity analysis that applies to all countries together. If it is desirable to see what the results would be if all countries' yields are responsive to price and if all countries could double crop, then an upper limit of 0.35 could be used.

AIR believes the lower estimate should not be below an estimate that includes the short-term component and the longer-term component (the sum of which the EWG Subgroup says is in the range of 0.1 to 0.25), and a double cropping effect of between 0.1 and 0.2, which would bring the range to 0.20-0.45.

We evaluated 0.20 and 0.45; the results are shown in Table 4.

Table 4. Corn Ethanol LUC Emissions at Different Yield-Price Levels*

Yield-Price Elasticity	Corn Ethanol Land Use Change Emissions (g/MJ)
0.20	21.3
0.25	19.6
0.45	14.7

* All other parameters at Purdue defaults

2.5 Crop Transformation Elasticity

Changing this parameter from -0.75 to -0.5 did not have a large impact on the corn ethanol results. We support the use of either value.

2.6 Cropland/Pasture Yield Adjustment

The cropland/pasture yield adjustments are incorporated by Purdue to reflect the fact that as cropland/pasture is converted to cropland, therefore earning a higher amount of rent, that their productivity should be higher than as cropland/pasture. Purdue incorporated a factor of 0.4 for the U.S. and 0.2 for Brazil. The authors admitted that there is not a lot of data to guide the use of this parameter, but suggested the adjustments made sense based on their understanding of the transition of cropland/pasture to cropland. In a one-sided sensitivity analysis, ARB, without explanation, requested that both these factors be run at zero.

Research performed by UNICA indicates this factor should be set at 0.6 for Brazil.[12] If Purdue believes that the value should be 0.2 for Brazil and not 0.6, Purdue and CARB should justify this selection. We examined the impact of these parameters being 0.4/0.6 (U.S./Brazil) and 0.6/0.6. All three results are shown in Table 5. The complete GTAP output is shown in Appendix A.

Table 5. Impact of Cropland/Pasture Yield Adjustment

Cropland/Pasture Yield Adjustment	Corn Ethanol LUC Emissions (g/MJ)
0.4/0.2 Purdue Baseline (U.S./Brazil)	19.6
0/0	24.6 (+26% from 19.6)
0.4/0.6	17.8 (-9.1%)
0.6/0.6	16.27 (-17%)

The cropland/pasture yield adjustment has a significant effect on emissions. We recommend that the cropland/pasture yield adjustment be set at 0.4/0.6 (US/Brazil).

2.7 Food Consumption Held Constant Analysis

At CARB's request, Purdue performed two "constant food consumption" analyses – one that assumed food consumption is held constant in the developing world(regardless of commodity price responses to the ethanol shock), and one that assumed that food consumption remains constant globally. Table 6 shows the impact of these two cases on the Purdue baseline emissions of 19.6 g/MJ.

Table 6. Food Constant Emission Impacts

Assumption	Emissions (g/MJ)
Baseline	19.6
Food Constant – Developing	24.4
Food Constant – Global	27.2

Under the "food constant – developing" sensitivity case, it is assumed that governments would act to ensure that their nations experience no reduction in food consumption. As a result, the GTAP model assumes that more land would be converted around the world at 2004 yield levels, but as discussed below, there are excellent and more practical options that involve no land use change.

Given this context, it is useful to evaluate how much food would be reduced in different nations with the U.S. corn ethanol shock. Table B-1 in Appendix B of the Tyner report shows that the food consumption index impacts for the US corn ethanol shock are largest in Middle East and North Africa, at -0.37%, followed by the U.S. and Russia, at -0.21% and -0.22% respectively. Sub-Sahara Africa experiences a -0.17% decline, Central America experiences a -0.18% decline, with most other regions in the -0.02% to 0.08% range. All reductions are less than one-half of one percent.

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[12] Letter from Joel Velasco and Marcos Jank (UNICA) to Mary Nichols, April 16, 2009.

On the average, these are very small reductions in food consumption, however, not everyone in a region is at the average so they should be viewed with concern. The predicted reductions in food consumption could be entirely eliminated if affected regions see even slight improvements to crop yields over 2004 levels. The implementation of techniques such as improved seed, more efficient input use, and better management practices could not only prevent additional land from being converted, but could actually lead to afforestation in some of these regions if the practices are implemented successfully. There are very significant yield gaps between the developed and developing nations, with the developing nations having much lower crop yields than the developed nations. [13] These gaps are closing with time. Improving regional yields would be an excellent way for the governments of developing nations to improve food production in their regions without the need to convert more land to crops. Thus, the impact of holding food constant, either in developing nations, or globally, is somewhere between zero and numbers shown in the table above.

If CARB is going to show the impact of holding food constant, we recommend that the effect be characterized as between zero and the modeled value, inasmuch as the emissions will depend entirely on how a “constant food scenario” is implemented.

2.8 Conservation Reserve Program (CRP) Effects

As indicated earlier, CRP land has already been introduced in the GTAP model, along with cropland/pasture. It was not included in the analysis of LUC because, according to Tyner, (1) it has not been thoroughly tested, and (2) Purdue expects the government to continue to support the CRP for a variety of reasons.

CRP has been in the model for over a year, so there has been plenty of time to test whether this part of the model works. While we also expect the government to support the CRP program, nonetheless there have been fluctuations of land in and out of the CRP, and over the last few years, the amount of land in the CRP has declined and has been reconverted to crops, in spite of continued support from the government. This is shown in Table 7. [14]

Table 7. CRP Land Under Contract (million acres)

Item	2005	2006	2007	2008	2009
Land Under Contract	34.9	36.0	36.8	34.6	33.7

Most of the land in the CRP is in grass or pasture, and this is the land that would be converted back to crops. Adding another “pasture” land type like CRP basically would

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[13] Johnson, et al., Closing the gap: global potential for increasing biofuel production through agricultural intensification, Environmental Research Letter 6 (2001) 034028.

[14] Conservation Reserve Program, Annual Summary and Enrollment Statistics – FY2009, Farm Service Agency, USDA.

reduce the forest converted due to biofuel, because of the structure of the CET nest discussed in section 2.8.2.2.

The CRP land is turned off/on by the inclusion/exclusion of the following closure directive:

```
!Swap: to fix the CRP rents when USDA defends the CRP swap
tf(AEZ_COMM,"Oth_Ind_Se","USA")=p_HARVSTAREA_L(AEZ_COMM,"Oth_Ind_Se","USA")
```

An inspection of the amount of CRP land available in GTAP found 14,045,541 hectares (34,707,288 acres).

We implemented this swap to determine the effects on the corn ethanol LUC. The LUC emissions are 18.22 g/MJ, which are 7% lower than the Purdue baseline of 19.6 g/MJ. The complete results are shown in Appendix A. We did not have the time to validate these results.

We recommend including CRP, along with cropland pasture in the analysis. Validating the results should be straightforward, and there is ample evidence that some CRP lands are being utilized.

2.9 Modeling Recommendations

The following are our short-term recommendations:

1. The problems with distillers' grains trade with certain nations should be fixed.

2. The effect of an exogenous yield adjustment should be evaluated before being omitted.

3. The cropland/pasture yield adjustment should be set at 0.4 for the U.S. and 0.6 for Brazil.

4. If sensitivity testing is to be performed with the price-yield elasticity, it should be at 0.20 and 0.45.

5. The food constant emissions should be characterized as 0 to some value, because the emissions depend on how the food constant scenario actually plays out.

6. Purdue should state what their technical concerns are with the use of the CRP option. If they don't have technical concerns, then CRP lands should be included in the analysis. We note that the use of CRP land down to 32 million acres was included in EPA's land use estimates for the RFS.

The August 2011 Tyner paper indicates that the following issues will be addressed in the longer term:

- Sensitivity analysis of Armington structure
- Additional emission factors including carbon changes due to crop switching
- Soil carbon stock changes for cellulosic feedstocks
- Other approaches to the TEM approach for new lands converted
- Dynamic version of GTAP

We support all of these improvements, especially the dynamic version of GTAP. There are three others that should be included in this list:

- Testing of CRP option
- Development of data sources for cropland/pasture in Canada, Australia and the EU27
- Revisions to the Continuous Elasticity of Transformation (CET)

If Purdue has technical concerns with the use of CRP in the model, they should address those. Land is flowing into and out of the CRP all the time, and some land from CRP is reasonable to assume would be used in biofuel expansion scenarios.

There is likely to be cropland/pasture in other developed regions, including Canada, Australia and he EU27. These data should be found and included in GTAP.

Figure 2 in the Tyner report shows a top level nesting structure for forest, pasture, and cropland. The continuous elasticity of transformation of -0.2 governs the relative portions of these three land types.

The EWG Elasticity subgroup recommended keeping this value at -0.2, while possibly testing the values from -0.1 to -0.3. However, for the longer term they recommended a parameterization of this function.

> The CET function GTAP has but one parameter. This parameter, together with the share of returns to land of different types, determine the own and cross price elasticicities of land cover type. Babcock and Carriquiry demonstrated that this method leads to cross price elasticities that are not consistent with common sense and empirical estimates. For example, the cross price elasticity of forest land in the U.S. with respect to crop returns is an important factor in GTAP determining how much forest land is converted to cropland in response to biofuels-induced crop price increases. The value for this parameter in GTAP is -0.174: a 10% increase in crop returns decreases forest land by 1.74%. *But this responsiveness is 35 times a great as the maximum response of forest land to crop returns over a 15 year time period using the response of forest land to changes in own forest returns as estimated by Lubowski (2002) and Lubowski, Plantinga, and Stavins (2006). This suggests that GTAP's estimate of how much U/.S. forest land is*

> *converted to cropland in response to increased crop prices is too large* (emphasis added).

The Subgroup's report goes on to suggest a method for modifying GTAP to calibrate the CET elastisities to estimated own and cross price elasticities.

Given the fact that (currently) 74% of LUC emissions for corn ethanol are from the forest-to cropland conversion, this would be a very important area for future development of the model.

3.0 Emissions

This section discusses the AEZ Emissions Factor Model data sources and methodology for calculating the carbon changes associated with expansion of U. S corn ethanol. Since forest-to-cropland land-use transitions account for 74% of the carbon emissions associated with the expansion of U. S. corn ethanol that is modeled in the draft Tyner 2011 report, these comments focus primarily on the forest-to-cropland conversion methodology as presented in the Gibbs and Yui 2011 and Plevin et al. 2011 draft reports.[15,16] Further, since 60% of the forest-to-cropland conversion emissions occur in the U. S., an additional focus on the inputs related to the U. S. factors is warranted.

As summarized by Plevin et al. 2011, the agro-ecological zone emission factor (AEZ-EF) model combines matrices of carbon fluxes (Mg CO2/ha/year) with matrices of changes in land use (ha) by land-use category projected by the GTAP model. The carbon fluxes are aggregated into 19 regions and 18 AEZs. The model contains separate carbon stock estimates (Mg C/ha) for biomass and soil carbon by GTAP AEZ and region. The carbon stock data is combined with assumptions about carbon loss from soils and biomass, carbon remaining in harvested wood products, and foregone sequestration.

Plevin et al. 2011 indicate that the AEZ-EF model includes the following sources/sinks of greenhouse gas emissions:

1. Above-ground live biomass (trunks, branches, foliage)
2. Below-ground live biomass (coarse and fine roots)
3. Dead organic matter (dead wood and litter)
4. Soil organic matter
5. Harvested wood products
6. Non-CO2 climate-active emissions (e.g., CH4 and N2O)
7. Foregone sequestration

In the following sections, comments are provided on each of these sources/sinks.

3.1 Forests

3.1.1 Total Carbon Stocks

Gibbs and Yui 2011 present the results of their analysis of a number of geographically-explicit data sets for above ground carbon and soil carbon. They provide estimates of the average amount of soil carbon and biomass carbon stored in pastures, croplands and forests for each GTAP region and AEZ. The spatial detail of their analysis is a major improvement over the look-up tables from the Woods Hole Research Center (WHRC) used in prior ARB analyses. For example, Gibbs and Yui indicate that their new estimates for above ground biomass are over 50 Mg C/ha lower than WHRC values in the

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[15] Evaluation of ILUC Related Topics, H. Gibbs and S. Yui, 2011.

[16] Agro-ecological Zone Emission Factor Model, R. Plevin, et al, 12-September 2011.

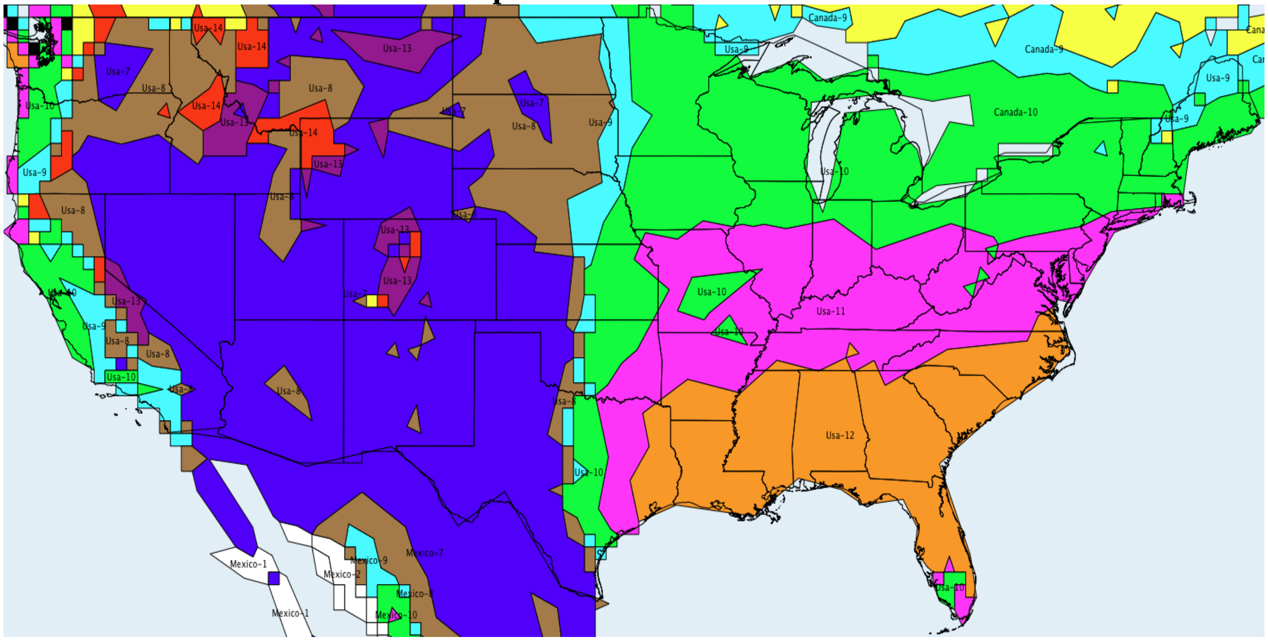
US, Canada, Europe, and Russia. This is a particularly important change because 83% of the total forest-to-cropland conversion emissions occur in the U. S., Canada, and Europe in the Tyner 2011 corn ethanol case. While the new estimates are improved, Gibbs and Yui highlight several remaining important issues. For example, Gibbs and Yui acknowledge that considerable uncertainty still exists because scientists are using a range of available sensors and methods to estimate the spatial distribution of biomass in lieu of the Lidar ideal. In addition, they indicate:

> The estimates we provide may be under or overestimating the values on the ground due to spatial variability. The science of mapping forest carbon stocks has improved considerably, but more attention has focused on estimating changing areas of forest rather than their carbon stocks. Moreover, our approach took a weighted average of forest carbon stocks within a region, and the actual value of any given forest may be higher or lower than the average.

With regard to future improvements, Gibbs and Yui indicate that "distinguishing between accessible and inaccessible forest would be an excellent next step." This is important because Gibbs and Yui acknowledge that they provide estimates for average forest biomass carbon averaged across accessible and inaccessible forests and GTAP deals with land use change in accessible forests.

Although the Plevin expansion of U. S. corn ethanol case involves calculations of land use change and conversion emissions throughout the world, over 91% of the forest-to-cropland conversion in the U. S. occurs in three of the AEZs, numbers 10, 11, and 12. These three zones are located as wide bands across the eastern U. S., in a north to south orientation, with zone 10 (temperate, sub humid) comprised of the northern tier of U. S. states East of the Mississippi, zone 11 (temperate, humid) comprised primarily of central states, and zone 12 (temperate, humid year round) comprised of the southern states. This is shown in the Figure below.

AEZ Map of the United States



The land use changes in these three zones (190,860 ha in zone 10; 99,780 ha in zone 11, and 32,290 ha in zone 12) actually total more forest-to-cropland conversion than the net world-wide conversion of 290,637 ha shown in Table 4 of Tyner 2011. Because of the dominance of the land use changes in these three U. S. zones, we have focused our comments on refined estimates of the factors used in the U. S., in general, and in these three zones, in particular.

The first major comment is that the Plevin et al. and Gibbs and Yui estimates of forest carbon stocks should be compared with the latest U. S. greenhouse gas inventory data.[17] Gibbs and Yui discuss how their results compare with Harris, 2009. However, the 2011 U. S. inventory has detailed estimates of carbon stocks in all the forest categories that should be used to compare with and to refine the ARB estimates. In particular, Table 7-8 has carbon stock estimates for U. S forests that differ in many cases from the new ARB estimates. Annex 3.12 of the U. S. inventory has detailed breakdowns in Tables A-214 and A-216 by region, by state, and by forest type that can be used to compare with the Gibbs and Yui and Plevin et al. estimates. In addition, more detailed data for each state are available through the USDA Forest Service.[18]

In addition, Heath et al. 2011[19] provides information on the forest carbon stocks in both

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[17] U. S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2009, EPA 430-R-11-005, April 15, 2011.

[18] USDA Forest Service (2010a) Forest Inventory and Analysis National Program: User Information. U.S. Department of Agriculture Forest Service. Washington, DC. Available online at <http://fia.fs.fed.us/tools-data/docs/default.asp>.

[19] L. Heath, J. Smith, C. Woodall, D. Azuma, and K. Waddell, “Carbon stocks on

private and public forests, using methods consistent with the 2010 U. S. inventory. Figures 1 to 4 from Heath et al. 2011 are shown below.

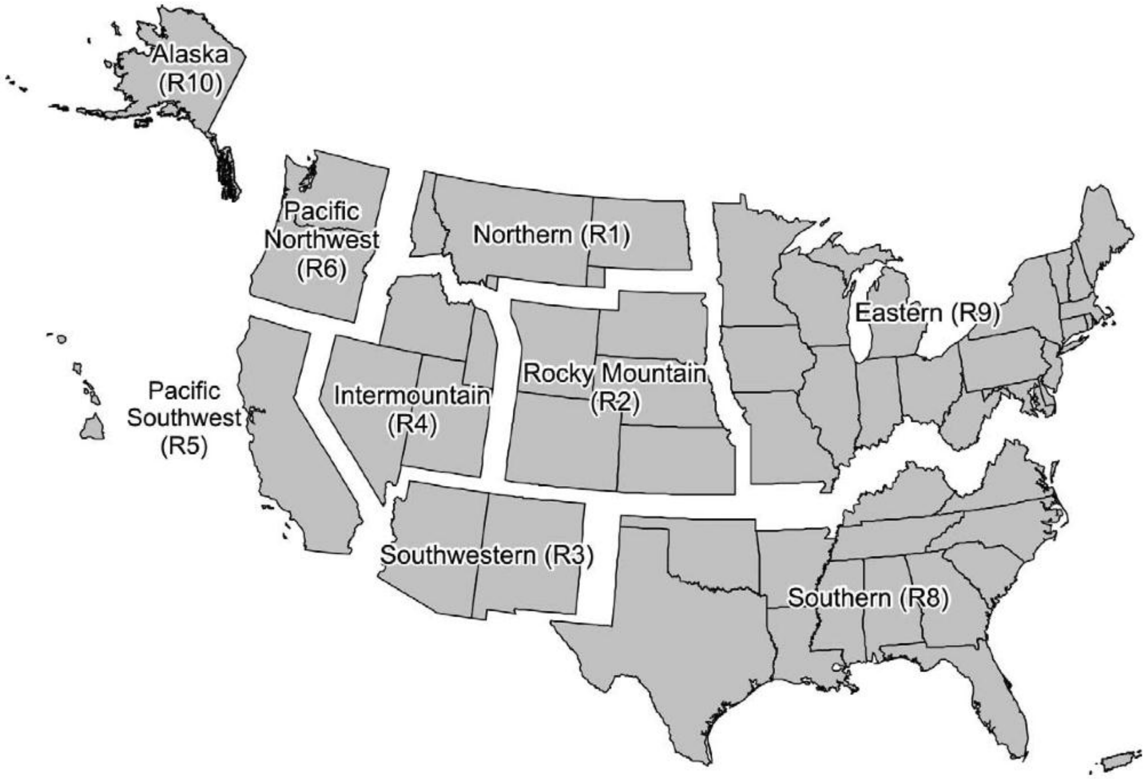

Fig. 1. Map of USDA Forest Service, National Forest System regions.

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forestland of the United States, with emphasis on USDA Forest Service ownership," Ecosphere, **2**, 1-21 (2011).

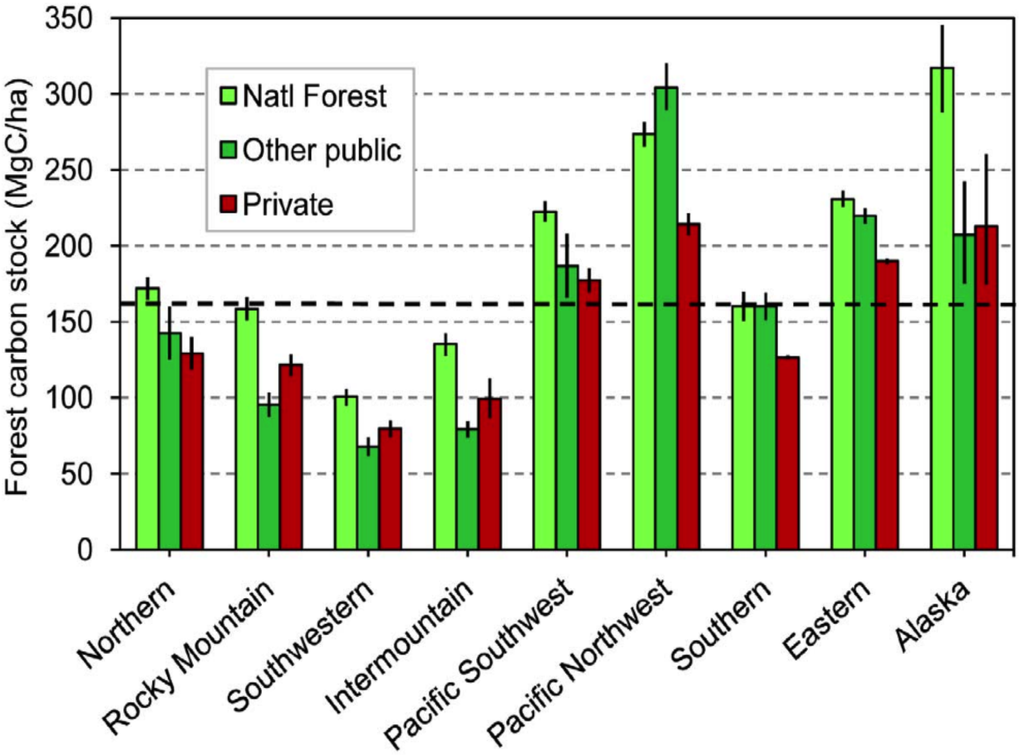

Fig. 2. Mean forest carbon density (Mg C/ha) by ownership by National Forest System region, 2005. Horizontal dashed line represents the overall average carbon stock on U.S. forestland, 162 Mg C/ha. Error bars indicate a 95% confidence interval of uncertainty about the regional average, from carbon conversion factors and sampling error.

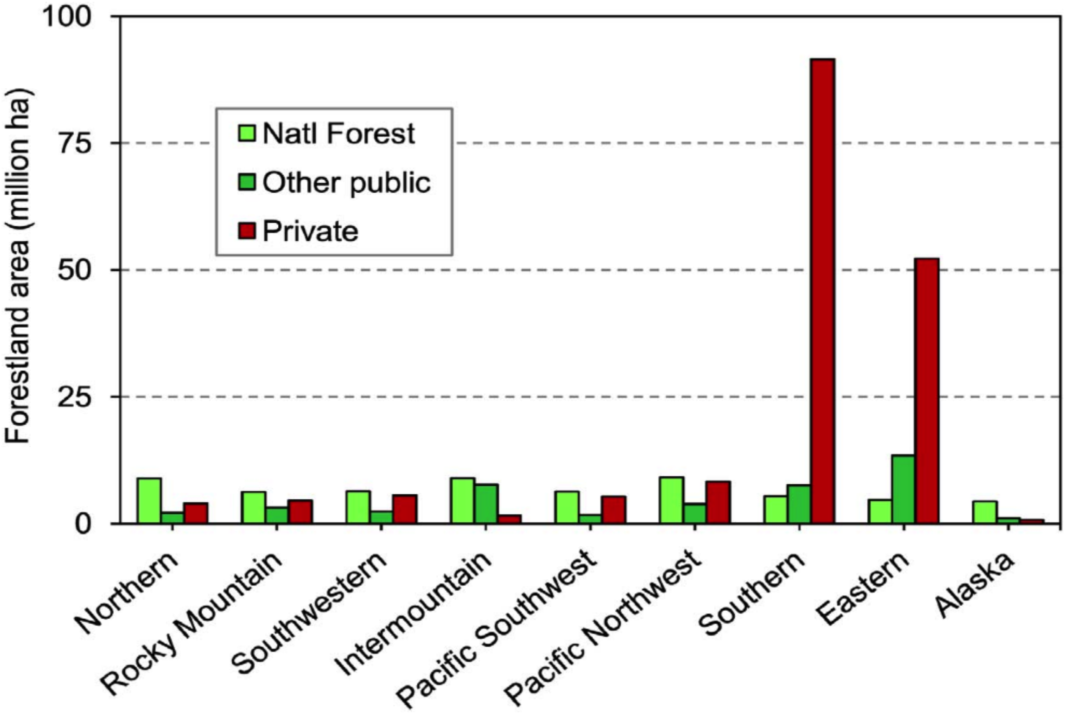

Fig. 3. Forestland area (million hectares) by ownership summed by National Forest System region, 2005. Error bars for a 95% confidence interval of sampling error for forest area are not included because they are too small for the resolution of the figure.

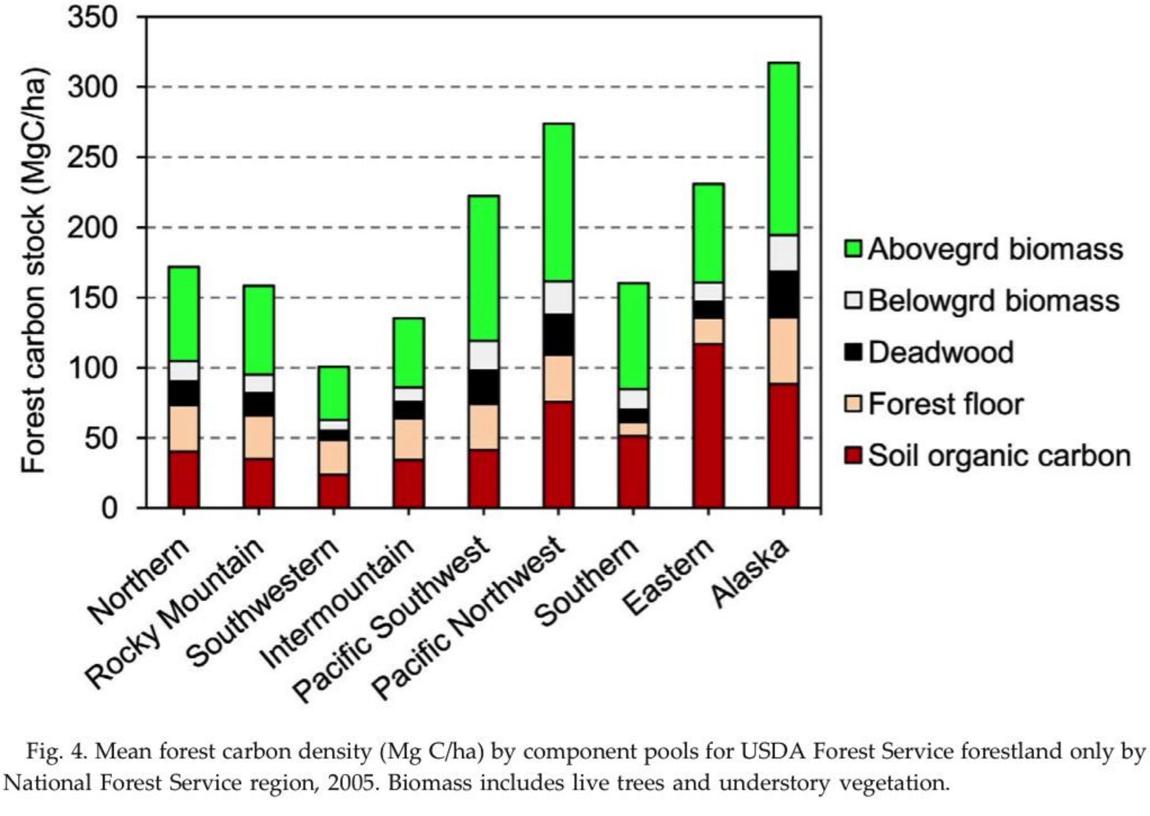

Fig. 4. Mean forest carbon density (Mg C/ha) by component pools for USDA Forest Service forestland only by National Forest Service region, 2005. Biomass includes live trees and understory vegetation.

Heath et al., in their Figure 2, show that the carbon density in private forests is substantially lower than in national forests and lower than in forests overall in the U. S. In their Figure 3, Heath et al. show that the vast bulk of private forests are located in the Southern and Eastern Forest Service regions. These two regions, as shown in their Figure 1, essentially overlap with the three AEZs used in the ARB analysis. These figures demonstrate that the carbon density in private forests in the same regions where the ARB predicts land use change is less than in forests overall. Thus, the results for private forests in the Eastern and Southern regions would be useful first cut at identifying carbon density of accessible forests that the GTAP model utilizes. Since the most likely conversions would occur on private forests within areas near existing cropland infrastructure, further refinements could be evaluated by comparing the spatial breakdown of the biomass in the 66 zones of the Kellndorfer et al. data set with the spatial breakdown of the locations of cropland shown in Gibbs and Yui 2011. For example, across the northern tier of states that comprise AEZone 10, existing cropland is clustered in the Midwestern locations that have lower aboveground biomass in the NBCD Zone map from the Kellndorfer data set.

Moreover, Heath et al. show the breakdown of average forest carbon density in National Forests within the various regions in their Figure 4. Inspection of these breakdowns compared to the biomass carbon stocks used in the draft Plevin et al. analysis reveals that the carbon stocks in the U. S. national inventory are substantially below the Plevin estimates. For example, the total biomass carbon plus the total soil carbon stocks in the Plevin et al. model equate to 289 Mg C/ha in AEZ 10, 219 Mg C in AEZ 11, and 189 Mg C in AEZ 12. This can be compared to an estimated 190 Mg C/ha in the private forest land of the Eastern zone of the U. S. inventory and 125 Mg C/ha in the private forest land of the Southern zone of the U. S. inventory. Clearly, although the boundaries of these zones are somewhat different, there are substantially more carbon stocks in the draft ARB estimates than in the more refined U. S. inventory.

There are several reasons for these differences. First, Plevin estimates the below ground carbon using a world-wide default value of 25% whereas the U. S. inventory uses a value of 20%. Second, it is likely that there is double-counting of the forest floor/litter portion of the biomass carbon in the Gibbs and Yui estimates, both counting it as litter and as soil carbon. Gibbs and Yui refer to the likely cause of double-counting when they indicate:

> Although the IPCC implies that litter refers to the organic layers on the surface of mineral soils, soil science considers litter to be restricted to freshly fallen leaves, with decomposing leaves considered humus.

In forests, there is a continuing supply of deadwood that together with leaves and needles that have been shed results in a layer on the forest floor of fresh and decomposing carbonaceous material. The procedures for sampling and estimating the amount of such material vary substantially around the world. In addition, the procedures for sampling and analyzing soil properties vary, too. The documentation for the Harmonized World Soils Database (HWSD) that was the basis for the Gibbs and Yui soil carbon estimates indicates that the variables have been determined in many laboratories according to various methods and these methods are not necessarily comparable. The biggest issue is the treatment of the O horizon (the topmost layer of soil which is above the mineral soil) which is a mix of decomposing organic materials. The Soil Survey Manual indicates:[20]

> Depth is measured from the soil surface. The soil surface is the top of the mineral soil; or, for soils with a 0 horizon, the soil surface is the top of the part of the 0 horizon that is at least slightly decomposed. Fresh leaf or needle fall that has not undergone observable decomposition is excluded from soil and may be described separately.

Since the forest floor usually contains a layer of organic material on top of the mineral soil, the IPCC default of calling such material litter rather than a separate soil layer can lead to potential double-counting. The HWSD documentation indicates:

> Reliability of the information presented here is variable: the parts of the database that still make use of the Soil Map of the World such as North America, Australia, West Africa (excluding Senegal and Gambia) and South Asia are considered less reliable…"

The documentation goes on to indicate that update of the HWSD is foreseen for the near future, specifically referring to an excellent database from the U. S. – the Natural Resources Conservation Service U.S. General Soil Map (STATSGO). Indeed STATSGO is the database that was used for soil organic carbon in the 2010 U. S. inventory. Therefore, the ARB estimates should incorporate the U. S. inventory estimates for soil organic carbon.

Third, the Plevin et al. estimates for a number of components come from less refined sources than the U. S. inventory. For example, the PAN et al. 2011 analysis is a global carbon analysis developed by workshop participants for a related purpose and does not have the detailed breakdown by AEZ or forest type that is possible with the U. S. inventory. Plevin et al. use the Pan et al. 2011 estimates for deadwood carbon stocks. However, Woodall et al. 2009[21] point out that globally only about 13% of countries inventory deadwood, and they do so using a diversity of sampling methods and deadwood component definitions. It is interesting to note that the total carbon stocks in the Pan et al. 2011 analysis for the U. S. as a whole, 167.1 Mg C/ha in 2007, is very similar to the 2010 U. S. inventory, also confirming that the current carbon stock estimates in forests in the AEZModel are too high.

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[20] Soil Survey Manual, Third Edition, Chapter 3, page 4.

[21] C. Woodall, J. Rondeux, P. Verkerk, G. Stahl, Estimating Dead Wood During National Forest Inventories: A Review of Inventory Methodologies and Suggestions for Harmonization, Environmental Management (2009) 44:624–631
DOI 10.1007/s00267-009-9358-9.

3.1.2 Fate of Carbon in Land Use Change

3.1.2.1 Fate of Above Ground Live Carbon (AGLC) – HWP, Landfills, Energy, and Emissions

The Plevin et al. analysis currently uses placeholder values representing the fraction of AGLC that remains sequestered in harvested wood products (HWP) after 30 years, with different values for developed and developing regions (currently 20% and 5%, respectively). The text indicates that they are examining a new analysis of HWP produced by UC Davis for inclusion in the AEZ-EF model. Because of the importance of this portion of the model, the draft analysis should be made available for public comment before it is included in the model.

In the Plevin analysis, it is important to account not only for harvested wood that is sequestered in products and landfills, but also for wood products that are burned for energy that offsets fossil fuel use. There are now several existing models and analyses of the fate of AGLC, especially for the U. S. For example, Plantinga and Birdsey 1993, a reference in the Plevin et al. draft, included estimates of carbon in harvested wood out to the year 2040. In addition, Heath et al. 1996[22] extended that analysis to include estimates of the fate of carbon from wood harvested and removed from U. S. forests from 1900 to 1990.

Heath et al. conclude:

> On a percentage basis, by 1990 approximately 35% of the total C removed is stored in products and landfills, 30% has been returned to the atmosphere through decay or burning without energy production, and 35% has been burned for energy, partially offsetting fossil fuel use. Forest products industries contribute to the last end-use by burning virtually all residues used during processing of logs, and wood is burned in power plants, waste incinerators, and the home. This category is often a source of confusion in reporting C in wood products. Because such C is not sequestered in a solid state, it is considered an emission in some accounting frameworks. However, it has helped mitigate increasing atmospheric CO_2 concentration by offsetting fossil fuel use, and in this respect it is not equivalent to emissions from decay.

In addition to the 1996 paper, Heath and a number of other authors designed a model for USDA called Forest Carbon Budget Model (FORCARB2), which produces estimates of carbon stock and stock changes for forest ecosystems and forest products at 5-year intervals. The model can track the percent of carbon from forests that is either emitted, burned for energy, landfilled, or still in-use for softwood and hardwood from different

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[22] L. Heath, R. Birdsey, C. Row, and A. Plantinga. 1996 Carbon pools and flux in U. S. forest products. In: Forest Ecosystems, Forest Management, and the Global Carbon Cycle, M. Apps and D. Price, eds. NATO ASI Series I: Global Environmental Changes, Volume 40, Springer-Verlag, P. 271-278.

parts of the country. [23] The Forest and Agricultural Sector Optimization Model (FASOM) model used by EPA to evaluate U.S. land use changes due to corn ethanol also uses the FORCARB methodology. [24] In particular, Table A-7 from the final FASOM report for EPA shows that between 22% and 40% of harvested wood in the Southeastern Region ends up as emissions after 30 years, the remainder is in products, landfills, or used in energy.

Since the result of historic forestry and forest products management practices along with historic use and disposal practices have resulted in only 30% of AGLC being returned to the atmosphere through decay or burning without energy production in the U. S., the placeholder in the Plevin analysis should be changed to indicate that 35% of the AGLC is sequestered and another 35% is given credit for offsetting fossil fuel use in the U.S.

The historic Heath et al. results should be a baseline against which any new analyses should be evaluated. In addition, any analysis should take into account current forest product industry and disposal practices as well as the potential for future product and disposal practices that could sequester or offset additional carbon. For example, Lippke et al. 2011[25] point out that 50% of the above ground biomass now goes to product mills and that about 24% of the residual above ground biomass may be recoverable for use as fuel. They note that some of this material is already collected in the U. S. in regions where the terrain and logistics support the collection cost. They also indicate that the recovery of forest residuals is much more prevalent in Europe,

3.1.2.2 Fate of Below Ground Live Carbon (BGLC)

The Plevin et al. analysis assumes that all the carbon stored in below ground live carbon releases CO_2 due to decay upon conversion of forest to cropland. However, in the natural cycle of growth and decay in forests, the roots that make up below ground live carbon act as a source of soil organic carbon as well as CO_2. Therefore, not all the BGLC releases CO_2 when forests are harvested. In addition, the decay process in soil is a complex mix of chemical, physical and biological processes. Therefore, there is substantial uncertainty as to the extent and timing of CO_2 release. While there is only limited information regarding how to handle this issue, one way that has been used is to assume a fast decaying portion with a half-life of one year and a slow decaying portion with a half-life of 50 years.[26] Another approach is to assume three compartments, a fast

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[23] Heath, Nichols, Smith, and Mills, FORCARB2: An Updated Version of the U.S. Forest Carbon Budget Model, USDA, Northern Research Station, NRS-67, August 2010.

[24] Beach and McCarl, U.S. Agricultural and Forestry Impacts of the Energy Independence and Security Act: FASOM Results and Model Description, Final Report, January 2010. See in particular, Appendix A, Section A.1.5.1.1 “Forest Carbon Accounting.”

[25] B. Lippke, F. Oneil, R. Harrison, K. Skog, L. Gustavsson, and R. Sathre, Life cycle impacts of forest management and wood utilization on carbon mitigation: knowns and unknowns, Carbon Management (2011) 2(3), 303–333.

[26] D. Bragg and J. Gulden, Estimating Long-Term Carbon Sequestration Patterns in

decaying component, a slow-decaying component, and a long-lived component.[27]

The decomposition and decay of forest biomass involves the progressive breakdown of complex organic materials to simpler organic materials and finally to inorganic molecules. The plant materials provide energy for heterotrophic decomposer organisms -- such as fungi, animals (which range from large to very small), and bacteria – resulting in the release of CO_2. As the organic carbon is broken down, some is stabilized in clay-silt-sized organomineral complexes. In addition, some of the more resistant materials, such as lignin, become humus. Humus is an amorphous polymeric organic matter that plays an important role in water retention, soil structure, and nutrient cycling. Post and Kwon indicate that the fast decomposing component has a turnover time of months to years, the stabilized component has a turnover time of the order of decades, and the recalcitrant component has a turnover time of 1,500 to 3,500 years or longer. The Plevin et al. model should include a provision that a portion of the carbon in below ground live carbon as well as in dead and decaying forest materials is retained in the soil for a period of decades and another portion is retained in soil indefinitely.

3.1.2.3 Fate of Above Ground Deadwood and Litter

The Plevin et al. analysis assumes that all the carbon stored in above ground dead wood and litter releases CO_2 due to decay upon conversion of forest to cropland. However, depending on the clearing practices involved in the conversion, the fate of some portion of these carbon pools may be different. Plevin et al. include a provision for clearing by fire, which is common in some parts of the world, but for the U. S., it is assumed that the fraction of clearing by fire is zero percent. If the deadwood or a portion of the deadwood is collected and burned for fuel, replacing the use of fossil fuel, then the Plevin analysis should provide a carbon credit for the fossil fuel that is not being combusted. If the deadwood is landfilled, then the deadwood carbon would be stored for a very long time, and there should be a carbon credit for deadwood carbon storage that would have not occurred if the land had not been cleared. If the deadwood is simply piled somewhere and allowed to continue decomposing, then none of it should be debited against the clearing, because all that had happened was to move it to a different location.

In the case of litter, it is not clear exactly what the litter component in the Plevin analysis consists of and whether some portion is being double-counted with the soil organic carbon component. The U. S. Inventory makes a clear distinction between litter and soil organic carbon. It defines litter C as the pool of organic C (also known as duff, humus, and fine woody debris) above the mineral soil and includes woody fragments with diameters of up to 7.5 cm.[28] Using the U. S. Inventory data for litter and soil organic carbon would avoid any potential double-counting.

Even- and Uneven-Aged Southern Pine Stands, USDA Forest Service Proceedings RMRS-P-61. 2010.

[27] W. Post and K. Kwon, Soil Carbon Sequestration and Land-Use Change: Processes and Potential, Global Change Biology (2000) 6, 317–328.

[28] U. S. Inventory, supra note 15, at page 7-18.

The fate of the litter component depends on the details of the management practice during clearing and conversion to cropland. However, it is also known that a fraction of the carbon from decomposing litter is transformed into stable organic complexes, or humus that have very long lifetimes.[29] The portion of humus varies in forest systems depending on the nature of the tree species and the soil. Nevertheless, it would be important to account for the fact that not all the deadwood and litter decays and decomposes with the release of CO_2. For example, Woodall 2010, in a study of deadwood C in forests in the North Central U. S. cautions that "a reduction in any given forest carbon pool C on any given site is not necessarily an emission."[30] Woodall points out that often the forest C stocks transfer their C to another stock. He specifically gives the example of live tree C transferring to dead woody material C transferring to soils. Woodall et al. 2009[31] also point out that the inherent nature of deadwood resources is that of decay and transition from standing dead wood, to downed dead wood, to soil organic matter. In addition, the IPCC Guidelines make provision for transitions to soil organic matter in the disturbance matrices in Tables 2-1 and 5-7. [32]

3.1.2.4 Fate of Soil Organic Carbon

Plevin et al. base the estimates of soil carbon loss on IPCC guidance. The factors used for AEZs 10 to 12 (from Table 14 of Plevin et al.) assume a 31% loss in soil carbon. The text indicates that "the IPCC approach accounts for losses in the top 30 cm only, though recent evidence indicates SOC changes occur at deeper levels, too." The AEZ model, however, appears to assume a 31% loss of soil carbon to 100 cm depth, instead of 30 cm. The literature review by Murty et al. 2002[33] indicates that, while there was considerable scatter in the individual data points, consistent with earlier reviews conversion of forest to cultivated land led to an average loss of approximately 30% of soil C. However, when Murty et al. restricted the analysis to studies that had used appropriate corrections for changes in bulk density, soil C loss was 22%. Therefore, Plevin et al. should use the 22% loss factor. A 22% factor is also more consistent with the findings of Mann 1986[34] who examined soil data from 50 different sources and found that cultivated soils had on average 20% less soil C than uncultivated soils as well as the review by Post and Mann

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[29] D. Murty, M. Kirschbaum, R. McMurtrie, and H. McGilvray, Does conversion of forest to agricultural land change soil carbon and nitrogen? a review of the literature, Global Change Biology, 8, 105-123 (2002).

[30] C. Woodall, Carbon Flux of Down Woody Materials in Forests of the North Central United States, International Journal of Forestry Research Volume 2010, Article ID 413703, 9 pages doi:10.1155/2010/413703

[31] Woodall et al. 2009, supra note 19.

[32] 2006 IPCC Guidelines for National Greenhouse Gas Inventories,

[33] Murty et al., supra note 26.

[34] L. Mann, Changes in soil carbon storage after cultivation. Soil Science, 142 (5), 279-288, 1986.

1990.[35]

The lack of consistent use and definitions for litter and the O horizon in soils in the various studies raises the question of whether there would still be double counting if the U. S. Inventory litter and soil C data were used, since the IPCC and Murty et al. soil carbon loss estimates are based on soil carbon measurements that include the O horizon. As an alternative, the existing soil carbon data in Plevin could be used and the litter component eliminated.

3.1.3 Accounting for Foregone Sequestration

Plevin et al. use values of foregone sequestration derived from IPCC defaults together with a 25% correction to account for added BGLC. They also assume a mix of 10% new stands (< 20 years) and 90 % old stands (>20 years). The resulting yearly foregone sequestration is multiplied by 30 to arrive at the foregone sequestration over the assumed time horizon of the study. For AEZs 10 and 11, the resulting foregone sequestration is 75 Mg C/ha; for AEZ11 it is 47 MgC/ha.

The sequestration totals appear much too high. For example, the estimated foregone sequestration is roughly equivalent to the total above ground carbon in the trees that are being cleared. Since those trees are already in mature forests, they would not have grown to double their biomass over the next 30 years. In fact, the U. S. EPA estimates of the rate that the current U. S. forests are sequestering carbon are about 1/10 of the rates used by Plevin et al. in AEZs 10 and 11, where the bulk of the forest conversion occurs. For example, the 2010 U. S. inventory indicates[36] that, overall, average C in forest ecosystem biomass (aboveground and belowground) increased from 67 to 73 Mg C/ha between 1990 and 2010, which is an increase of 6 Mg C/ha in 20 years or 0.3 Mg C/ha/yr. This can be compared with the rate of 2.5 Mg C/ha/yr assumed by Plevin et al. for AEZs 10 and 11.

A particularly relevant comparison is provided by Woodall 2010.[37] Woodall reported on the sequestration of C in various above ground forest components in the north central U. S. based on the results from 185 forest plots measured in 2002 and 2007. Woodall reports that standing live trees sequestered a mean of 0.25 Mg C/ha/yr and standing dead trees sequestered a mean of 0.12 Mg C/ha/yr. These data are particularly relevant because the measurements were made in the north central U. S. states where expansion of corn ethanol is most likely.

Another comparison of interest is the study by Bragg and Guldin[38] that evaluated several ways to sequester carbon in southern loblolly pine forests. While intensively managed

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[35] W. Post and L. Mann, Changes in soil organic carbon and nitrogen as a result of cultivation, pages 401-406 in: Soils and the Greenhouse Effect, Ed by F. Bouwman, John Wiley and Sons, 1990.

[36] U. S. Inventory, supra note 15, at page 7-14.

[37] Woodall 2010, supra note 19.

[38] Bragg and Gulden, supra note 24.

even-aged pine plantations were estimated to be able sequester carbon at about 1 Mg/ha/yr over a 100 year time frame, the case that most closely applies to the Plevin analysis - an uneven-aged loblolly/shortleaf pine stand with 20 5-year cutting-cycle harvests under the selection method – only sequestered 0.38 Mg C/ha/yr on average.

Although there are examples of growth rates in the U. S inventory in the range assumed by Plevin et al., they are for urban trees in some cities and the U. S. inventory indicates that urban trees grow faster than forest trees because of the relatively open structure.[39]

Since a forest-to-cropland conversion is most likely on forest land that has marketable wood, it is not likely that young forests would be displaced. There is also information on the average age of U. S. forests in Pan et al. 2011[40] that can be used to refine sequestration estimates. Finally, Woodall et al. 2006,[41] in a study of the density of U.S. forests concludes that the forests of the U.S. may be broadly viewed as mature and that the majority of forests in the U.S. are fully occupied in a contiguous manner (except for forest/rangeland intermixes of the western U.S.).

3.1.4 Recommendations for Forest Emissions in the U.S.

With regard to improving the estimates of forest carbon stocks, the first recommendation is to use the 2010 U. S. Inventory as the basis of the Plevin et al. land use change estimates for the U. S. The U. S. inventory effort is well-developed, includes estimates of above ground live carbon in forests on private land, and uses consistent definitions of the various deadwood, forest floor, and soil carbon pools so as to avoid double-counting. This is a short-term recommendation.

With regard to the fate of above ground live carbon (AGLC), the placeholder in the Plevin analysis should be changed to indicate that 35% of the AGLC is sequestered and another 35% is given credit for offsetting fossil fuel use based on the Heath et al. 1996 study. This is a short-term recommendation. With regard to the 30% of AGLC that has historically been returned to the atmosphere through decay or burning without energy production in the U. S., consideration should be given to two scenarios, (1) retention of current practices, and (2) increased sequestration through increases in landfilling of wood products over time and increased use of residual forest materials for fuel use that offsets fossil fuel use.

With regard to below ground live carbon, provision in the model should be made to account for the fact that a portion of this carbon pool as it decays and decomposes result in long-lived soil organic carbon. With regard to deadwood and litter in the U.S., which

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[39] U. S. inventory, supra note 15, at page 7-49.

[40] Y. Pan, J. Chen, R. Birdsey, K. McCullough, L. He, and F. Deng, Age structure and disturbance legacy of North American forests, Biogeosciences, **8**, 715–732, 2011.

[41] C. Woodall, C. Perry, and P. Miles, The relative density of forests in the United States, Forest Ecology and Management, 226, 368–372 (2006)

Plevin et al estimates is not burned, it is either simply left to decompose, which it would have done anyway without being cleared, or some of it is landfilled, in which case there should be a carbon credit instead of debit, or some of it is burned for fuel, in which case there should also be a credit because it replaced some fossil fuel. In the short-term, deadwood and litter emissions should clearly be considered zero for forest conversion. In the longer term, the actual fate of deadwood and litter in landfills and for energy should be studied.

With regard to soil carbon loss upon conversion to cropland, the results of the Murty et al. 2002 literature review for studies that had used appropriate corrections for changes in bulk density should be used, which would reduce the soil carbon loss factor to 22%. These are short-term recommendations.

With regard to foregone sequestration in the U. S., the results from the historic U. S. data in the 2010 U. S. Inventory should be substituted for the IPCC defaults. For AEZ 10, the results from Woodall 2010 should be used. This is a short-term recommendation.

3.2 Estimated Impacts of Recommendations

In this section, we estimate the impacts of the recommendations for changes in U.S. emissions, based on a comparison of emissions in the current AEZ Model and data in the 2011 U.S. Greenhouse Gas and Sinks Report. For this analysis, we have utilized the default Purdue modeling runs from the previous section (where the land use emissions for corn are 19.6 g/MJ). We evaluated three modifications:

- Not including forest litter and deadwood in the forest conversion estimates
- Increasing the HWP factor to 70% to account for carbon stored in landfills and burned for energy
- Reduction in foregone carbon sequestration emissions

We also evaluated the cumulative results of these changes, both the Purdue base and with cropland/pasture yield improvement at 0.6/0.6 for U.S./Brazil. Results are shown in Table 8.

Table 8. Effects of Emission Modeling Recommendations on Corn Ethanol LUC Emissions (first 3 changes are independent, not incremental changes)	
Case	LUC (g CO2 eq/MJ)
Purdue Base	19.59
Don't include forest litter and deadwood in forest conversion emissions, U.S.	18.20
Increase HWP factor for U.S. to 70% to account for carbon stored in landfills and burned for energy	18.01
Reduce U.S. foregone carbon sequestration estimates by 80% to account for data on average sequestration in U.S. forest	17.11
All three of the above	14.14
All three of above, with GTAP cropland/pasture yield improvement at 0.4/0.6	12.37

Results show significant impacts of utilizing the data and methods in the U.S. 2010 GHG Inventory.

Appendix A
Detailed GTAP Model Results

Sensitivity of Land Cover Changes Due to the Expansion of US Coarse Grains Ethanol (Hectares)

Region	Constrained CRP Land (Default)			Unconstrained CRP Land		
	Forestry	Cropland	Pasture	Forestry	Cropland	Pasture
USA	-352,518	1,002,559	-650,099	-333,784	946,687	-612,910
EU27	-81,190	127,825	-46,652	-76,392	120,496	-44,104
Brazil	-3,669	88,588	-84,957	-3,323	83,876	-80,547
Canada	-115,104	172,307	-57,191	-105,467	158,992	-53,522
Japan	-3,077	3,529	-452	-2,940	3,367	-427
ChiHkg	17,654	55,099	-72,754	16,292	52,427	-68,729
India	-1,919	4,738	-2,835	-1,714	4,145	-2,445
C_C_Amer	32,324	20,988	-53,313	31,059	19,781	-50,836
S_O_Amer	81,565	65,528	-147,074	78,340	62,319	-140,651
E_Asia	3,982	806	-4,788	3,785	776	-4,564
Mala_Indo	7,362	-3,860	-3,511	7,119	-3,779	-3,344
R_SE_Asia	2,504	2,635	-5,135	2,361	2,489	-4,846
R_S_Asia	-1,755	23,425	-21,672	-1,581	21,543	-19,961
Russia	189,329	8,750	-198,226	182,710	8,393	-191,155
Oth_CEE_CIS	-21,241	105,108	-83,842	-20,144	99,679	-79,554
Oth_Europe	-85	1,649	-1,563	-99	1,574	-1,481
ME_N_Afr	-80	86,017	-85,921	-66	81,845	-81,765
S_S_Afr	-44,179	274,380	-230,230	-40,425	260,879	-220,321
Oceania	-784	86,120	-85,350	-811	81,723	-80,876
Total	-290,881	2,126,191	-1,835,565	-265,079	2,007,210	-1,742,039

Sensitivity of Land Cover Changes Due to the Expansion of US Coarse Grains Ethanol (Hectares)

Region	Food Consumption is Allowed to Adjust (Default)			Food Consumption is Fixed Globally			Food Consumption is Fixed in Developing Countries		
	Forestry	Cropland	Pasture	Forestry	Cropland	Pasture	Forestry	Cropland	Pasture
USA	-352,518	1,002,559	-650,099	-395,148	1,038,800	-643,690	-353,308	1,019,778	-666,474
EU27	-81,190	127,825	-46,652	-119,440	171,726	-52,303	-95,096	146,613	-51,510
Brazil	-3,669	88,588	-84,957	-13,501	107,202	-93,689	-11,493	98,561	-87,059
Canada	-115,104	172,307	-57,191	-153,784	214,373	-60,593	-129,744	191,081	-61,332
Japan	-3,077	3,529	-452	-3,993	4,334	-340	-3,287	3,759	-473
ChiHkg	17,654	55,099	-72,754	18,491	67,642	-86,136	16,204	63,444	-79,639
India	-1,919	4,738	-2,835	-2,561	8,832	-6,273	-1,975	7,644	-5,684
C_C_Amer	32,324	20,988	-53,313	25,795	24,963	-50,766	25,488	23,064	-48,547
S_O_Amer	81,565	65,528	-147,074	60,755	74,081	-134,842	56,908	68,524	-125,430
E_Asia	3,982	806	-4,788	3,987	899	-4,879	3,775	875	-4,648
Mala_Indo	7,362	-3,860	-3,511	7,168	-3,349	-3,829	6,764	-3,199	-3,560
R_SE_Asia	2,504	2,635	-5,135	2,556	3,669	-6,214	2,416	3,368	-5,779
R_S_Asia	-1,755	23,425	-21,672	-2,908	31,754	-28,838	-2,491	28,414	-25,929
Russia	189,329	8,750	-198,226	146,533	21,143	-167,710	200,415	12,798	-213,334
Oth_CEE_CIS	-21,241	105,108	-83,842	-39,126	140,296	-101,187	-34,473	125,335	-90,911
Oth_Europe	-85	1,649	-1,563	-515	1,913	-1,397	-133	1,893	-1,761
ME_N_Afr	-80	86,017	-85,921	-3,069	130,526	-127,449	-2,982	121,304	-118,310
S_S_Afr	-44,179	274,380	-230,230	-158,966	361,252	-202,327	-148,298	329,033	-180,609
Oceania	-784	86,120	-85,350	-2,036	101,356	-99,340	-1,368	93,129	-91,805
Total	-290,881	2,126,191	-1,835,565	-629,764	2,501,410	-1,871,803	-472,679	2,335,418	-1,862,793

Sensitivity of Land Cover Changes Due to the Expansion of US Coarse Grains Ethanol (Hectares)

	Cropland-Pasture Adjustment Included, Transformation Elasticity -0.75 (Default)			Cropland-Pasture Adjustment Not Included, Transformation Elasticity -0.5		
Region	Forestry	Cropland	Pasture	Forestry	Cropland	Pasture
USA	-352,518	1,002,559	-650,099	-520,938	1,004,849	-483,928
EU27	-81,190	127,825	-46,652	-83,300	130,251	-46,970
Brazil	-3,669	88,588	-84,957	-33,301	87,468	-54,161
Canada	-115,104	172,307	-57,191	-119,591	176,200	-56,610
Japan	-3,077	3,529	-452	-2,916	3,430	-513
ChiHkg	17,654	55,099	-72,754	16,249	55,771	-72,014
India	-1,919	4,738	-2,835	-1,499	4,347	-2,851
C_C_Amer	32,324	20,988	-53,313	27,870	21,450	-49,319
S_O_Amer	81,565	65,528	-147,074	81,378	67,780	-149,153
E_Asia	3,982	806	-4,788	4,532	866	-5,398
Mala_Indo	7,362	-3,860	-3,511	7,892	-4,326	-3,574
R_SE_Asia	2,504	2,635	-5,135	3,239	1,976	-5,212
R_S_Asia	-1,755	23,425	-21,672	-1,567	23,514	-21,945
Russia	189,329	8,750	-198,226	197,657	7,593	-205,350
Oth_CEE_CIS	-21,241	105,108	-83,842	-21,973	108,706	-86,667
Oth_Europe	-85	1,649	-1,563	-223	1,810	-1,583
ME_N_Afr	-80	86,017	-85,921	-133	90,112	-89,962
S_S_Afr	-44,179	274,380	-230,230	-43,173	273,119	-229,881
Oceania	-784	86,120	-85,350	-1,570	86,438	-84,827
Total	-290,881	2,126,191	-1,835,565	-491,367	2,141,353	-1,649,919

Sensitivity of Land Cover Changes Due to the Expansion of US Coarse Grains Ethanol (Hectares)

	Cropland-Pasture Adjustment 0.4 for USA, 0.2 for Brazil (Default)			Cropland-Pasture Adjustment Not Included			Cropland-Pasture Adjustment 0.6 for USA, 0.4 for Brazil			Cropland-Pasture Adjustment 0.6 for USA, 0.6 for Brazil		
Region	Forestry	Cropland	Pasture	Forestry	Cropland	Pasture	Forestry	Cropland	Pasture	Forestry	Cropland	Pasture
USA	-352,518	1,002,559	-650,099	-539,856	889,790	-349,949	-264,535	1,054,620	-790,055	-264,545	1,054,445	-789,961
EU27	-81,190	127,825	-46,652	-84,134	130,103	-45,980	-79,654	126,669	-47,010	-79,367	126,490	-47,125
Brazil	-3,669	88,588	-84,957	-56,982	81,129	-24,177	42,570	95,565	-138,125	83,889	102,337	-186,191
Canada	-115,104	172,307	-57,191	-120,523	176,142	-55,628	-112,520	170,416	-57,893	-112,364	170,234	-57,870
Japan	-3,077	3,529	-452	-3,134	3,579	-446	-3,050	3,504	-455	-3,047	3,502	-455
ChiHkg	17,654	55,099	-72,754	16,389	55,718	-72,097	18,285	54,784	-73,060	18,364	54,742	-73,118
India	-1,919	4,738	-2,835	-1,976	4,898	-2,916	-1,888	4,679	-2,795	-1,883	4,667	-2,789
C_C_Amer	32,324	20,988	-53,313	26,020	20,294	-46,313	35,226	21,294	-56,527	35,207	21,287	-56,483
S_O_Amer	81,565	65,528	-147,074	79,151	65,951	-145,086	82,990	65,336	-148,309	83,578	65,355	-148,918
E_Asia	3,982	806	-4,788	3,953	797	-4,746	3,996	811	-4,802	3,996	811	-4,801
Mala_Indo	7,362	-3,860	-3,511	7,438	-3,949	-3,498	7,330	-3,815	-3,516	7,330	-3,815	-3,516
R_SE_Asia	2,504	2,635	-5,135	2,493	2,572	-5,066	2,515	2,667	-5,180	2,535	2,678	-5,206
R_S_Asia	-1,755	23,425	-21,672	-1,814	24,055	-22,245	-1,726	23,113	-21,385	-1,722	23,076	-21,347
Russia	189,329	8,750	-198,226	191,562	8,796	-200,468	188,439	8,764	-197,221	188,450	8,765	-197,248
Oth_CEE_CIS	-21,241	105,108	-83,842	-21,779	106,720	-84,909	-20,976	104,290	-83,273	-20,934	104,186	-83,210
Oth_Europe	-85	1,649	-1,563	-99	1,664	-1,571	-83	1,642	-1,560	-82	1,641	-1,561
ME_N_Afr	-80	86,017	-85,921	-146	87,050	-86,887	-46	85,504	-85,448	-38	85,474	-85,425
S_S_Afr	-44,179	274,380	-230,230	-47,727	278,449	-230,691	-42,288	272,346	-230,014	-41,928	272,082	-230,109
Oceania	-784	86,120	-85,350	-1,474	85,570	-84,146	-453	86,371	-85,933	-426	86,388	-85,962
Total	-290,881	2,126,191	-1,835,565	-552,638	2,019,330	-1,466,818	-145,869	2,178,558	-2,032,561	-102,986	2,184,345	-2,081,297

Sensitivity of Land Cover Changes Due to the Expansion of US Coarse Grains Ethanol (Hectares)

Region	Yield-to-Price Elasticity 0.25 (Default)			Yield-to-Price Elasticity 0.2			Yield-to-Price Elasticity 0.4			Cropland-Pasture Adjustment Not Included, Yield-to-Price Elasticity 0.1		
	Forestry	**Cropland**	**Pasture**	**Forestry**	**Cropland**	**Pasture**	**Forestry**	**Cropland**	**Pasture**	**Forestry**	**Cropland**	**Pasture**
USA	-352,518	1,002,559	-650,099	-361,270	1,043,974	-682,666	-321,228	870,623	-549,420	-598,927	1,014,144	-415,198
EU27	-81,190	127,825	-46,652	-94,650	146,679	-52,042	-46,097	78,416	-32,310	-136,337	202,631	-66,305
Brazil	-3,669	88,588	-84,957	-5,321	98,744	-93,431	1,129	60,689	-61,764	-85,551	115,619	-30,030
Canada	-115,104	172,307	-57,191	-131,094	193,720	-62,619	-69,197	110,781	-41,594	-179,571	254,666	-75,093
Japan	-3,077	3,529	-452	-3,632	4,098	-466	-1,650	2,055	-405	-5,290	5,780	-489
ChiHkg	17,654	55,099	-72,754	19,690	65,065	-84,755	12,206	30,885	-43,094	23,857	95,841	-119,677
India	-1,919	4,738	-2,835	-3,950	8,497	-4,550	2,129	-3,049	920	-11,190	21,510	-10,321
C_C_Amer	32,324	20,988	-53,313	35,407	23,781	-59,174	24,339	13,371	-37,718	36,802	30,561	-67,363
S_O_Amer	81,565	65,528	-147,074	87,614	72,337	-159,952	65,423	46,426	-111,826	101,570	91,134	-192,692
E_Asia	3,982	806	-4,788	4,167	911	-5,079	3,395	536	-3,928	4,602	1,200	-5,802
Mala_Indo	7,362	-3,860	-3,511	7,514	-3,578	-3,933	6,825	-4,368	-2,461	7,895	-2,728	-5,168
R_SE_Asia	2,504	2,635	-5,135	2,155	3,524	-5,664	3,301	455	-3,739	1,035	6,050	-7,082
R_S_Asia	-1,755	23,425	-21,672	-2,407	29,034	-26,632	-208	9,688	-9,482	-4,473	46,659	-42,190
Russia	189,329	8,750	-198,226	199,805	12,244	-212,148	160,438	714	-161,220	231,000	22,958	-253,960
Oth_CEE_CIS	-21,241	105,108	-83,842	-25,112	119,593	-94,462	-11,311	67,334	-55,993	-36,850	162,709	-125,877
Oth_Europe	-85	1,649	-1,563	-113	1,846	-1,732	-4	1,120	-1,119	-194	2,411	-2,214
ME_N_Afr	-80	86,017	-85,921	-178	96,553	-96,364	175	57,968	-58,131	-532	127,264	-126,715
S_S_Afr	-44,179	274,380	-230,230	-56,557	310,469	-253,927	-12,303	180,605	-168,294	-96,392	418,157	-321,744
Oceania	-784	86,120	-85,350	-882	95,463	-94,557	-448	60,150	-59,707	-1,906	120,156	-118,254
Total	-290,881	2,126,191	-1,835,565	-328,814	2,322,952	-1,994,151	-183,088	1,584,399	-1,401,286	-750,452	2,736,722	-1,986,175