**Review of EPA's RFS2 Lifecycle Emissions
Analysis for Corn Ethanol**

**For:
Renewable Fuels Association (RFA)**
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1.0   Summary

EPA evaluated emissions changes due to Renewable Fuel Standard (RFS2) in five general areas – agriculture, biofuel production and transport, tailpipe, domestic land use, and international land use. EPA used the following models to estimate the various emission changes:

Agriculture, domestic:	FASOM
Agriculture, international:	FAPRI
Biofuel production and transport:	GREET, adjusted to 2022 timeframe using ASPEN
Tailpipe:	EPA MOVES Model
Domestic land use change:	FASOM
International land use change:	FAPRI

The largest category of emissions in EPA's analysis was the international land use emissions, comprising over one-half of the emissions from corn ethanol. EPA estimated that 4.8 million acres of new cropland would be needed to support an expansion of 2.6 bgy between a reference case containing 12.4 bgy of corn ethanol and 15 bgy of corn ethanol, with 0.3 million acres in the U.S., and 4.5 million acres needed abroad. Incremental agriculture emissions were small utilizing EPA's consequential lifecycle approach, due to the fact that while some agriculture emissions increased with increasing corn production, these emissions were mostly offset by reductions in other emissions from lower rice production and livestock production. The other categories of emissions from production and transport made up approximately 40% of total lifecycle emissions from corn ethanol. Overall, corn ethanol from a natural gas-powered dry mill producing DDGS was estimated at having either a 16% benefit or a 5% increase in emissions. This range was determined using two different time horizons and discount rates applied to the emission changes.

Air Improvement Resource, Inc. (AIR) obtained the FASOM model and the disparate components of the FAPRI model that were available on the EPA Docket, and we used these models to the extent we could to replicate EPA's analysis. We were able to replicate EPA's analysis for the most part for domestic land use emissions using FASOM. However, we were unable to perform several sensitivity analyses with FASOM because of a hidden startup file, and were unable to replicate FAPRI's estimates at all because of a lack of documentation and modeling spreadsheets that were provided with missing files, broken links, and other deficiencies. We also performed GTAP6 modeling of EPA's ethanol increase as a comparison. As another benchmark, Informa Economics also estimated land use changes using EPA's reference case and control case corn ethanol volumes. Finally, we reviewed in detail EPA's approach of using satellite data to estimate the types of land converted in other countries, and also the emission factors for converted land.

Numerous problems are identified with EPA's land use approach. As noted above, EPA used two different models to make its land use change estimates. These two models differed significantly on the impacts of the corn ethanol volume increase on key parameters affecting international land use change, such as the amount of land converted in the United States, U.S. exports, and effects on commodity prices. FAPRI, the model that generated 95% of the land use impacts, was higher on every parameter that caused it to overestimate the land use impact of corn ethanol. Our conclusion was that the models were not adequately linked to support such an analysis. Many of EPA's peer review comments agreed that this could be a serious problem.

Our other conclusion was that FASOM, the model used to generate domestic land use impacts, did not include all available land inventories to convert, hence, it reduced exports and increased prices since the land available to the model could not increase supply commensurate with the demand increase. The solution to this discrepancy is to significantly revise and update FASOM with new land inventories, revise both models with improved distillers grains land use credits and price-yield impacts, then see if the two models can be better linked and calibrated focusing on exports, prices and the prediction of amount of land converted in the U.S. There were numerous other changes recommended for both models, but particularly for FASOM, since this was the only model we were able to effectively review. When these updates are completed, and assuming this linkage is possible (which is a big "if"), we expect the estimated land use impacts of corn ethanol will be significantly less.

Our modeling using GTAP6, which was the model utilized by the California Air Resources Board (CARB) for its land use change analysis, showed a 1.1-1.6 million acre increase for the 2.6 bgy ethanol increase, with 35%-45% of the land use changes coming from the U.S., a much lower amount of land converted and a higher fraction of land from the U.S. than EPA's analysis shows. GTAP6 bases its endogenous yield changes on 2001 corn yields of about 138 bu./acre, and corrections are made exogenously for recent yield improvements (which were made in our estimates above). The model also includes a price effect on yield. The model was run with central value elasticities described in GTAP Working Paper 55, a recent paper by most of the parties performing modeling for CARB's Low Carbon Fuel Standard (LCFS). The upper end of the range used these central value elasticities, the lower end of the range assumed a price-yield elasticity near zero and yield elasticity with respect to are expansion of near 1.0, which are very similar assumptions made in FAPRI and FASOM. The land use impact as generated from GTAP6 would be lower than 1.1-1.6 million acres, if GTAP6 were also updated with improved information on the substitution of distillers grains for animal feed.

Informa's analysis showed a 2.2 million acre increase, but this is because Informa simultaneously analyzed both the 2.6 bgy corn ethanol increase *and* the 300 million gallon biodiesel increase from EPA's control and reference cases. Informa suggested that the location of the additional land increase could be in either Latin America (mainly Brazil or Argentina) or the United States, or some combination of these. Notably,

Informa's U.S. yield assumptions were about 10% higher in 2022 than EPA's analysis with FASOM and FAPRI.

After reviewing all three estimates, our conclusion is that the land converted to crops is much lower than the 4.8 million acres estimated by EPA for the 2.6 bgy increase of corn ethanol. And, we think most of this will be converted in the United States and nearly all of it will be pasture. The U.S. currently contains almost 70 million acres of combined cropland/pasture and idle cropland not currently included in FASOM and GTAP (efforts are underway by Purdue to include cropland/pasture in GTAP). If FASOM and FAPRI are revised, we think the GHG performance of corn ethanol relative to gasoline will likely exceed a 20% benefit by a significant margin, easily reaching the minimum greenhouse gas benefit for "conventional" biofuel that is not grandfathered in EISA2007. A summary of our recommended modeling changes is listed at the end of this section.

Our review of the type of land use conversions estimated in various countries using satellite data uncovered numerous problems that could lead to biases in overestimating forest conversion. For example, it is known that land cover changes evaluated on a wide scale are historically relatively rare, meaning that most land stays with its current purpose or use for a long period. However, EPA's examination of the cropland data between 2001 to 2004 shows for Brazil that 40% of the land that was cropland in 2001 was no longer cropland in 2004. This is highly unlikely. The accuracy of the land use changes reported between 2001 and 2004 in the Winrock analysis is unknown, and the pattern of changes reported raises several red flags suggesting that misclassification errors, rather than real land use changes, dominate the reported land use changes.

Overall, we think basing the types of land changes on the evaluation of the satellite data is the most uncertain part of the EPA analysis. A number of the EPA peer reviewers also reflected this uncertainty. Our view is that it is difficult to show that the land conversion due to corn ethanol occurs outside the U.S., and we believe that land conversions within the U.S. will be almost entirely grassland (pasture). If the model changes we have suggested are implemented, the models will likely reflect these conclusions.

Summary of Recommended Modeling Changes

1.   Both the FAPRI and FASOM models' treatments of the substitution of distillers grains from corn ethanol plants need to be updated to more recent information developed by Argonne and Shurson.

2.   The FASOM model needs to include distiller grains exports.

3.   The FASOM model's land inventories need to be updated to include 70 million acres of cropland/pasture and idle cropland.

4.   FASOM limits the conversion of pasture to no more than 10%. The impact of this assumption on land use changes needs to be determined, and it is not clear how this factor was developed.

5. FASOM needs to be run with the forestry module revised and enabled.

6. FASOM should be revised to account for the benefits of reduced enteric fermentation for beef cattle fed distillers grains.

7. Internal inconsistencies in FASOM should be addressed.

8. Once FASOM and FAPRI are modified, they should be run to examine linkage changes needed. Components to focus on are the estimated land converted in the U.S., exports, and price impacts. If these items cannot be closely aligned between the models (i.e., in the 3-6% range), then it is probably not adequate to use a Two-Model approach, and EPA should use the GTAP model or Informa's projections.

9. If Step 8 is successful, EPA should examine the effects of higher yields, and price-induced yield effects. For higher yields, we suggest using Informa's projections or those provided by major seed companies.

10. If GTAP is used, it's assumptions for the treatment of distillers grains should be updated (same comment as item 1 for FASOM and FAPRI). Its land use databases should also include the 61 million acres of cropland/pasture.

11. EPA should only account for lost carbon sequestered for perhaps 50 years instead of 80 years, due to the fact that some land converted by biofuels would have likely been converted eventually even without biofuels.

12. After reactivating the forestry module in FASOM, EPA should follow FASOM's procedures and estimates for the sequestering of building products in landfills.

2.0   Introduction

EPA released its RFS2 proposed rule on May 26, 2009. Two days of workshops were held by EPA in Washington, DC on June 17 and 18, 2009. Comments on the proposed rule were requested by September 25, 2009.

EPA used the FASOM model to evaluate domestic land use changes, and the FAPRI model to evaluated international land use changes. AIR acquired the FASOM model and GAMS software to run the model, and also downloaded from EPA's docket the portions of the FAPRI model that were provided by EPA. The purpose in acquiring these models was to replicate EPA's results, and to perform additional modeling utilizing some changes that we determined were more appropriate, and to determine the effects of those changes on land use changes. The FASOM model as provided contained a startup file that was very difficult to decode. Decoding this startup file is essential to performing alternative runs of the model. We did not receive assistance in decoding this model until two days before the comment period ended. Therefore, we were unable to include the results of our FASOM runs in this report. We were, however, able to replicate some of EPA's results for their various cases. We were unable to run the FAPRI model due to a lack of documentation and instructions on how to run the model. To our knowledge, no other organizations outside of the CARD experts have been able to run this model and replicate the EPA results. Our review is therefore based on the reports, spreadsheets and other materials provided by EPA in the docket.

This report provides AIR's technical review of EPA's lifecycle analysis for corn ethanol in EPA's proposed RFS2.

This report is divided into the following sections:

- ➢ Background
- ➢ Determination of Amount of Land Converted and Location
- ➢ Review of Types of Land Converted and Emission Factors

3.0   Background

This section provides an overview of EPA's lifecycle modeling for corn ethanol within the RFS2.

3.1   Lifecycle Methodology

EPA uses a consequential approach to estimate lifecycle emissions impacts of the RFS2, rather than an attributional approach. In the consequential approach, EPA initially projects the future without the RFS2, then predicts the future with RFS2, and finally estimates the impacts as the difference in all emissions (GHGs and other) between the two cases. In an attributional lifecycle approach, one would estimate the total emissions from each biofuel feedstock first (including gasoline and diesel fuel), and then use the before and after RFS2 volumes for all fuel types to weight the emissions together, and determine the difference in total emissions.

We strongly support EPA's consequential approach, because it includes changes in emissions that the attributional approach usually omits. For example, increasing biofuels brings about less domestic rice production, and therefore less rice methane emissions. This reduction in emissions from lower rice production is included in the consequential approach, but ignored in the attributional approach because rice emissions are not generally included in any of the lifecycle emissions of the various fuels (biofuels and petroleum products). CARB has used the attributional approach in developing its Low Carbon Fuel Standard. The consequential approach is much more robust, because it encompasses a wider range of impacts than the attributional approach.

EPA evaluated emissions changes due to RFS2 in five general areas – agriculture, biofuel production and transport, tailpipe, domestic land use, and international land use. EPA used the following models to estimate the various emission changes:

Agriculture, domestic:	FASOM
Agriculture, international:	FAPRI
Biofuel production and transport:	GREET, adjusted to 2022 timeframe using ASPEN
Tailpipe:	EPA MOVES Model
Domestic land use change:	FASOM
International land use change:	FAPRI

In contrast to the above, CARB used the GREET model, adjusted to current California conditions, for all of the emissions except the domestic and international land use emissions. CARB used Purdue's GTAP model to assess domestic and international land use emissions.

3.2   Overview of Results for Corn Ethanol

3.2.1   The Major Driver of Lifecycle Emissions: ILUC

Figure 3-1 shows emissions in g CO2 eq/mmBTU of fuel for gasoline, for corn ethanol with all land use impacts, and for corn ethanol with just the domestic land use impact. We focus on one of EPA's primary cases with a 100-year time period and 2% discount rate. We assume a natural gas dry mill plant with dry distillers grains, and have summed the international and domestic agriculture emissions.

The first two bars in this figure are directly from EPA's results. The third bar illustrates the likely outcome if all of the land that is converted is in the U.S. alone. In the second bar, EPA estimates that 0.3 million acres of land are converted in the U.S. (6.4%), and 4.4 million are converted outside U.S. (93.6%) Dividing the emissions impacts by the acres, the U.S land conversions create 37% less emissions than the international conversions. In addition, much less total land is needed when the land is converted in the U.S., because corn yields estimated by EPA in 2022 are much higher in the U.S. than in the rest of the world (ROW) - almost twice as high as the ROW on a production-weighted basis. Also, the domestic land use emissions were estimated using FASOM without the forestry module turned on.

Figure 3-1
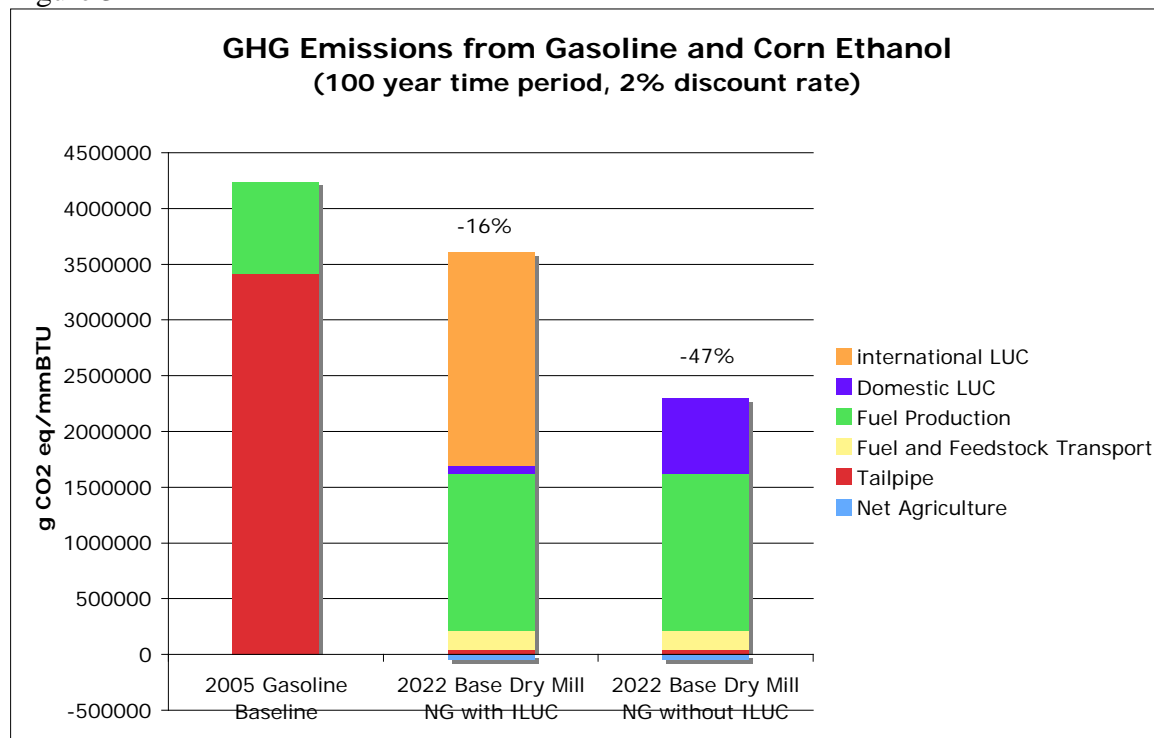
The figure shows that with EPA's mix of domestic and international land use changes, corn ethanol achieves a 16% reduction from 2005 gasoline. For corn ethanol, the international land use changes comprise the largest single category of emissions. In the third bar, we show that if all or nearly all of the land changes occurring were to occur in the U.S. at the same emissions rate as the 0.3 million acres, *and the remainder of the EPA*

modeling is correct, corn ethanol may achieve up to a 47% reduction.[1] Clearly, it is critical to examine the land use changes that EPA has estimated in detail.

3.2.2 EPA's Sensitivity Results

A summary of EPA's results, or the percent reductions for corn ethanol as compared to gasoline, are shown in Table 3-1 below. These results are for a natural gas fired dry mill with dried distillers grains operated in the 2022 timeframe. EPA estimated results for a number of different sensitivity cases, and we have shown only the most significant cases. The columns are briefly explained below:

Time horizon: The length of time, in years, over which benefits or disbenefits are aggregated
Discount rate: The discount rate, per year, applied to benefits and disbenefits
Primary: EPA's primary case, which assumes pasture replacement and a mixture of different ecosystems converted
No pasture replacement: Mixtures of ecosystems are converted, but lost pasture is not replaced
Grassland only: Pasture is replaced, but only grasslands are converted

EPA examined other sensitivity cases, for example, year of analysis (2017 vs. 2022), change in soil carbon emissions, length of time of foregone carbon sequestration, and a different fuel volume (higher). The first two had minimal impacts, and the second two had more moderate impacts. Interestingly, EPA did not evaluate the impacts of different crop yield projections, or different distillers grains usage rates on lifecycle emissions, which we highly recommend in a later section as items potentially having a significant impact.

Table 3-1. Range of Benefits of Corn Ethanol versus Gasoline				
Time Horizon	Discount Rate	Primary	No Pasture Replacement	Grassland Only
100	2%	*-16%*	-34%	**-48%**
100	0%	-36%	NA	NA
30	0%	*+5%*	-24%	-38%
30	7%	**+54%**	NA	NA
50	0%	-17%	NA	NA
50	2%	-2%	NA	NA

NA = not available from EPA

Table 3-1 indicates that the range of benefits could be from +54% to -48% for corn ethanol, a very wide range (shown in bold). The benefits most often shown by EPA are the 16% benefit, which corresponds to a 100-year time horizon with a 2% discount rate, with pasture replacement and a mixture of ecosystems converted. EPA also represents the

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[1] This is not our "best estimate" of the reduction in GHG emissions for corn ethanol. In a later section we critically review the EPA modeling in more detail, which will have a significant effect on this result.

other end of the range with the 30-year, 0% value of an increase in GHG emissions of 5%. These two ends of the range are shown in italics. EPA gives very little guidance as to the central benefit (or emission change) it is estimating for corn ethanol. The emission change in both of these cases means that corn ethanol does not meet a 20% GHG emission benefit, the minimum requirement for conventional non-grandfathered biofuels in EISA2007.

Clearly, if the ILUC value is high, then time horizon and discount rate matter very much in this analysis. However, if the ILUC value is relatively low (contrary to EPA's current analysis), then these items are much less important. So a threshold question to be asked is whether EPA's ILUC were developed correctly or not. The evidence, as we lay out in Section 4, shows that EPA's estimate is too high, and that therefore time horizon and discount rate would have less impact on the benefits of corn ethanol versus gasoline. But even so, the time horizon and discount rate issues should be examined on a fundamental basis without respect to whether the ILUC values are high or low.

Our view based on EPA's analysis alone is that the benefit for corn ethanol should be estimated over a long time period, and with no discount rate. However, we also do not think it is instructive to try to select a most appropriate benefit for corn ethanol from Table 3-1, because a number of key factors are not adequately included in EPA's current land use and lifecycle analysis.

4.0 **Determination of Amount of Land Converted and Geographical Location**

This section review's EPA's estimates of the amount of land converted and the geographical location of land converted. The section is divided into the following subsections:

- EPA's two model approach
- Reactive nature of modeling
- FASOM review
- FAPRI Review
- Use of GTAP to estimate land changes and locations
- Informa analysis of land needed

4.1 Two-Model Approach

EPA uses two different models to estimate the land use changes – FASOM for domestic land use changes, and FAPRI for non-U.S. land changes. FASOM is a very detailed model for the U.S. situation; FAPRI models trade between a number of major nations, and includes a U.S. module, but the U.S. module in FAPRI is more aggregated than FASOM. It would be far preferable to have one model estimating both U.S. and non-U.S. changes, so that conclusions could be reached without concerns about the linkages between the two models. For example, do they both predict the same impact on U.S. exports and commodity prices of increased volumes of biofuels?

The locations of land changes in FASOM/FAPRI are shown in Figure 4-1, which we created from the various spreadsheets provided in the docket.

Figure 4-1

2022 Cropland Change, FASOM/FAPRI

Total=4.77 million acres

Y-axis: Cropland Change (million acres)

X-axis categories: Brazil, India, Nigeria, USA, Paraguay, China, Other Latin America, ROW, Other Africa, EU, Mexico, Indonesia, Argentina, Russia, South Africa, Other CIS, Thailand, Philippines, Iran, Australia, Pakistan, Morocco, Egypt, Vietnam, Western Africa, Tunisia, Algeria, Japan, Other Eastern Europe, Canada, Uzbekistan, Other Middle East, South Korea, Ivory Coast, Cuba, Iraq, Columbia, Uruguay, Guatemala, Russia and Ukraine, Taiwan, Venezuela, Peru, Myanmar, Malaysia, Turkey, Other Asia, Ukraine, CIS, Bangladesh
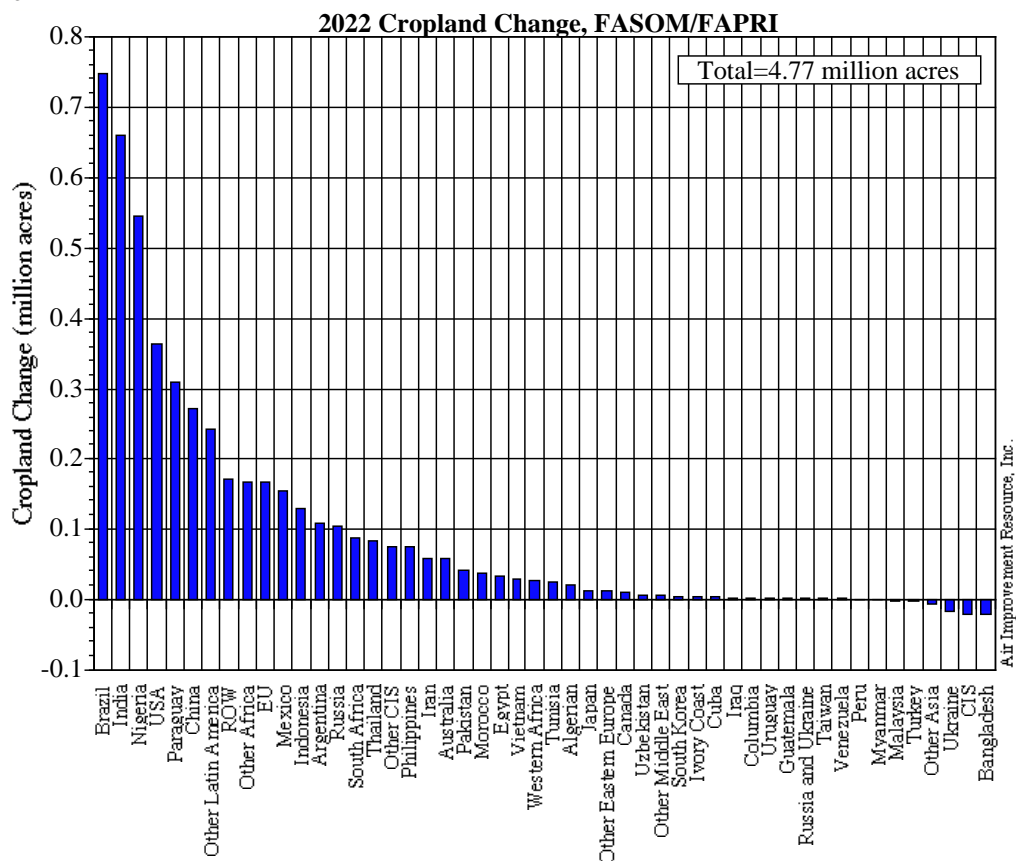
Air Improvement Resource, Inc.

Figure 4-1 shows that the top 6 areas with predicted land use changes are Brazil, India, Nigeria, the U.S., Paraguay, and China. As indicated earlier, all the non-U.S. land changes are generated by FAPRI, and the U.S. land changes come from FASOM. Since the RFS-2 is a U.S. control program, the implication of all the international land use changes in this analysis for the control program reflects that there is little or no land available in the U.S to absorb this control program without a large impact on exports and world commodity prices. As will be shown later in this report, this is simply not true, and the land use databases and the models' use of these databases in both FASOM and FAPRI for the U.S. need to be critically reviewed and revised (among other changes that are also needed).

We have shown that the overall land use changes EPA has estimated are driven by the international land use changes, and not the domestic land use changes. The international land use changes are a function of (1) how much increased biofuels reduce U.S. exports, and (2) how much increased biofuels raise commodity prices. Of course, other factors influence ILUC as well, such as trade preferences between nations, etc.[2] If increased biofuel use does not significantly reduce exports or increase commodity prices, then there should be little international land use change. As EPA indicates:

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[2] If prices are higher, there is more incentive for supplies to be increased worldwide. If U.S. exports drop significantly, other nations will fill in the drop in exports from the U.S.

"The impact on the international agricultural sector is highly dependent on the U.S. export assumptions. As we are using the FASOM model to represent the domestic agriculture impacts with an assumed export picture, the international agriculture sector impacts should be based on a consistent set of export assumptions. Therefore we worked with both models to build a consistent set of assumptions in order to have an equivalent basis for modeling domestic and international impacts." (Section 2.6.3 of DRIA)

We assume that by "building a consistent set of assumptions," EPA means items like consistent corn and soybean yields in the future, consistent oil prices, similar or equal assumptions with respect to distillers grains, and so on. We concur that it appears that EPA worked hard to ensure a nearly equivalent set of input assumptions. However, having both models use a consistent set of input assumptions does not, by itself, guarantee that the two models are appropriately linked and can be used to provide consistent land use change estimates. At least three critical outputs of each model must be examined further to determine if this approach can be used – the impact on exports, the impact on commodity prices, and the predictions of both models of domestic land use changes. If these three parameters are significantly different between the two models, then it is unlikely that the analysis will result in a reasonable and realistic estimate of land use changes.

EPA presents Figure 2.6-14 comparing export impacts of various parts of the RFS2, and concluded that:

"[T]he total changes in projected export impacts….are relatively consistent across both models with the possible exception of impacts related to increased biodiesel production." (Section 2.6.3 of DRIA)

This figure is reproduced below.[3]

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[3] "Draft Regulatory Impact Analysis: Changes to Renewable Fuel Standard Program", EPAA-420-D-09-001, May 2009.

Figure 2.6-14.
Comparison of FASOM and FAPRI Projected Change in U.S. Exports by Scenario, 2022
(tons per million ethanol equivalent gallons)
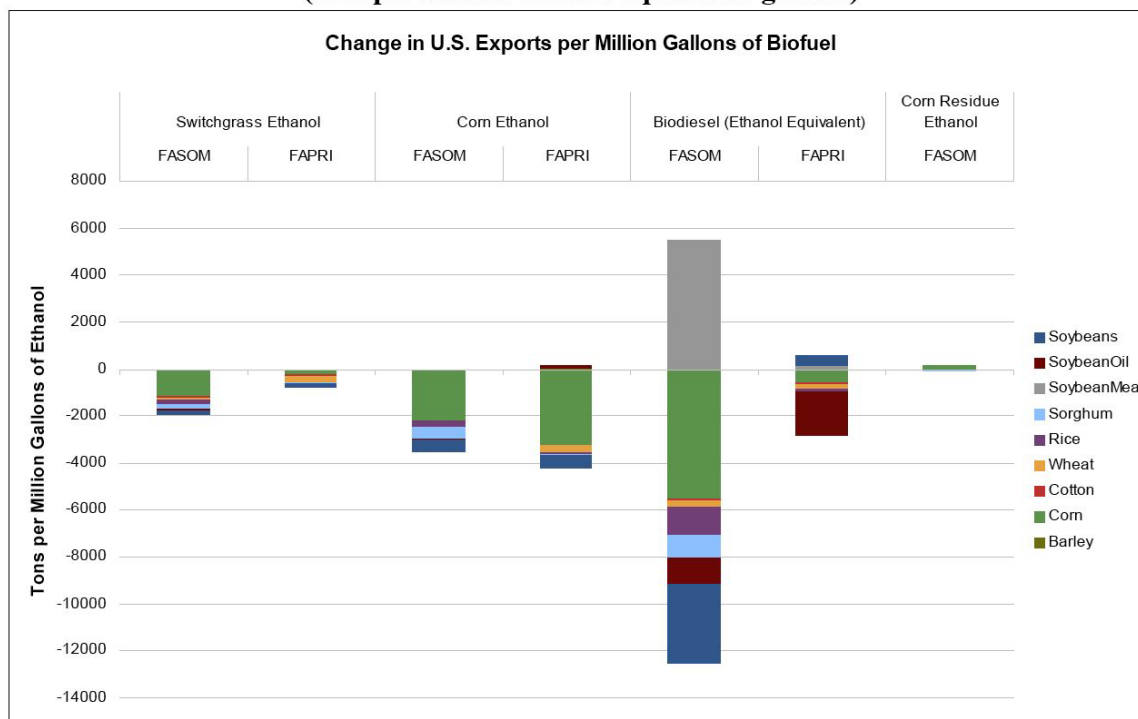
The figure shows that for corn ethanol, the FAPRI U.S. export impacts are greater than for FASOM. This would lead to greater international land use changes from FAPRI than if the FASOM export impacts were used in FAPRI. But EPA apparently considers these to be similar enough for the proposed rule, because EPA concluded:

> "For the analysis conducted and presented here we have used both the FASOM and FAPRI results as-is with no adjustments. Because the impact on international land use could be significantly different if we had used the FASOM export prediction than the FAPRI prediction, we intend to further refine the models with the goal of having the export response more closely aligned for the final rule."

With regard to changes in commodity prices, FASOM predicted that the increase in ethanol would increase the price of corn by $0.15 per bushel, and soybeans by $0.29/bushel. FAPRI predicted that the ethanol increase would increase the price of corn by $0.22 per bushel, and soybeans by $0.42 per bushel. The FAPRI price increases, on which the international land use changes are based, are ~45% higher than FASOM. This higher price increase would tend to cause more international land use changes to take place than if the price increases were more in line with FASOM.

With regard to the amount of land converted in the U.S., EPA presents Figure 2.6-16, a comparison of changes in acres per thousand gallons of biofuel, and concludes that,

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"FASOM and FAPRI also show similar domestic land use change responses" (DRIA, see footnote 3)

Figure 2.6-16.
Comparison of FASOM and FAPRI Domestic Crop Acre Changes by Scenario, 2022
(acres per thousand ethanol equivalent gallons)
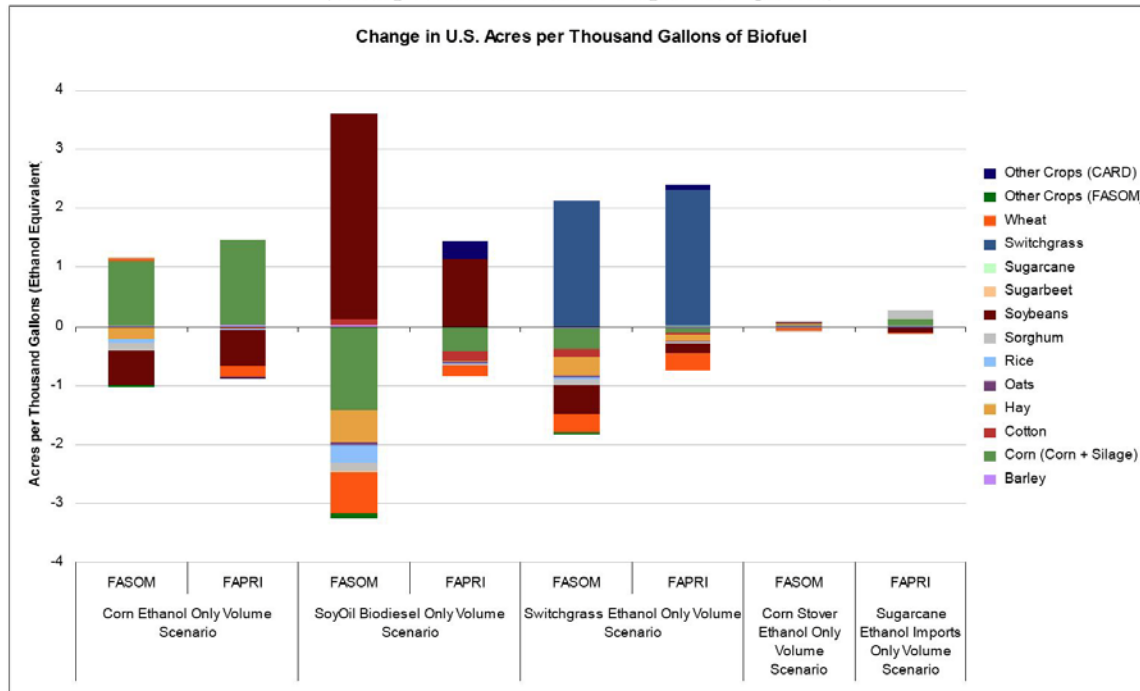
EPA's basis for this statement is that the two bars at the far left appear similar. However, this figure only shows the plusses and minuses of crop changes per thousand gallons of ethanol, and it does not show the net crop changes, or the total new crop acreage. As noted in the Background, for the corn only scenario, FASOM predicts that 0.3 million acres of new cropland are needed in the U.S. However, FAPRI predicts that 1.46 million acres of new cropland are needed in the U.S. Therefore, FAPRI predicts *almost 5 times the amount* of cropland is needed in the U.S. than FASOM.

The fact that FAPRI shows greater cropland is needed in the U.S. than FASOM also illustrates a tendency for the FAPRI model to over-predict land use change. This raises another important, fundamental question with regard to a domestic policy to increase biofuels: which model predicts domestic land use changes better – FASOM or FAPRI? We presume that EPA believes FASOM predicts domestic land use changes better, otherwise, we assume EPA would have used FAPRI for all land use change estimates. If EPA favors FASOM domestically, and if FAPRI strays far from FASOM with regard to exports, prices, and domestic land use change, then FAPRI should be re-calibrated to FASOM or not used at all.

These very significant differences between FASOM and FAPRI on parameters that have a direct influence on land use changes show that the so-called "linkages" between the

models are, for the most part, broken or tenuous, in spite of the fact that the models "appear" to be using a consistent set of input assumptions. There is little similarity between the two models on changes in U.S. exports, changes in commodity prices, and the change in domestic acreage converted. This argues strongly against EPA's two-model approach. At the same time, serious questions are raised about whether FAPRI should be relied upon to predict international land use impacts.

The comments of the peer reviewers on using these two models in a linked fashion were somewhat contradictory. EPA's peer review report on Model Linkage states the following:

> "The peer reviewers generally agreed that EPA's approach of linking partial equilibrium models was preferable to using a general equilibrium model such as the GTAP model, especially given the fact that no existing model comprehensively simulates the direct and indirect effects of biofuel production both domestically and internationally…..despite the fact that all the reviewers pointed to problematic areas of the current partial equilibrium approach, most of them believed the existing approach to be more reasonable than relying wholly on the GTAP model." (I-6) [4]

The latter part of the first statement is erroneous. GTAP does indeed estimate both direct and indirect land use change, but does not differentiate between the two land use changes since they have the same overall effect. Nonetheless, the report states that the peer reviewers (perhaps reluctantly) generally support the two-model approach. However, with regard to the linkages between the two models, some of the comments were more hard-hitting:

> "Dr. Wang expressed concern over the transparency of the modeling approach, particularly with regard to the linkage between FASOM and FAPRI. He recommended that the DRIA present domestic land-use change results from both FASOM and FAPRI in order to provide an indication of the similarities and differences between the two models."

> "Mr. Searchinger…..began by stating the biggest problem with the EPA analysis stems from commingling FASOM and FAPRI results…..he drew attention to the difference in predicted changes in crops and livestock production and exports. He noted that the differences shown in the export predictions in Figure 2.6-14 seem to be large and difficult to reconcile…"

> "Dr. Wang commented that the linkage of FASOM and FAPRI may be a very challenging if not impossible task. In addition, he stressed that the outputs and inputs of the two models and the information flows between the two models should be clearly presented in the DRIA…."

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[4] "Lifecycle Greenhouse Gas Emissions due to Increased Biofuel Production", Model Linkage, July 31, 2009, prepared by ICF International.

"Dr. Banse stated that linking models and ensuring consistency between models is a well-known problem…"

In response to Charge Question 3: What components of the model results should we be comparing to ensure consistency, the ICF summary mentions that:

"Dr. Banse expressed that a certain degree of inconsistency is unavoidable with partial equilibrium models. However, he noted that the most important variable for the analysis are trade volumes, therefore, at a minimum, both partial equilibrium models should generate similar trade figures."

We think that a key component to evaluate to ensure consistency is the whether the models produce the same land use change for the U.S., since (1) the RFS2 is a U.S. biofuel mandate, (2) U.S. exports and commodity prices have a very significant impact on international land use change, and (3) both models overlap completely in this area. As noted earlier FASOM predicts a 0.3 million acre change for the US while FAPRI predicts a 1.5 million acre change, about five times as much. Also, not one reviewer mentions price impacts as in important driver of international land use change.

Lastly, Mr. Searchinger makes two statements we would like to address:

"Mr. Searchinger noted that the most significant omission from the current analysis is the conversion of wetlands, especially peat lands, for biofuel crop production. He also commented that forest-to-pasture conversion spurred directly by meat prices is not included in the current analysis because the FAPRI model operates entirely within the crop sector where diverted crops for feed are replaced entirely by new feed. He pointed out that this is one weakness of the FAPRI model, noting that the model probably underestimates land-use change because proportionally more land must be cleared to replace meat production through pasture than through crops."

The first statement is clearly not true for corn-to-ethanol, and may not be true also for biodiesel because the model does assume some land converted in places that grow palm oil. But the increase in biodiesel as a result of RFS2 would be met from growing more soybeans in the U.S., rather than importing palm oil from Indonesia.

The second statement is also an erroneous conclusion. First, "diverted" crops for feed are not replaced entirely by new feed. Distillers grains from ethanol plants replace much of these crops, and also have a significant land use credit, as is recognized by GTAP, FASOM and FAPRI. But the credit is even higher than used in these models, as we discuss in detail in Section 4.3.2. Second, EPA's analysis does include pasture replacement for pasture replaced by crops. But as will be shown in Section 4.5, pasture intensification is occurring in areas outside the U.S., and this factor also appears to be ignored or misunderstood by Mr. Searchinger.

Overall, after running FASOM, GTAP6, and attempting several times to run FAPRI, and comparing results between the models and various sensitivity cases, we do not agree with the peer reviewers that EPA's use of the Two-Model approach is better than GTAP. It is very difficult to peer-review these models, unless they are run by the peer reviewers under the exact conditions of those used by the EPA, and unless these same peer reviewers perform sensitivity analysis of the model outputs to various inputs. Secondly, we disagree with Mr. Searchinger's overall assessment that FAPRI underestimates land use change. As we will show, FAPRI *overestimates* land use change, relative to GTAP, relative to forecasts by Informa, and through examination of key parameters (presented earlier in this section) between FASOM and FAPRI. If appropriate modifications were made to FAPRI, however (as discussed later), it is possible that it could more accurately assess land use changes due to biofuel increases.

4.2 Reactive Nature of Equilibrium Modeling

The FASOM and FAPRI models are partial equilibrium models that take into account dynamic changes in agriculture demand, crop yields, oil prices, etc. But the general nature in which equilibrium models work is that the models are "shocked" for an increase in corn ethanol, over a number of years, for example, from 2010 to 2022. The models achieve equilibrium between supply and demand at a certain price for all agriculture products in each of the years of analysis. The increase in ethanol in each year increases demand for a feedstock (corn). The model reacts to this demand by first increasing prices. The increase in price causes additional supplies to be provided (due to the cultivation of new land, for example). There are either elasticities of substitution between land types, for example, between crops and pasture, or lag variables that govern how quickly or slowly supplies can be increased. If these elasticities or lag variables indicate a certain "sluggishness" in land supplies, prices can increase higher and domestic exports are reduced. The models therefore can show that domestic supply cannot meet increased demand due to ethanol, so exports are affected and the models predict international land use changes.

It is important to understand that the equilibrium models are reactive in nature, i.e., they do not anticipate demand increases and therefore increase supplies, so that prices and exports are thereby much less affected. However, increases in demand due to biofuel mandates are known by interested parties many years in advance. These interested parties are not reactive, they are proactive in nature. Knowing that there is a greater demand for corn for ethanol, and knowing that export demand should stay strong for a few years, domestic farmers will plant more corn in anticipation of increases in demand and higher prices.

The knowledge that demand will be increasing may also indicate that land is not as sluggish in converting from one use to another (not from crop to crop, but from pasture to crop, for example) as the models assume. If the elasticities of substitution (or lag variables) between crop and pasture used in the models were developed from time periods in which shocks occurred that were relatively sudden and unforeseen (for example, a 6-month or 1-year increase in oil prices), these elasticities could be lower than

they should be for foreseen events like biofuel mandates. This problem of possibly overestimated sluggishness in domestic land supplies will lead directly to overestimates of international land conversion.

Based on the problematic areas discussed above, we highly recommend that EPA examine the elasticities of substitution (or lag variables) between different land uses like cropland and pasture, and determine if these elasticity inputs are appropriate for an event like a biofuel mandate, where the information is known for many years. The development of these elasticities was not discussed in any of the documentation that was provided in the docket. It may be appropriate to use somewhat higher elasticities of substitution between different land use types for a biofuel mandate than for many other events. We further recommend that EPA perform sensitivity analysis of their international land-use estimates to these elasticities of substitution or lag variables.

4.3   FASOM

This section discusses nine major concerns we have with FASOM, as follows:

- The model as provided was not transparent
- The land use credits of distillers grains from ethanol plants must be updated
- The FASOM model does not include DG exports
- The FASOM model does not include the full inventory of land available for crops and pasture
- The model did not include the forestry sector
- The model has problems with the pastureland definition and conversion of pastureland
- The model's treatment of CRP Land
- The FASOM model should be revised to include reduced enteric fermentation from cattle fed DGs
- The model should include an effect of increased price on yield
- The model may not be internally consistent

If these concerns were appropriately addressed, we believe the FASOM model would show less impact of corn ethanol in the RFS2 on prices and U.S. exports, and would indicate a greater quantity of land converted in the U.S. as opposed to internationally, which would result in lower overall land use emissions because of higher U.S. crop yields, and a smaller fraction of forest converted.

4.3.1   The model as provided was not transparent

At the outset, our first comment on FASOM is that the model as provided is not fully transparent. The model contained a startup file that would run the various EPA cases such as reference, control, corn-only, etc. However, we were unable to perform many desired sensitivity runs, such as for improved distillers grains assumptions, and disabling the FASOM limitation that only 10% of pasture can be converted in the entire calendar year range of the run. The startup file, which was purposely made unintelligible to the user,

prevented these modeling runs from being made. We repeatedly requested assistance from EPA on how to decode the startup file to perform these sensitivity runs, but EPA did not provide this assistance in a timely manner, so that we were not able to provide the results of our analysis in these comments.[5] We hope to be able to conduct these sensitivity runs once we understand how to decode the startup file.

4.3.2 The land use credits of distillers grains from ethanol plants must be updated

Since both FAPRI and FASOM account for the land use effects of distillers grains in some fashion, this section discusses the distillers grain assumptions used in both the FAPRI and FASOM models.

Distillers grains (DGs) are a co-product of producing ethanol from corn. They are a protein and fat-rich feed source that is used to feed livestock at feedlots and farms. In the analysis of the corn ethanol lifecycle, DGs fulfill two purposes. First, the energy of these co-products can be subtracted from the total energy used to produce ethanol. Second, DGs significantly reduce the land-use impact of ethanol made from corn by displacing some of the corn and other feed ingredients in livestock diets.

DGs can be provided from the ethanol plant in the "wet" or "dry" form. If they are dried, then the ethanol plant uses more energy (typically natural gas to fuel dryers). Conversely, energy use by the ethanol plant is much lower if DGs can be provided in the wet form. However, in the wet form this feed source must be utilized relatively quickly before it deteriorates.

With regard to land use, distillers grains are particularly important in reducing the land-use impacts of ethanol from corn. Most corn in the U.S. is used to feed livestock, so when DGs from an ethanol plant are used to feed livestock, they supplant some raw corn products and soybean products that would have been supplied without the DGs. As a result, somewhat less corn (and soy) needs to be planted to feed livestock, and less land is used than if DGs were not fed to livestock. In addition, the U.S. exports significant quantities of DGs that replace some corn and soybean meal that does not need to be exported for animal feed.

The amount of land credit applied to DGs is a function of two factors. One is the mass ratio of raw corn and soy products that DGs replaces in the livestock diet. Recent research by Argonne indicates that 1 lb of DGs replaces about 1.28 lbs of the regular diet, weighted over the different livestock types.[6] This greater-than-one-to-one replacement ratio is due to the fact that DGs are generally higher in protein and fat than the traditional diet they are replacing. The second item that affects the land use credit is the amount of soy meal in the base diet that is being replaced. Because the yield on soybeans per hectare is much lower than corn on a volume basis, the more soybean meal there is in the

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[5] EPA staff were working on getting us access to the startup file on September 22nd.

[6] "Update of Distillers Grains Displacement Ratios for Corn Ethanol Life-Cycle Analysis", Arora, Wu, and Wang, Argonne National Laboratory, September 2008.

base diet that DGs are replacing, the greater the land-use credit. The recent Argonne analysis found that 24% of the 1.28 lbs of base diet (or 0.303 lbs) replaced by 1 lb of DGs was soybean meal.

Table 4-1 shows the FASOM and FAPRI distillers grains feed replacement assumptions. Both models assume that DGs are used as feed for beef cattle, dairy cattle, swine, and poultry. FASOM assumes that 1 lb of distillers grains replaces 1 lb of feed, with the feed being 91.5% corn and 8.5% soybean meal.

FAPRI assumes that 61% of DGs are used for beef, 21% for dairy, and 9% each for swine and poultry. FAPRI further assumes that 1 lb of DGs replace 0.97 lb of corn and 0.03 lb of soy meal for beef and diary, 0.89 lb of corn and 0.11 lb of soy meal for swine, and 0.79 lb of corn and 0.21 lb of soy meal for poultry. When these fractions are weighted together, for all livestock FAPRI assumes 94.7% corn and 5.3% soy meal is replaced by DGs.

Table 4-1. Distillers Grains Assumptions in FASOM and FAPRI		
Parameter	FASOM[7]	FAPRI[8]
Mass replacement ratio	1.0	1.0
% Corn	91.5%	94.7%
% Soy	8.5%	5.3%

To address this issue in more detail, RFA contracted with Dr. Gerald Shurson from the University of Minnesota to (1) provide an independent review of the Argonne analysis, and (2) review the FASOM and FAPRI assumptions. [9] Dr. Shurson performed his own independent analysis of both sources, and found that the Argonne analysis is basically correct, that DGs are replacing more than 1lb of the base feed (he found it replaced 1.22 lbs of base feed versus Argonne's 1.28), and that it replaced more soy than Argonne estimated. The reasons for this difference are that Dr. Shurson expanded the analysis to include poultry, where Argonne did not include poultry. He also had slightly different numbers for beef cattle, dairy cattle, and swine.

These differences in DG feed replacement have a very significant effect on the land use credit, mainly because the yield from soy is lower than the yield from corn. This is shown in the figure below, which was presented by RFA at the January 30 CARB workshop, and is also shown and explained in detail in the AIR Land Use Report.[10]

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[7] "Agricultural Impacts of the Energy Independence and Security Act: FASOM Results and Model Description, Final Report, October 2008. EPA states in the Draft RIA that the fractions of corn and soy are 90% aand 10%, but the FASOM report indicates otherwise. It is possible that EPA changed FASOM's assumptions to be consistent with FAPRI's.

[8] DRIA, see footnote 3, and "An Analysis of EPA Biofuel Scenarios with the CARD International Models", November 2008, by CARD Staff.

[9] "A Scientific Assessment of the Role of Distillers Grains (DGS) on Indirect Land Use Change, Dr. Jerry Shurson, University of Minnesota.

[10] "Land Use Effects of U.S. Corn-Based Ethanol", Air Improvement Resource, Inc, February, 2009.
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Figure 4-2

Land Use Credit versus Percent Soy in Base Feed and DG Ratio
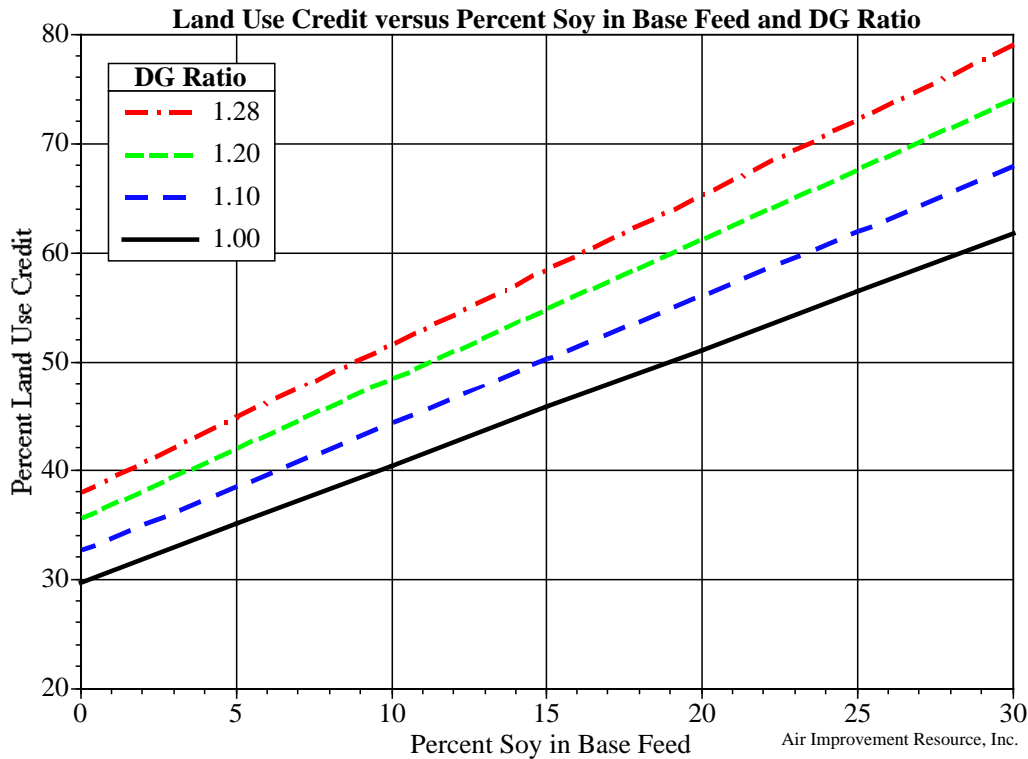
The DG ratio in this chart is the ratio of the mass of DGs to mass of feed replaced, so that if 1 lb of DGs replaces 1.28 lbs of feed, that would be found on the upper (red) line. We show the percent land use credit on the vertical axis and the percent soy in the base feed on the horizontal axis.

At zero percent soy in the base feed that DGs replace, and a DG ratio of 1.0, we see that the land use credit is about 30%. As the percent of soy is increased that DGs replace, the land use credit increases rapidly. This increase is because the land use credit for soy is higher than the land use credit for corn (because the soy yield is lower than the corn yield). If we use the values in the Argonne report (1.28 DG ratio and 24% soy), we obtain a land use credit of 71%. If we use the values developed by Shurson, we obtain a land use credit of 74%. The land use credits by EPA (FAPRI and FASOM), Argonne, and Shurson are compared in Table 4-2.

Table 4-2. Comparison of DG Land Use Credits			
Source	% Soy (remainder is corn)	DG Ratio	Land Use Credit
FASOM	8.5%	1.00	39%
FAPRI	5.3%	1.00	36%
Argonne	24%	1.28	71%
Shurson	25%	1.25	74%

Clearly, the distillers grains land use credits being assumed in the FASOM and FAPRI models are far too low. EPA must update the FAPRI and FASOM model estimates to either the Argonne or Shurson estimates, as they are much more representative of how DGs are actually used than the assumptions in FAPRI. This change in assumptions will significantly reduce the land use impact of corn ethanol.

In the DRIA, with respect to DGs, EPA relates its review of the Argonne paper:

> "A recent paper by Argonne National Laboratory estimates that 1 pound of DGs can displace more than a pound of feed due to the higher nutritional values of DGs compared to corn. However, the Argonne replacement ratios do not take into account the dynamic least cost feed decisions faced by livestock producers. The actual use of DGs will depend on the maximum inclusion rates for each type of animal (based on DGs energy and protein content), and the adoption rate (based on the feed value relative to price)."

As a rebuttal, in his comments on the Draft RIA, Shurson states:

> "On page 352 of the EPA report, the authors criticize the Argonne displacement ratios suggesting that they do not take into account the "dynamic least cost feed decisions faced by livestock producers." It appears the EPA authors do not fully understand least cost feed decisions. When DGS is priced favorably (which it has and will continue to be) relative to other competing feed ingredients such as corn and soybean meal, it is generally added to livestock and poultry feeds at the highest dietary inclusion rate possible in order to minimize feed costs without compromising animal performance. The deficiencies of the Argonne report were that it did not account for DGS use in the poultry industry, and the dietary inclusion rate for swine used in the calculations of displacement ratios was below current industry feeding practices. In my report (Shurson, 2009), I included poultry estimates and calculated a more realistic overall DGS displacement ratio."

Dr. Shurson's conclusions about least cost feed decisions driving maximum inclusion rates are also echoed in a recent report by Jacinto Fabiosa, Co-Director of FAPRI at Iowa State University. [11] Fabiosa developed a least cost feed ration model for finishing hogs, and found that at a 20% inclusion rate, a displacement rate of 1lb of DG for 1 lb of feed, and a 19% soy meal composition in the base feed, that the land use credit was 45%. Fabiosa states:

> "The first issue we are interested in addressing is whether the basis of the feed rations matters, that is feeding trial rations versus estimating them from feed ratios derived from a least-cost optimization.........The results of this study, however, suggest that for the swine grower finisher feed ration there is no big

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[11] "Land Use Credits to Corn Ethanol: Accounting for Distillers Dried Grains with Solubles as a Feed Substitute in Swine Rations", Fabiosa, Working Paper 09-EP-489, April 2009, Center for Agriculture and Rural Development, Iowa State University.

difference in these two approaches because DDGS turns out to be a very dominant feed ingredient in a swine feed ration."

Figure 4-2, developed by AIR, predicts a 50% land use credit with these parameters (lb for lb, with 19% soybean meal), which is higher than 45% developed by Fabiosa. The difference in land use credits between AIR and Fabiosa is due to the Fabiosa approach accounting for the loss of soy oil when the soy meal is substituted away. AIR agrees with this adjustment, thus, Figure 4-2 probably overstates the land use credit by about 5 percentage points. However, if the Fabiosa approach were utilized with all livestock and poultry (not just swine), and all of these results were combined, it is likely that the overall land use credit of DDGs would be in the 66-69% range (5 percentage points less than the 71-74% range shown in Table 4-2), which is still much higher than the 36-39% range currently utilized by FASOM and FAPRI.

To illustrate how critical this is to EPA's lifecycle analysis, the current EPA analysis indicates that domestic and international land use emissions are 1,990,938 g CO_2/mmBTU (100-year, 2% discount rate). EPA uses a 36% land use credit for DGs, so without the 36% credit they would have been 3,110,841 g CO_2/mmBTU. Reducing this latter number by 65%, we obtain 1,088,794 g CO_2 eq/mmBTU. Thus, incorporating more appropriate, scientifically-derived DDG credits would reduce the current land use impact by 902,144 g CO_2 eq/mmBTU, which reduces the current estimate by more than 50%. This one adjustment would increase the current EPA 16% benefit for corn ethanol from a natural gas dry mill with DDGS (100-year, 2% discount rate) to 39%.

EPA must either update the DG land use credits for corn ethanol for all livestock and poultry types in FAPRI and FASOM for the final rule, or explain in detail why the Argonne, Shurson, AIR, and Fabiosa analyses are in error.

4.3.3   The FASOM model does not include DG exports

Not only are the DG land use credits too low in the model, but the model currently does not include DG exports, which have been rising quickly. One of the major drivers of predicted international land use change is that the model predicts a drop in U.S. exports of corn. The FASOM report indicates:

> "…the model does not currently include DDG exports, and those exports may rise under the Control Case and at least partially offset the reduction in corn exports." (page 2-26, FASOM Report)

We are aware that EPA has used the FAPRI model, and not the FASOM model, to estimate international land use changes, and that the FAPRI model documentation does indicate that the model accounts for DG exports. However, much of EPA's dependence on using the FAPRI model for estimating international land use emissions hinges on the similarity of export impacts between FASOM and FAPRI. FASOM impacts on exports are already lower than FAPRI's, and incorporating this adjustment into FASOM would make them more dissimilar. For example, some of the corn being exported in FASOM

would not have to be exported if FASOM exported DGs that are already being produced in ethanol plants. Thus, FASOM's net exports of grains and oil seeds would be lower if the DG exports were included, making FASOM's exports lower still than FAPRI's. Therefore, FAPRI's export impacts, and therefore its international land use impacts, cannot be relied upon to give a reasonable estimate of land converted outside the U.S.

EPA should ensure that FASOM incorporates DG exports as well as domestic use, so that EPA can properly assess export differences between FASOM and FAPRI in determining whether it can reasonably rely on FAPRI to predict international land use changes, or whether FAPRI international land use emissions should be adjusted for the differences in FASOM and FAPRI exports.

      4.3.4   The FASOM model does not include the full inventory of land available for crops and pasture

The documentation for FASOM indicates the following sources for its inventory of cropland:

> "The area of baseline cropland included in the model is land in crop production based on USDA National Resources Inventory (NRI) data and USDA National Agriculture Statistics Service (NASS) data on county-level harvested acreage, i.e., cropland area included in FASOM is equivalent to estimated harvested cropland….idle cropland (is) not included in the reported FASOM cropland and (is) not explicitly tracked by FASOM."   (A-4 of FASOM report)

We examined the USDA/NASS data for 2002 and compared cropland and pasture between this source and the FASOM model. [12] The results are shown in table 4-3.

Table 4-3. Land Inventory Comparison Between FASOM and USDA/NASS		
Land type	Source	Acres (millions)
Ag crop land use	FASOM	295
Cropland	USDA/NASS	442[1]
Pasture land use	FASOM	239
Pasture/range[2]	USDA/NASS	586

[1] According to USDA/NASS, this breaks down into 307 million acres harvested, 62 cropland/pasture, 39 idle, 17 crop failure, and 16 cultivated summer fallow. Idle land includes CRP, which is 34 in 2002 (CRP Fiscal Year 2002 Summary, Ending Enrollment). If we eliminate the failure and fallow, there were 101 million acres of cropland/pasture, CRP land, and otherwise idle land that were available in 2002 for conversion to crops.

[2] This does not include forest land grazed, which is 134.

FASOM indicates there are 295 million acres of agriculture cropland in use in 2002. The USDA/NASS data indicate that there are 442 million acres of cropland available, but that 307 million were harvested, which agrees well with FASOM's 295 million acres. FASOM has CRP land in the inventory, but for all but one sensitivity case, EPA does not

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[12] See www.ers.usda.gov/Data/MajorLandUses/

allow CRP land to be less than 32 million acres. However, FASOM does not contain the 62 million acres of cropland/pasture, the 5 million acres of non-CRP idle land, the 17 million acres of crop failure land, and 16 million acres of cultivated summer fallow. Assuming that crop failure and a certain amount of summer fallow are going to occur to some extent no matter the scenario, there are still 67 million acres of combined cropland/pasture and idle land that FASOM cannot convert to crops as biofuels are expanded. As a result, the model increases prices and restricts exports, thereby predicting international land use changes. With respect to pasture, FASOM has 239 million acres used in 2002, but the USDA/NASS source indicates there are 586 million acres of pasture/range land. This 586 million acre estimate does not include either forest land grazed or cropland pasture. Certainly some of the difference in these two estimates is for dry land and is used somewhat for grazing, but could not support agriculture in a meaningful way without irrigation. However, it appears that the 10% restriction on conversion of pasture is somewhat arbitrary. This will be discussed further in section 4.3.6.

These data clearly show that FASOM's land inventory is highly and artificially constrained such that U.S. supplies of crops cannot meet U.S. demand with biofuels without a significant effect on exports. If the land inventory were improved, FASOM could show much less impact of biofuel expansion on both price and exports.

EPA should update FASOM to include the idle land and cropland/pasture, and the model should allow the selection of these lands as well as CRP land in modeling the RFS2. Or, EPA should explain in detail why the model does not need to be updated for these factors, and why inclusion of these would not affect its land use values.

4.3.5 Lack of inclusion of the domestic forestry sector

The FASOM modeling runs did not include the forestry component of the model. The report indicates:

> "In addition, as noted earlier, the forestry component of the FASOM model was not used for this analysis because of currently ongoing model updates. However, we plan to use the combined version of the model in future analyses if feasible. Using the combined version of the model would enable examination of the interaction between these sectors, including land allocation and competition between cellulosic feedstocks from the agricultural and forestry sectors. (page 1-20 of FASOM Report)

EPA must include the updated U.S. forestry sector model in the LUC analysis. Including this land will increase predicted land converted in the U.S. and should reduce land converted internationally. It will also increase the GHG emissions domestically, but reduce emissions internationally more than the U.S. increases.

4.3.6 Problems with the pastureland definition and conversion of pastureland

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There are two problems with how FASOM treats pastureland. One is that the model does not contain an inventory of pastureland that may include land that is considered pastureland but is not currently being used (i.e., idle pastureland), rather pastureland is estimated by the model based on the number of livestock by type and region and FASOM livestock budgets indicating the amount of pasture used per head. As a result, when cropland expands on pasture, it always involves livestock reductions, when in reality this may not be the case.
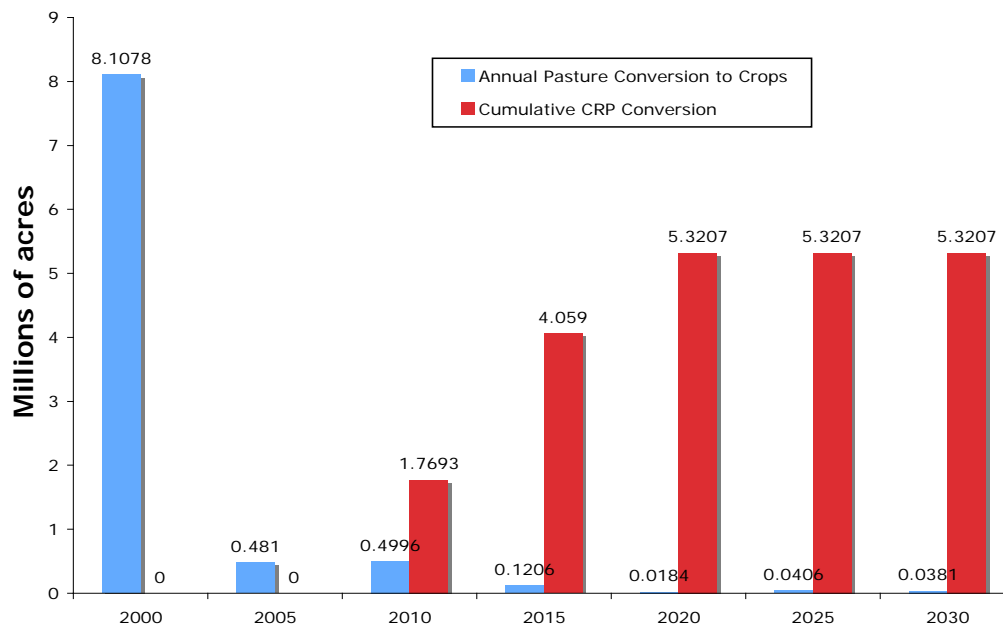
The second concern is that:

> "[T]here is a constraint placed on land movements such that no more than 10% of the original endowment of pastureland can be converted to cropland on a regional basis over the entire time horizon modeled. This assumption is based on professional judgment. Work is ongoing to further explore the potential for pastureland conversion to cropland and incorporate additional detail in land conversion specification." (pages 1-11 and 1-12 of FASOM Report)

The limitation that no more than 10% of pastureland can be converted to cropland over the period of analysis is limiting conversion of land to cropland in the U.S., and thereby transferring these conversions overseas where the emission impact is higher due to lower yields and denser, unmanaged forests. For example, Figure 4-3 shows pasture converted to crop over the period of analysis of the EISA FASOM analysis, and also shows the cumulative CRP conversion over the same period. The plot shows significant pasture conversion to crops in calendar year 2000, and after that the conversion of pasture to cropland is miniscule. CRP land gets converted in between 2010 and 2020, but these conversions level out because of the assumption that CRP land will not dip below 32 million acres. As a result, FASOM assumes there is very little land available in the U.S. for conversion to crops to support the RFS2 volumes.

Figure 4-3

Land Conversions to Crops With Reference Case

Source: FASOM run of EPA Reference Case, Table 7, Agriculture Activity Summary Over Time

A second concern here is the period of analysis that EPA used with FASOM. It used from 2000-2030 for analysis of the RFS2. Since the RFS2 did not really begin until 2008-2009, it is unclear why EPA started the period of analysis in 2000. It should probably being in 2007. If it did, some of the pasture that Figure 4-3 shows as being converted in 2000 would perhaps have been available in 2008-2010. *EPA should determine what effect starting the FASOM analysis in 2000 has on the results.*

We were unable to run the FASOM model disabling the 10% function to determine the impacts on U.S. land conversions. However, we were able to disable the CRP floor in the same manner described in the FASOM report, by changing the CRP floor to 19 million acres instead of 32 million acres. This could be considered a "proxy" for disabling the 10% limit. Our results showed that when we lowered the CRP floor to 19 million acres, that FASOM predicted that 1.4 million acres of additional total cropland would be used in the U.S. for the corn only case. As a result, much less land would be needed internationally (the reductions in international land would exceed 1.4 million acres because the international land generally has lower crop yields).

EPA needs to explain in detail the technical basis for the 10% assumption, the uncertainty involved in this assumption and the impacts of this assumption on U.S. versus non-U.S. conversion and land use emissions for at least the corn-only case, if not all the other cases involving the use of U.S. land.

4.3.7 Treatment of CRP Land

With regard to CRP land, EPA states:

"FASOM generally holds CRP land area fixed at initial levels, but for the EISA analysis, CRP land is permitted to convert back to cropland under the constraint that a minimum of 32 million acres of land remains in the CRP to be consistent with the 2008 Farm Bill and USDA assumptions. In addition, we explore a sensitivity analysis where the land area remaining in the CRP is allowed to fall to about half of the baseline CRP area in FASOM." (page 1-15 of FASOM Report)

From our review, we believe the baseline CRP assumption should go to whatever equilibrium level the model determines is appropriate, and that the sensitivity case could be some minimum level like 32 million acres. The previous section showed that the FASOM model limits pasture conversions over the entire time range used in the analysis to 10% of total pasture land. Additionally, a later section shows that FASOM omits substantial amounts of cropland pasture (61 million acres), idle land (6 million acres), and pasture/rangeland. If the land inventories in FASOM were updated, the model would probably indicate that much less CRP land would be utilized to meet RFS2.

EPA did perform an economic sensitivity case on the 32 million acre CRP floor assumption, but did not perform any land use change emissions sensitivity to this assumption. We note that when the 32 million minimum acre area was relaxed, the corn-only case showed a larger impact on exports than when it was not relaxed. (see Figure 3-6 in the FASOM report). It is not clear if this case results in higher or lower land use changes.

EPA should examine this sensitivity case in detail, and explain whether relaxing this requirement changes the fraction of land converted domestically versus internationally, and what impacts this has on the overall land use changes.

4.3.8 The FASOM model should be revised to include reduced enteric fermentation from cattle fed DGs

EPA has the correct methodology for estimating the net changes in enteric fermentation, both nationally and internationally, due to livestock population changes. However, the Argonne paper on Distillers Grains also shows that beef cattle fed DGs increase their weight quicker, and have a shorter lifecycle than cattle that are not fed DGs. Therefore, these cattle have less lifetime enteric fermentation than cattle not fed DGs. EPA should estimate the change in the fraction of beef cattle consuming DGs, both nationally and internationally, and the resulting changes in enteric fermentation for cattle consuming DGs. EPA indicated that it would consider incorporating this issue:

"Enteric fermentation emissions are impacted by type and quality of feed. As described in DRIA Chapter 5, the mix of feed types used will change based on the increased use of corn in ethanol and changes to corn prices. This change in feed type is not reflected in enteric emissions shown here. The direction of this change would likely be additional reductions in enteric fermentation emissions due to the fact that use of ethanol co-products DDGS as feed have been found to reduce

enteric fermentation emissions. We plan to include these CH_4 reductions as part of the final rule analysis." (Section 2.6.2.3 of the DRIA)

The reduced enteric fermentation is for shorter lifecycle for beef cattle because of the improved performance (i.e., weight gain) of beef cattle fed DDGs, therefore, it would not apply to dairy cattle, swine, or poultry. Therefore, one way of estimating the impact of reduced enteric fermentation is by (1) estimating the increase in DDG mass with the 2.6 bgy ethanol increase, (2) multiplying by the fraction of DDG that is used by beef cattle (38% - Shurson, 2009), (3) estimating the lifetime consumption of DDGs per head, (4) estimating the number of cattle with reduced emissions, and (5) multiplying the number of head of cattle by the lifetime emission reductions as shown by Argonne.

EPA should account for reduced enteric fermentation for beef cattle fed DGs.

4.3.9   The model should include an effect of increased price on yield

The FASOM and FAPRI models do not include any factor for the effect of price increases of commodities on crop yields. As the FASOM model documentation indicates:

> "Although it is possible that sufficient increases in commodity prices could induce farmers to adopt higher cost practices that increases productivity but are not profitable at lower commodity prices, FASOM does not directly incorporate yield responses to changes in prices."

At the outset, we think that because FASOM's land inventories are incorrect, the model is highly land-constrained, such that an increase in ethanol results in price increases and export reductions. If the model is fixed to include these various land inventories, the increase in prices and export impact should be smaller. Nonetheless, we think the model should also incorporate a price effect on yield.

CARB's analysis of price-yield impacts utilized information from Purdue GTAP research of the price-yield impacts for corn, with an average yield elasticity of 0.32. [13] CARB also tested the sensitivity of results to price-yield elasticities ranging from 0.1 to 0.6. Recent research by Purdue indicates that recent price-yield elasticity for corn could be 0.25. [14] We recommend a factor of between 0.25 and 0.32.

4.3.10 The model may not be internally consistent

EPA estimated the domestic land use change as the difference in the Control Case, with 15 bgy of corn ethanol, and all other sources of biofuels, and a "Corn Only" case that

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[13] "Proposed Regulation to Implement the Low Carbon Fuel Standard, Volume I, Initial Statement of Reasons", California Air Resources Board, March 5, 2009.
[14] "Global Land Use and Greenhouse Gas Emissions Impacts of U.S. Maize Ethanol: The Role of Market Mediated Responses", Hertel, Golub, Jones, O'Hare, Plevin, aand Kammen, GTAP Working Paper No. 55, 2009.

subtracted 2.6 bgy of corn ethanol from the Control Case. EPA obtained a domestic land use change of 0.3 million acres.

Another method of estimating the domestic land use change of the corn only case is to increase corn ethanol by 2.6 bgy from the Reference Case, which had 12.4 bgy of corn ethanol. When we utilized the FASOM model in this manner, the difference in total domestic agriculture crops was 1.4 million acres, rather than 0.3 million acres.

The reasons for these differences are not clear, and should be explained.

4.3.11 The model is correct to assume that when land is converted, it will have the same productivity as the current land

The FASOM model (and also the FAPRI model) assumes that as crop area is expanded, the productivity of new land is the same as the current land. We support this assumption. As a part of evaluating this issue for our analysis of the CARB LCFS, Informa Economics was hired by RFA to evaluate this issue in Brazil. [15] Informa Economics examined the increase in soybean production, which doubled in the world from 1989-1991 to 2006-2008, with much of the increase coming in Latin America. If the elasticity of crop yield with respect to area expansion was low, then we should expect to see yields drop significantly. Informa's analysis indicated:

> "…the combination of substantial soybean area growth and increasing yields in Brazil and Argentina demonstrated that it is mathematically unlikely that the assignment (based on judgment) of a value of 0.5 to the elasticity of crop yields with respect to area expansion is correct….it cannot be determined that yields on new area have been meaningfully different than yields on area previously planted to crops (i.e., that the elasticity is less than 1.0)."

Thus, we do not think there is evidence that productivity of land that is converted to cropland is less than current cropland, and believe to the contrary, that there is evidence to support both model's assumption of equal productivity on this issue.

4.3.12 EPA's sensitivity cases with FASOM

The FASOM report examined a number of sensitivity cases, as follows:

- High CRP reversion scenario
- Low corn yield scenario
- High corn yield scenario
- High energy price scenario

These were all compared to the Base Case, which is the Reference Case. Outputs examined were changes in harvested corn acreage, corn prices, and corn exports. The

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[15] See reference 13.

analysis did not evaluate changes in land use and land use emissions. Furthermore, the DRIA also did not evaluate the sensitivity of land use to these parameters. Part of the reason for this, we suppose, is that EPA's land use changes are driven almost entirely by FAPRI rather than FASOM.

The high CRP reversion and high yield scenario showed a lower corn price increase for the control case. The reference case increased corn prices by 15 cents per bushel. The high CRP reversion scenario increased prices by 11 cents per bushel. The high CRP and high corn yield scenarios also increased corn production significantly, with the high corn yield scenario increasing corn production by almost 1 billion bushels. With regard to corn exports, however, these were impacted more by the RFS2 for the high CRP and high yield scenarios, however, corn exports in both of these cases exceeded the base scenario. Other exports (for example, soybeans) were not shown.

These FASOM sensitivity cases raise significant questions concerning what the international land use impacts would be if the FAPRI model were adjusted to have the same corn price, production and export impacts as FASOM for these sensitivity cases. For example, the high corn yield case shows greatly increased production, higher exports, much less impact of the RFS2 on corn price, but somewhat greater export reductions due to the RFS2 (even though overall exports are much higher). No doubt it is somewhat difficult to adjust or balance FAPRI to FASOM's predictions on these three parameters. This is the fundamental reason why using two different models to predict land use changes is precarious at best.

A second concern we have is that EPA did not evaluate these sensitivity cases and their impact on the "Corn-Only" case, instead of (or in addition to) the Reference case. The Reference case includes biodiesel increases that use land and dedicated energy crop cellulosic ethanol increases that also utilize land. Therefore, the sensitivity cases may include crop interaction effects not directly related to corn ethanol.

If EPA is going to continue to use the two-model approach, it must decide which model represents the U.S. the best, and calibrate the other model to that best model in terms of prices and exports before estimating international impacts. The sensitivity cases should also be examined for the "Corn-Only" case in addition to the Reference Case, and should include land use effects as well as economic effects.

4.4   FAPRI

This section discusses four concerns we have with FAPRI, as follows:

- We could not replicate EPA's results with the model
- The land use credits of DGs from ethanol plants are too low
- The model should include the effect of price on yield
- The model was not adequately linked with FASOM

For the second and third issues, we refer to the same comments we provided for FASOM in the previous section. The following sections discuss the first and fourth concerns.

4.4.1 We could not replicate EPA's results with the model

Unlike the FASOM model, we could not replicate EPA's results with the FAPRI model. We contacted Dr. Bruce Babcock of Iowa State University, and Dr. Babcock indicated that no one outside of his staff would be able to replicate the model's results. In our view, this is a serious problem. FAPRI is currently generating 95% of the land use emissions in EPA's analysis, however, if EPA modifies FASOM as indicated earlier the FASOM model should show much more conversion in the U.S., it should show a much greater fraction of land converted in the U.S. Nonetheless, not being able to replicate EPA's results, and perform sensitivity modeling with the model is a unprecedented and troubling issue with regard to the far-reaching impact of RFS2.

4.4.2 The model was not adequately linked with FASOM

Section 4.1 showed that the FAPRI model was not well linked with FASOM: the FAPRI model shows 5 times as much land converted in the U.S. as FASOM, the commodity price impacts are higher than FASOM, and domestic export impacts are higher. All of these differences will lead to more land being converted.

The extent to which FAPRI will be needed for the final rule is dependent on the effects of the FASOM model changes. If FASOM indicates some effect of corn ethanol on exports and prices, then FAPRI exports and prices (and land converted in the US) need to be calibrated to match FASOM much more closely than was done for proposed rule.

4.5 Pasture Replacement

EPA's estimates of pasture replacement come from its analysis of Brazil land use changes. Table 2.6-32 of the DRIA shows that in step one, cropland expansion increases are 747,000 acres, and the step two pasture replacement adds an additional 439,848 acres. The pasture replacement step represents a 58% increase, and is 37% of total acreage converted. The Brazilian pasture replacement ratios are applied to all other countries.

Table 2.6-39 of the DRIA shows the weighted average emissions factors for both crop expansion and pasture replacement for 10 major regions of the world. The weighted average emission factor of all the regions in this table is 114 MT CO_2-eq/acre. AIR's analysis of the emission factors for crop expansion and pasture replacement indicates that the emission rate of the pasture replacement step has about 20% less emissions per acre than the cropland expansion step. Thus, the 58% increase in acres is mitigated somewhat by the lower emissions from the replacement step. But the net impact of the pasture replacement step for both the land increase and the somewhat lower emission factors is a 46% increase in land use emissions for corn ethanol.

EPA's 100 year-2% emissions for corn ethanol show a 16% benefit relative to gasoline. If pasture were intensified intentionally instead of replaced, the benefit of corn ethanol relative to gasoline would be 30% instead of 16%.

At the June EPA workshop, UNICA contractors presented much information that shows that pasture is being intensified, rather than being replaced. We understand the FAPRI worksheet for Brazil is being modified in response to this information.

RFA supports UNICA's comments on pasture intensification, and urges EPA to include this factor in their analysis for the final rule.

4.6   GTAP Results

The GTAP model developed by Purdue is the other model that has been adapted to predict land use changes in response to biofuel volume increases. [16] This model was used by California Air Resources Board to develop the land use changes for the Low Carbon Fuel Standard.[17] There are a number of items that need to be improved in the model before the land use results can be relied upon, which have were identified in RFA's comments on the Initial Statement of Reasons, and comments on the 30-day changes. [18,19] However, we can use the existing model to show the differences in amount of land converted and the geographical location of converted land.

To model EPA's control and reference cases using GTAP, one must estimate an ethanol "shock" and apply this to the GTAP model. The GTAP model uses a 2001 database, which includes 1.75 bgy of ethanol. The ethanol shock in this case is the difference between the Control and Reference cases, or 2.6 bgy, so the GTAP model was shocked to 1.75+2.6 = 4.35 bgy of ethanol, which represents a 54% increase in ethanol output from the 2001 level.

In the analysis of land use effects for CARB, University of California Berkeley and Purdue varied four different elasticities, as follows:

- Elasticity of effective crop land wrt harvested crop land expansion[20]
- Elasticity of crop yield wrt price
- Elasticity of land transformation across cropland, pasture and forestry
- Elasticity of land transformation across crops within cropland

For this analysis, we select the same values (i.e., the "central values") for these parameters as in the recent GTAP Working Paper # 55, as follows: 0.66, 0.25, -0.2, and

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[16] R. Keeney and T. W. Hertel (2008). Indirect Land Use Impacts of US Biofuels Policies: The Importance of Acreage, Yield and Bilateral Trade Responses, GTAP Working Paper 52. Purdue University.
[17] See reference 13.
[18] Letter from Bob Dinneen of RFA to Mary ..Nichols, April 17, 2009, and accompanying report.
[19] Letter from Bob Dinneen of RFAA to Mary D. Nichols, August 19, 2009, and accompanying document.
[20] wrt = with respect to

-0.5. [21] The land use changes by country are shown in Figure 4-4 below. These land use changes represent either pasture or forest converted to cropland, and not cropland switching. Forty-five percent of the predicted land use changes occur in the U.S., demonstrating a completely different result from the 5% or so from the U.S. predicted by EPA's combined FASOM/FAPRI analysis. Furthermore, this GTAP run shows 1.9 million acres being converted for the 2.6 bgy, instead of EPA's 4.7 million acres.

The FASOM and FAPRI models assume that the first and second elasticities shown above are 1.0 and 0.0, that is, yields on newly converted land are the same as the existing land, and that there is no influence of commodity prices on yields. In a second GTAP run, we set the first elasticity to 0.95 and second elasticity to 0.1 (we were unable to get the model to converge with 1.0 and 0.0). The land use change results are shown in Figure 4-5. In this case, 1.7 million acres are converted, which is 10% less than the previous case, and 64% less than EPA's FASOM/FAPRI predictions. In this case, 37% of the converted land is in the U.S.

Figure 4-4

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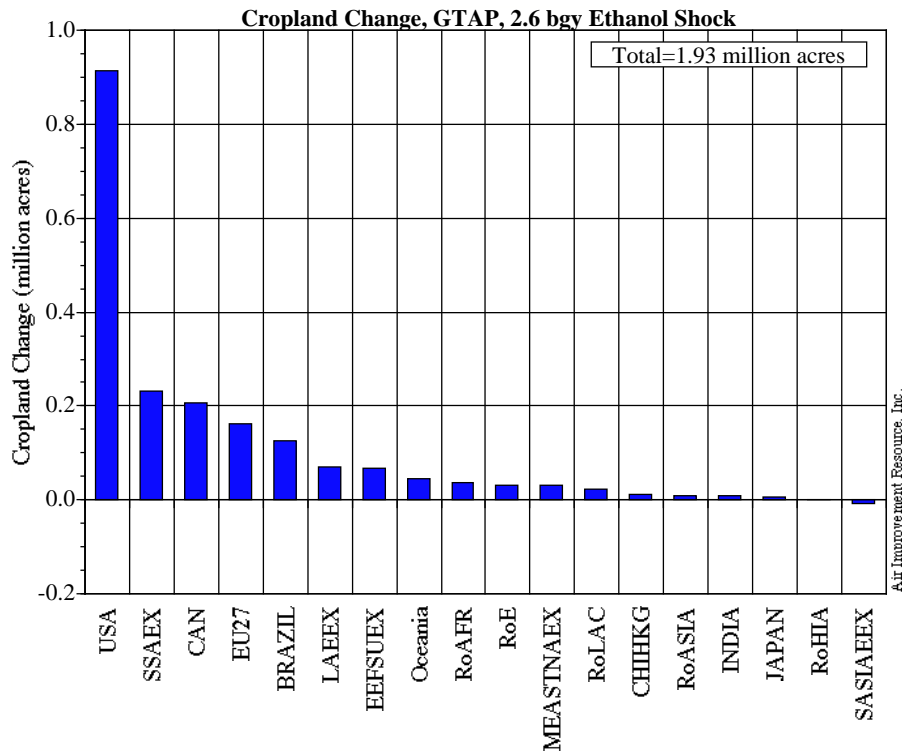
[21] See reference 14, Table S4.

Figure 4-5

Cropland Change, GTAP, 2.6 bgy Ethanol Shock, ETA=0.95, YDEL=0.1
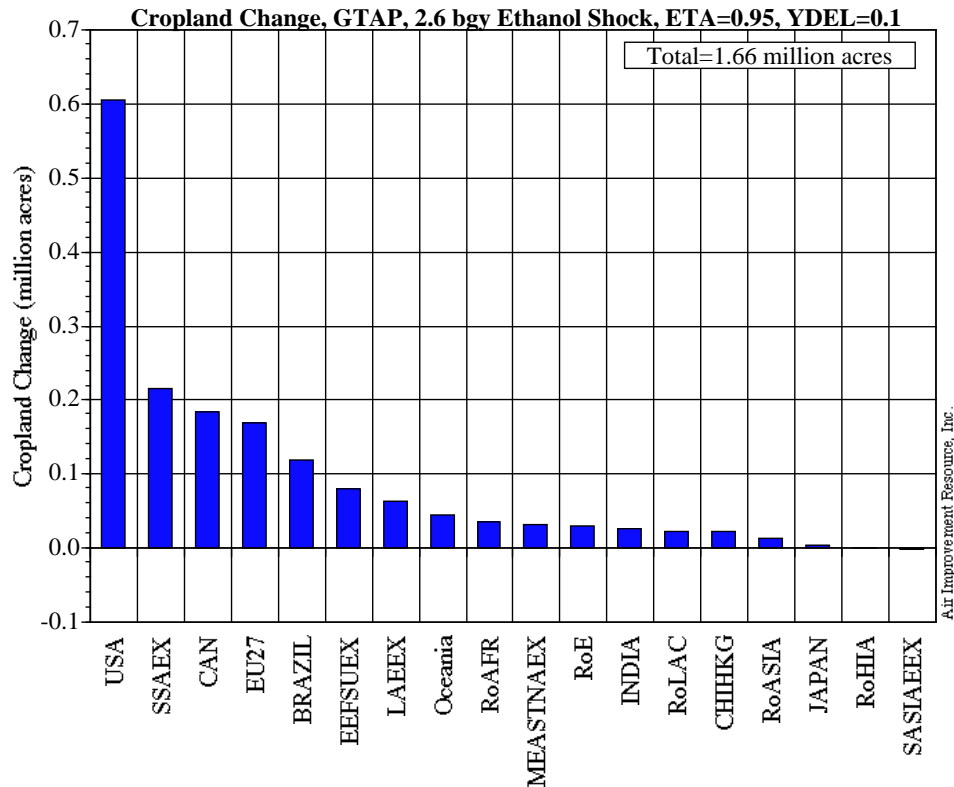
It is important to note that the acreages converted above are from the GTAP output, and have not been adjusted for exogenous yield gains between 2001 and 2022. Purdue University developed a procedure for incorporating exogenous yield improvements, and this is discussed in CARB's ISOR Volume 2. Basically, the land use changes from GTAP are adjusted using the percent yield improvement between the base year and the projection year, such that the percent reduction in land use changes is equivalent to:

100*1-(1/(1+%corn yield improvement)

This adjustment assumes (1) that the % gains in corn yields are the same in the ROW as the U.S., and that (2) the gains in yields on non-ethanol land are equivalent to demand increases. USDA estimates a 30.4% corn yield improvement between 2001 and 2022 (from 138 bu/acre to 180 bu/acre), so this translates to a 23.4% reduction in land use. Thus, according to the recommended procedures, the two land use changes from GTAP are 1.5 million acres and 1.3 million acres.

Finally, like FASOM and FAPRI, we have repeatedly pointed out that GTAP needs to also update its treatment of DGs. The model currently includes about a 31% land use credit for DGs. If that were updated with more recent information (as presented in Section 4.3.2 of this report), the net land use change in either of the above cases would be much less than 1 million acres.

Thus, this brief analysis of land use changes with GTAP, utilizing the ethanol volume difference between the control and reference cases selected by EPA, shows land use changes that are much lower than FASOM/FAPRI, with between 36%-47% of the land use changes occurring in the U.S., instead of the 6% shown in EPA's FAPRI/FASOM analysis. If the concerns we have identified are addressed, FASOM will show a greater fraction of land converted in the U.S., and at lower emission rates. This will narrow significantly the differences in projections of the two models.

EPA should make the recommended changes to FASOM, or explain clearly why it thinks the recommended changes are inappropriate, and also clearly explain why GTAP predicts a much greater fraction of land converted in the U.S., and much less land converted for its ethanol volume increase than FASOM/FAPRI.

4.7   Informa Results

RFA contracted with Informa Economics to provide an independent estimate of land use changes as a result of EPA's volumes of corn ethanol for the Reference and Control cases. [22] The Reference Case assumed EPA's Reference Case volumes for both ethanol and biodiesel, and the Control Case assumed the EPA's control case volumes for corn ethanol and biodiesel, but omitted cellulose ethanol. Informa made the same assumption with regard to minimum CRP land (32 million acres) as EPA. Their estimates took into account increases in demand for food, and updated the distillers grains assumptions to be consistent with the Shurson modifications to the Argonne analysis. Their corn yields for both Control and Reference cases were higher than USDA's, at about 200 bu/acre. This estimate is based on their evaluation of the market penetration of improved seed genetics. They did not include any effect of price on yields in this analysis.

Informa estimated that 2.2 million additional acres of land worldwide would be needed for crops in 2022 for the Control Case over the Reference Case as defined above. Informa indicated that this land could come from Argentina and Brazil, or the U.S. (or some combination of the three countries). This 2.2 million acres is somewhat higher than the GTAP analysis, but far lower than EPA's FASOM/FAPRI analysis concludes. Part of the 2.2 million acre increase could be attributed to the biodiesel increase as a part of the RFS2; not all would be assigned to corn ethanol.

4.8   Summary of Land Use Comments

Our analysis has shown that EPA's two-model analysis has significant problems in the linkages between the two models. FAPRI predicts much more land converted in the US than FASOM, and the FAPRI estimates higher price impacts and higher export impacts, all pointing to higher international land use impacts.

Also, we have shown that FASOM should be significantly modified for the analysis for the final rule, and that if FASOM still shows significant export and price impacts, then

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[22] "Analysis of the Proposed Rulemaking for the Expansion of the U.S. Renewable Fuel Standard", Informa Economics for RFA, September 209.

FAPRI needs to be better calibrated to FASOM for price, exports, and amount of land converted in the US before FAPRI can be relied upon for the international land use impacts. This calibration process could be quite difficult, but EPA should not finalize the rule with significant differences between the two models on these parameters.

The estimated land use impact due to corn ethanol is estimated by EPA at about 4.8 million acres, with about 0.3 million acres in the U.S. and 4.5 million acres internationally. The Informa analysis estimates 2.2 million acres (with revised DG assumptions and somewhat higher yields than EPA's), and GTAP in its current form estimates between 1.3 and 1.5 million acres, without the updated DG impacts. With updated DG impacts, GTAP's estimates would be even lower than 1.3 to 1.5 million acres.

As indicated earlier, EPA's FASOM/FAPRI modeling approach estimates that 95% of the land use impact is international. But there are many problems that must be solved with FASOM; it does not include a significant amount of land (for example, almost 70 million acres of cropland/pasture and idle land) that could be readily converted to crops. A 1-2 million acre increase in crops would only be 1-3 % of the available cropland pasture plus idle land (there is still in excess of 500 million acres of pasture and rangeland in the U.S.). Therefore, it is very difficult to imagine that 95% of a 1-2 million acre increase in crops could not be met almost entirely within the U.S., and with very little price or export impact. EPA's analysis needs to be significantly revised for the final rule, and when it is, it will show much less land is needed than the draft rule estimates.

5.0   Comments on EPA's Assumptions About Lost Carbon Sequestration

EPA's lifecycle modeling method starts by estimating the immediate emissions from land conversion from the amount of land converted and the emission factors of the land converted. After the initial conversion, there are soil carbon losses for a number of years, as well as lost carbon sequestration that may occur for a number of years. GHG benefits include carbon stored by the new crop system, and tailpipe benefits of biofuels relative to gasoline.

EPA assumes that lost carbon sequestration from grass or forest converted continues for 80 years after the land is converted. EPA also assumes that the forests that are converted are relatively young forests (20 years) with high carbon sequestration rates. There are two problems with this assumption:

- It is a worst-case assumption in that it assumes that *all* of the land that is converted would not have been converted for use to anything else for the entire 80-year period.

- It is also a worst-case assumption that the carbon sequestration rate is based on that of a young forest, instead of a more mature forest

These issues are discussed further below.

5.1   All the land that is converted would not have been converted for any other purpose for 80 years

EPA assumes that all of the land that is converted would not have been converted for any other purpose for 80 years. In other words, none of the land would have been converted for crops for food, or for urban uses, or for any other intention. This is simply a worst case assumption that needs to be revised. Some land may not be converted for 80 years, but some fraction of the land probably would have been converted for crops, and some for urban uses.

EPA seems to have based its 80-year estimate on how long new forests accumulate carbon:

> "Foregone sequestration was assumed to continue at a constant rate for 80 years. Studies have estimated that new forests grow for 90 years to over 120 years. More recent estimates suggest that old growth forests accumulate carbon for up to 800 years. Our proposed estimate that foregone sequestration continues for 80 years is within the range supported by the scientific literature and the 2006 IPCC guidelines."

Basing the length of carbon sequestration on the amount of time carbon builds up in a forest is a valid technique, if one is assured that the forest will remain without disturbance

for a long time. However, assuring all the forest converted to crops would have remained for 80 years, is a completely different matter.

While we don't have projections of what fraction of the land would get converted by 80 years, we think that EPA should choose a shorter period to estimate lost carbon sequestration, to account for the fact that some of the land would be converted for other purposes. The length of foregone sequestration has a significant effect on the weighted average emission rate. Figure 2.8-10 from the DRIA shows this effect below.

Figure 2.8-10.
Weighted Average Emissions per Acre of Forest to Cropland Conversion in Brazil
Different Lengths of Foregone Sequestration
(NPV, r=2%, T=100 years)
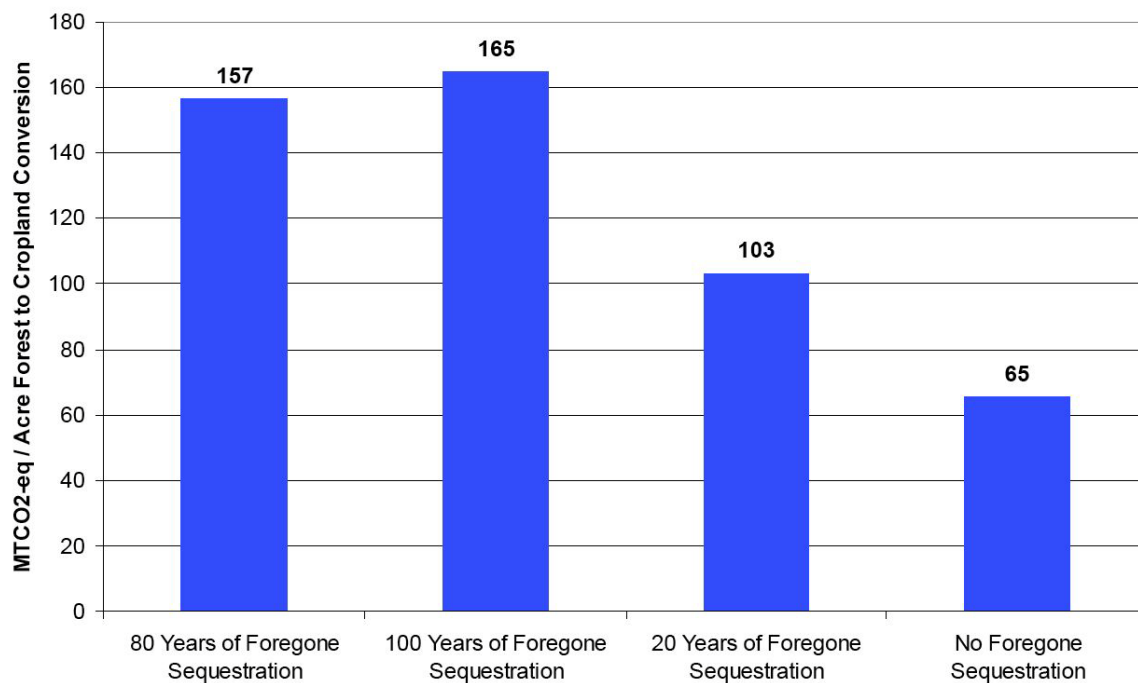
The figure shows weighted average emissions per acre of forest to cropland conversion in Brazil for 80 years, 100 years, 20 years, and no forgone sequestration. The weighted emissions for 20 years of sequestration are 34% lower than for 80 years.

We recommend that EPA select a period between 20 and 80 years, for example, 50 years, to take into account some of the forest being converted that would likely have been converted for other reasons anyway. The emission rate would be about 129 Mt CO2 eq/acre, or 18% less than EPA's current assumption.

5.2   Age of forest assumed for sequestration purposes is likely quite different than age of forest assumed for estimating conversion

EPA is using the rates of carbon accumulation for a 20-year old forest to estimate carbon sequestration, but does not indicate how old the average forests are being converted for the purpose of estimating emission factors of conversion. These two assumptions must be the same. The younger the forest, the higher the sequestration, but the lower the mass upon conversion.

EPA should ensure that it is using the same average age for carbon sequestration and for developing the emission factors for forest conversion.

6.0   Review of Types of Land Converted and Emission factors

This section reviews information provided by Winrock International regarding the types of land that are converted in different countries based on satellite data, and emission factors for the land converted. It also reviews EPA's assumption not to include carbon from forests stored in building products. This section is divided into the following subsections:

- Uncertainties in distribution of land cover
- Uncertainties in estimating the change in land cover over time
- Uncertainties in estimating the carbon stored in vegetation in various regions
- Comparison Winrock and Woods Hole datasets
- Comparison of Winrock and other datasets
- Additional concerns with using the carbon stock data
- Carbon stored in building products

The goal of the Winrock report[23] is to improve the emission factors for land conversion in selected countries of the world to provide an improved assessment of the greenhouse gas impacts of expanded biofuel use. Winrock has produced two versions of the report, one in October 2008 and a second in April 2009. Although there are differences in the reports/analyses that are addressed in these comments, the fundamental approach is the same in the two reports. Winrock estimated the extent of recent land use change using MODIS satellite imagery from 2001 and 2004 and developed greenhouse gas (GHG) emission factors for various types of land use conversion. The GHG emission factors included CO_2 emissions from changes in biomass and soil carbon stocks and, in some cases, non-CO2 emissions from biomass burning due to land clearing and methane emissions from rice cultivation.

The key assumptions/inputs in the analysis are 1) the distribution of land cover of various ecosystems at a point in time as determined from satellite imagery, 2) the estimation of changes in land cover/land use over some period of time, 2001 to 2004 in this case, and 3) the carbon stocks in biomass and soil in the various ecosystems that may have changed. There are important issues regarding the uncertainty in the Winrock analysis in each of these areas.

The Winrock analysis relies on the global analysis (in 1-km resolution pixels) of land cover developed with the MODIS (Moderate Resolution Imaging Spectroradiometer) satellite sensor to estimate changes in land use. The reports summarizes the data and the MODIS methodology, noting that the algorithm development and validation efforts for the MODIS Land Cover Product are based on a network of test sites developed to represent major global biomes and cover types. The accuracy for the land cover product,

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[23] N. Harris, S. Grimland and S. Brown, April 2009, Global GHG Emission Factors for various land-use transitions, Winrock International Report submitted to EPA; N. Harris, S. Grimland and S. Brown, October 2008, GHG emission factors for different land-use transitions in selected countries/regions of the world, Winrock International Report submitted to EPA.

version 3, is noted as 75-80 percent globally; 70-85 percent by continental regions; and in individual classes ranges from 60 in closed shrubland to 90 percent for barren/sparse. The Winrock analysis used version 4 of the MODIS data which is noted as being validated to Stage 1. The report notes that a Stage 1 validation means that the product accuracy has been estimated using a small number of independent measurements obtained from selected locations and time periods and ground-truth/field program effort.

The description in the October 2008 Winrock report of the accuracy of the MODIS data is appropriate as far as it goes, but omits two important issues. The first is the extent to which the MODIS land cover data agrees or disagrees with other satellite-based estimates. This omission was partially corrected in the April 2009 report. The second is the accuracy of the MODIS data to detect land use changes over time. This issue is not addressed in either report. Each issue will be discussed in turn.

6.1   Uncertainties in the distribution of land cover at one point in time

Since knowledge of the error structure of the land cover data in use is important, there has been a major international effort[24] to evaluate the accuracy of such estimates and foster "best practices" in such evaluations. The 2006 GOFC-GOLD (Global Observation of Forests and Land Cover Dynamics) report indicates that currently, there are a number of global land cover estimates that have been produced from optical, moderate resolution remote sensing and focused on characterizing the different vegetation types worldwide. Typically, they distinguish among a limited set of land cover types, based on both multi-spectral signals and the change in those multi-spectral signals through an annual cycle. The result is normally a map with a legend that distinguishes among land covers based on vegetation form and cover – for example, deciduous and evergreen forests, woodlands, savannas, or shrublands. Non-vegetated surfaces, such as barren ground and snow or ice, are also distinguished by the spectral and temporal signal. The report also indicates that agriculture is typically included, but since human activity cannot be sensed directly, some types of agriculture may be omitted (*e.g.,* pastures) or recognized only with some difficulty.

MODIS is one of these land cover products. The statistical description of accuracy in the Winrock reports, which is taken from the MODIS documentation, suggests that there are a substantial portion of the pixels for which the land cover is miss-classified. The GOFC-GOLD report points out that global, coarse-resolution land cover maps constructed from remotely-sensed data are limited in the accuracies they can achieve. This classification error arises due to limitations associated with the instruments themselves, atmospheric influences that interfere with the signal from the surface, and limitations on the precise geolocation of the pixels. In addition, the large size of the pixels in comparison to the heterogeneity of the vegetation within a pixel means that the radiometric response arises due to a mix of land cover types. Because of the large amount of data that must be

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[24] A. Strahler, L. Boschetti, G. Foody, M. Friedl, M. Hansen, M. Herold, P. Mayaux, J. Morisette, S. Stehman and C.Woodcock, "GLOBAL LAND COVER VALIDATION: RECOMMENDATIONS FOR EVALUATION AND ACCURACY ASSESSMENT OF GLOBAL LAND COVER MAPS," Luxemburg: Office for Official Publications of the European Communities, GOFC-GOLD Report 25, March 2006.

analyzed to form the map, complex decision tree algorithms have been developed to decide which land use type each pixel belongs to.

Reference information from a sample of training sites is used as the "ground truth" to calibrate and train the complex algorithms used in these efforts. A concern with the MODIS accuracy analysis is that the training sites/reference data it uses are not from a probability-based sample. Friedl, et al. 2002[25] acknowledge this noting:

> "In the long run, validation of the MODIS global land cover product will require a carefully designed probability-based sample design. This type of approach is the only means of providing objective and statistically defensible accuracy statistics. Unfortunately, current resources do not provide for this type of effort, and so for the short term, validation efforts will rely on the more opportunistic strategies described above."

Because of all these issues, there have been several efforts to compare the various land use products. For example, McCallum et al. 2006[26] compared four satellite derived 1 km land cover datasets and reported that while the datasets have in many cases reasonable agreement at a global level in terms of total area and general spatial pattern, there is limited agreement on the spatial distribution of the individual land classes. There was also varying levels of agreement in different regions. The authors suggest that users exercise caution when using any one particular product and utilize several of these products in order to show the magnitude of possible differences. They note that this becomes even more crucial if these datasets are being used for analysis at the continental or regional scales. They note that disagreements occur mainly along edges and transition zones between ecosystems. Unfortunately these transitional zones are where land use changes are most likely.

Herold, et al. 2008[27] also compared four global land cover maps including the MODIS 2001 product that Winrock relied upon and found that, overall, there was limited ability of the four global products to discriminate mixed classes characterized by a mosaic of trees, shrubs, and herbaceous vegetation. The authors point out that confusion in the shrublands and herbaceous vegetation cover often reflects landscapes with mixtures of life forms and thus heterogeneous landscapes. The Herold et al. study further shows that class accuracy is a driver of spatial disagreement between the different datasets. Less accurate classes show lower agreement among the datasets. The transition zones between

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[25] Friedl, M. A., D. K. McIver, J. C. F. Hodges, X. Zhang, D. Muchoney, A. H. Strahler, C. E. Woodcock, S. Gopal, A. Schneider, A. Cooper, A. Baccini, F. Gao and C. Schaaf (2002). "Global land cover from MODIS: Algorithms and early results." *Remote Sensing of Environment* **83**(1-2): 287-302.

[26] I. McCallum, M. Obersteiner, S. Nilsson, A. Shvidenko, "A spatial comparison of four satellite derived 1 km global and cover datasets," International Journal of Applied Earth Observation and Geoinformation, **8**, 246–255 (2006).

[27] M. Herold, P. Mayaux, C. Woodcock, A. Baccini, C. Schmullius, "Some challenges in global land cover mapping: An assessment of agreement and accuracy in existing 1 km datasets," Remote Sensing of Environment, **112**, 2538 – 2556 (2008).

core areas of land cover types or major ecosystems contain the largest amount of land cover dataset discrepancy. This result is particularly problematic, the authors note, since these transition areas represent the regions where land cover changes primarily occur.

The April 2009 Winrock report references the Herold et al. 2008 study as well as other comparisons of land use cover products. However, the report does not mention the study by Fritz and See 2008[28] who developed a methodology for comparing land cover datasets and applied it to the MODIS and GLC-2000 datasets with emphasis on areas of agreement and disagreement for forest cover and agricultural lands. This information is particularly relevant to the Winrock analysis. They presented maps showing spatial variations and patterns in the areas of uncertainty and disagreement. The map of agreement/disagreement for agriculture is shown below. They also investigated two hot spots of disagreement in greater detail. Among the conclusions was that agricultural areas cannot be mapped very well in areas where ancillary data sources are rare and where the natural vegetation shows a similar spectral–temporal behavior as the agricultural areas. Not only are there areas where the maps disagree about the extent of agriculture, the more detailed investigation showed that, indeed, both maps may be in substantial error in situations where the spectral signals have only subtle differences.
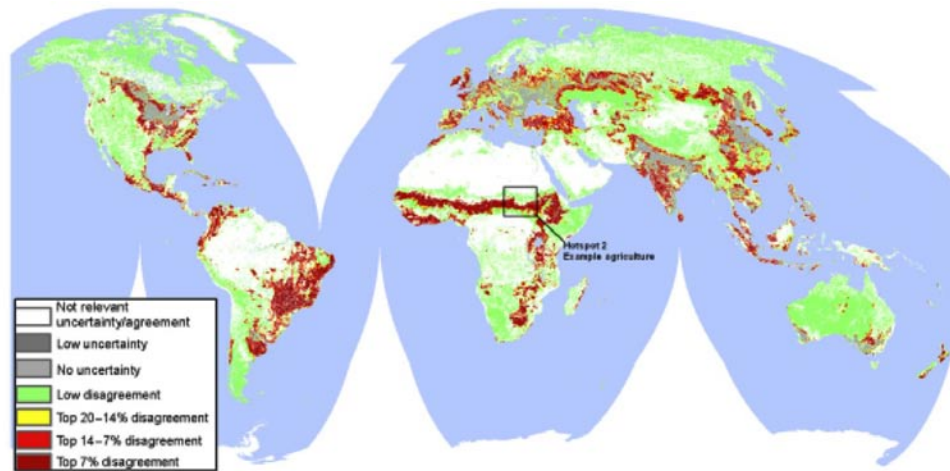

Fig. 5 Fuzzy disagreement map for agricultural distribution with thematic uncertainty layer.

These comparisons among land cover products reveal patterns in the data that indicate there are systematic biases in the various products along with the general issues of uncertainty noted above.

Therefore, EPA and Winrock should consider all the available comparisons of the MODIS data with other land use products to more fully identify and understand the limitations in the use of the data and the spatial patterns in the uncertainty.

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[28] S. Fritz and L. See, "Identifying and quantifying uncertainty and spatial disagreement in the comparison of Global Land Cover for different applications, " Global Change Biology, **14**, 1057–1075 (2008).

6.2   Uncertainties in estimating the change in land cover over time

The Winrock reports both indicate that the MODIS product was chosen, even though there are other land cover products available, because it uses the same 17-category classification scheme at both time periods which allows for direct comparison over multiple regions and years, since the purpose of the analysis was to analyze change in land use and cover over time.

Unfortunately, there is little or no discussion of the accuracy and/or uncertainties associated with determining changes in land use or land cover in either Winrock report. This discovery is particularly important because, as the GOFC-GOLD report stresses "the process of validating a land cover change product has special considerations which make it different from that of an individual land cover characterization." The 2006 report also indicates "Validation of land cover change presents its own unique set of problems. If change is to be determined by overlaying successive thematic maps, misclassifications in either map will spuriously appear as change."

The only discussion in the October 2008 Winrock report is the acknowledgement that:

> "Comparing two products directly is not the best way to analyze change in LU/LC, as errors in the interpretation of the first map can be compounded when compared to a second map. The ideal way would be to conduct a change analysis directly and interpret the change. However, this is a major effort to not only perform the change detection but also to interpret what the change is (from what to what). A comparison of the two LU/LC maps to obtain change is not the most desirable approach but it is the only approach available given the products that exist. Very few countries have LU/LC products that have been prepared using change detection techniques for full change detection in all LU/LC classes. For example, the US has two LU/LC data bases (the National Land Cover data bases for 1992 and 2001), yet we are still waiting for a change map for the 11+ year period."

Although Winrock acknowledges the potential for major errors in the assessment of change, the data are reported in Table 3 of the October 2008 report and Annex 5 of the April 2009 report and discussed in both reports with little recognition of the errors, problems, and uncertainty in the data.   For example, the data are reported to the nearest hectare which is typically six or more significant figures. The discussion of examples in the October 2008 report also treats the data as if it were "ground truth" to the nearest hectare. In the April 2009 report, the data is often presented and discussed in terms of percentages, but there is still too little recognition of the uncertainty in the data.

The 2006 GOFC-GOLD report has a separate section discussing the validation of land cover change. GOFC-GOLD is also preparing a "best practices" document on validation

of land use change;[29] the report is scheduled for release in 2010. It is instructive to review these materials to assess the appropriateness of the Winrock and EPA use of the land use change data as reported in Table 3 and Annex 5. The 2006 report notes that an accuracy assessment of this type of data is concerned with the changes between two time periods, as opposed to an instantaneous mapping of land cover. It notes "At the global scale, the complexities arising from this simple change in reference frame can be daunting."

The report enumerates several important considerations as follows:

> "First, there is no possibility of deriving a static global set of validation sites, such as might be used in validating a single time-frame land cover map. Land cover change is spatially distributed in a heterogeneous way and dynamic over time. Change events also represent relatively rare cases in time-series land cover mapping efforts, especially so at the global scale. Thus, any simple or stratified random sample which was created to efficiently assess single time-frame global land cover would be inadequate for assessing change classes. If a global validation set for assessing land cover map accuracy were created, it may only be of use to the portion of the change matrix which represented areas not undergoing change and only for the time periods concurrent with the change detection study.

> Second, validation information must be gathered at each validation site for both time 1 and time 2 states. At the global scale, the possibility of acquiring such data is compromised by uncertain availability and high cost, certainly double that of a single time-frame classification assessment per site. This added temporal dimensionality also complicates sampling considerations. A change detection validation is not concerned only with the individual cover classes, but with all of the possible from-to land cover change class combinations as well.

> Third, the success of global change detection studies is a function of independently derived time 1 and time 2 map characterizations. If the initial products are of inferior quality, then the validation exercise could end up being an investigation of errors found in the input land cover characterizations, not a measure of actual land cover change. As moderate- and coarse-resolution global data sets consist predominately of difficult-to-map mixed pixels, and change typically occurs at subpixel scales, there is reason to believe that the ability to measure change may be limited. The likelihood of successfully using a post-classification approach to change detection at the global scale is suspect."

Based on these best practice guidelines, EPA's use of the land change data from 2001 to 2004 without any attempt at validation is highly suspect. It is an example of the situation the GOFC-GOKD report warns of in which "… land cover maps are too often being used without an appreciation of their inherent uncertainties, which may be large." The report

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[29] M. Herold, S. Stehman and C. Woodcock, Report of the GOFC-GOLD/CEOS Workshop on Land Cover Change Accuracy Assessment, Jena, Germany, October 13-17, 2008, GOFC-GOLD Report No. 38, June 2009.

also indicates "Maps without associated accuracy data remain untested hypotheses." Thus, the land use change data Winrock provided and EPA is using is best characterized as an untested hypothesis.

The GOFC-GOLD report offers additional insight that can aid us in judging the data in Table 3 and Annex 5. For example, the report notes that the change category is exceedingly rare. It notes that deforestation (change from forest to non-forest) is often an abrupt and spatially dramatic event while reforestation (non-forest to forest) is a longer process that takes many years. Inspection of Table 3 and Annex 5 indicates that the change data violates these expectations. For example, the question of whether the changes calculated between 2001 and 2004 are rare or not can be tested by evaluating the sum of the diagonals in the matrix. This sums up the portion of forests remaining forests, cropland remaining cropland, grassland remaining grassland, etc. For the U. S., the data in Table 3 indicate that 29 % of the classifications changed between 2001 and 2004. In Russia, 23 % of the classifications changed; in India 22 % of the classifications changed; in China 31 % of the classifications changed. For all the countries reported in Table 3, the portion of classifications that changed are much larger than one would expect over a three-year period. This raises a red flag concerning the validity of the data. Annex 5 presents similar data for a much larger number of countries. However, the matrix of changes between 2001 and 2004 are very similar for the countries included in the October 2008 report so although there are some small differences in the land use change estimates between the two versions of the report, the pattern of results is the same in both analyses.

Looking across individual rows or down columns in Table 3 or Annex 5 raises additional concerns. The case of other classifications becoming forests is particularly enlightening since reforestation is a slow process and three years is not long enough to see major changes due to reforestation. The substantial portions of other classifications becoming reported as forests in a three-year period throughout the various countries raises another red flag. These reported changes are misclassifications issues not "on the ground reforestation."

For the purposes of the use of these data by EPA, the substantial portions of cropland in 2001 that became other land uses by 2004 as well as the substantial portion of other land uses in 2001 that became cropland in 2004 raise a third red flag. Such changes over a short time period are unexpected; they are also likely misclassification errors. The April 2009 report acknowledges such uncertainty when it notes the data in Table 7 indicating that only 40% of existing cropland in Brazil in 2001 remained as cropland three years later. After discussing reasons why cropland may be miss-classified, the report acknowledges "this example raises the issue of how to identify land use dynamics over a landscape that the MODIS data cannot detect."

Thus, inspection of the data in Table 3 and Annex 5 reveals several important issues and questions that would need to be resolved before the data is used to inform policy. Since no attempt to validate the change data has been made, estimates of future land use related to biofuel use should come from other approaches until a valid land use change analysis is available.

There are additional reasons why the Winrock land use change data should not be used at this point in time. GOFC-GOLD report notes that using global data sets, all of the various types of land cover change can be detected. However, they conclude that assessing the accuracy of each type requires a separate validation exercise based on the variation of the temporal dynamics of the change.

The GOFC-GOLD report also indicates that the MODIS land cover team is producing annual versions of its global map, beginning with 2000 through the life of the MODIS mission. However, the report goes on to note that "the intent is not to document interannual change, but rather to provide the best possible map using data from a particular year." Thus, some of the year-to-year differences in the maps may be related to subtle changes in the decision rules as the MODIS team attempts to improve the accuracy of the maps rather than real "on-the-ground" changes.

Finally, Herold et al. 2008 indicate that the magnitude of change is still smaller than the uncertainties and inconsistencies in existing global datasets that were not derived for change assessments. They point out that targeted and quantitative change observations may require different and specific monitoring approaches to be consistent and suitable on global scales and usually cannot be derived from moderate resolution data alone.

In summary, with no attempt to verify the land use changes reported in the Winrock report, and with very questionable changes reported over a three-year period, it is not suitable for use in policy assessments. We note that a peer review report[30] raises many of the same technical concerns that lead us to question the use of the Winrock land use change data without any evaluation of its accuracy. Specifically, one or more peer reviewers noted the following areas as problematic:

- The 3-year time period of the two MODIS data sets chosen and the error associated with each of those data sets.

- The coarse resolution of the satellite imagery.

- The change detection analysis performed on the two MODIS data sets from 2001 and 2004.

- The reclassification analysis performed by Winrock on the satellite data, especially the categories of excluded land and the role of the 'mixed' or 'other' category.

- The methodology for projecting land use change patterns caused specifically by biofuel production.

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[30] Emissions from Land Use Change due to Increased Biofuel Production: Satellite Imagery and Emissions Factor Analysis, Peer Review Report, July 31, 2009 Prepared by ICF International.

- Evaluation of error and uncertainty associated with the satellite imagery analysis.

For example, Dr. Gibbs answered the question as to whether it is scientifically justifiable to use the remote sensing data to estimate a specific land use change that would be applied to a biofuels overall lifecycle GHG impact by indicating no, in many cases remote sensing data alone is unlikely to estimate a specific land use change value for biofuels lifecycle analysis. Dr. Gibbs also noted that there was not a formal accuracy assessment of the change detection analysis provided by Winrock and, importantly, that subtracting the MODIS land cover maps is not a suitable method for change detection.

Dr. Houghton expressed the opinion that it will always be important to use ancillary data to help constrain findings based on remote sensing data. He described the approach Winrock took as being of questionable merit. He asked how the calculated change compares with the errors of one map raising the issue that the errors for one year may be greater than the change over 3 years. He also expressed the concern that there was not an evaluation of the specific errors in the change matrix so that the data product has *not* been accurately characterized.

In addition to the concern that the errors in the land use change data were not characterized, the peer review notes that four of the five peer reviewers highlighted potential problems with using remote sensing data to project the pattern of land use change caused specifically by biofuel production. For example, Dr. Tullis expressed several concerns with the way Winrock used regional-scale averages in various categories of percent land use change to spatially distribute biofuel changes predicted by FAPRI. He noted that the underlying assumption that land use changes directly related to biofuel production are highly correlated with agricultural expansion throughout the study area may not be the case. He offered suggestions for improving the analysis noting that a more robust approach would additionally attempt to predict the suitability of sites for direct biofuel production.

6.3   Uncertainties in estimating the carbon stored in vegetation and soil in various regions around the world

A second goal of the work presented in the Winrock report is to improve the emission factors for land conversion in key countries of the world to provide an improved assessment of the greenhouse gas impacts of expanded biofuel use. The October 2008 report covers thirteen countries or regions: Argentina, Brazil, China, EU, India, Indonesia, Malaysia, Mexico, Nigeria, Philippines, Russia, South Africa and the US. The April 2009 report extends the analysis to all the major countries of the world.

In order to calculate GHG emissions resulting from land use change, the Winrock reports indicate that various data were compiled for forest, cropland, grassland, shrubland and savanna land use categories, including data on soil organic carbon as well as carbon stocks present in above and belowground biomass. The GHG emission factors included CO_2 emissions from changes in biomass and soil carbon stocks and, in some cases, non-CO_2 emissions from biomass burning due to land clearing and methane emissions from

rice cultivation.

Currently, there are two datasets of carbon in biomass and soil that are in widespread use to estimate the changes in carbon stocks associated with land-use changes, primarily from forest to cropland or pasture. The first is the 2008 Winrock International report to EPA[31] on greenhouse gas emissions from different land-use transitions that is the subject of this review. Although the April 2009 Winrock report extends the dataset to more countries, the actual data on carbon stocks, by country, is not included in the report. The second dataset – from the Woods Hole Research Center – was used in the Searchinger et al. 2008[32] paper on land-use changes related to biofuel use and is routinely relied upon by the California Air Resources Board. It turns out that there are substantial differences between the two datasets in regard to the carbon stored in both above- and below-ground vegetation (particularly for forests) and soils. Therefore, it is of interest to evaluate and compare the two datasets. The first portion of this section of these comments describes the two data sets, provides comparisons where possible, and discusses reasons for why the data on carbon differs. The second portion evaluates the Winrock estimates for forest carbon stocks against other estimates in the literature for individual regions or countries. The third portion discusses some additional concerns/uncertainties over the use of any such estimates.

6.4 A Comparison of Winrock and Woods Hole Datasets

6.4.1 Winrock International Data

For forest carbon stocks, Winrock used various recent studies of forest biomass in different regions. These data sources typically provide maps of biomass developed with a combination of ground surveys and satellite imagery. For soil carbon stocks, Winrock used a digital soil carbon map of the world that shows the distribution of the soil organic carbon to 30 cm depth. The map is available from the US Department of Agriculture, Natural Resources Conservation Service. Maps of carbon to 30 cm and to 100 cm are available; the 30 cm map was chosen because Winrock indicates that land use change (e.g., tilling for cropland conversion) typically affects only the upper layers of the soil profile.

The October 2008 Winrock report evaluated the GHG impacts from land use conversions among 5 ecosystems (forests, shrubland, savanna, grassland, and cropland) in the 13 areas. A key input to these calculations is the average carbon stock (in tons C per hectare) in biomass in each of these five ecosystems in each of the 13 areas, as reported in Table 16 of the 2008 Winrock report. Table 16 also includes the carbon in soil (in tons C per hectare) in each of the 13 areas. Although the carbon stocks used in the 2009 report are not explicitly included in the report, the GHG emission factors in Table 17 of

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[31] N. Harris, S. Grimland and S. Brown. 2008. GHG emission factors for different land-use transitions in selected countries/regions of the world. Winrock International Report submitted to EPA.

[32] T. Searchinger, R. Heimlich, R. Houghton, F. Dong, A. Elobeid, J. Fabiosa, S. Tokgoz, D. Hayes, T-H. Yu, "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases through Emissions from Land-Use Change," Science, 319, 1238-1240, February 29, 2008.

the 2008 report and Annex 6 of the 2009 report for the countries included in the 2008 report are nearly identical. This similarity means that the carbon stocks for individual countries reported in the 2008 report must have been used as the input data in the 2009 report.

6.4.2 Woods Hole Research Center Data

The actual carbon data used by Searchinger et al. is included in Tables D-1 through D-10 in supporting material.[33] The carbon data is also available in an Excel spreadsheet, which is referenced to Table D-1 through D-11 in the Searchinger et al. on-line supporting material.

The data is presented as levels of carbon per hectare (in metric tons or Mg C per hectare) held in the vegetation (biomass) and soils of different types of ecosystems in ten world regions. The ten world regions are denoted as the United States, Canada, North Africa and Middle East, Latin America, Pacific Developed, South and Southeast Asia, Africa, the combination of India, China, and Pakistan, Europe, and the Former Soviet Union. Within each region, estimates of the carbon in vegetation (a combination of carbon above and below ground) and the carbon in soil is provided for various types of ecosystems along with estimates of the extent of the ecosystems in units of million hectares.   Since the focus of the Searchinger et al. paper was on conversion of forest and grassland to cropland, the carbon data presented is restricted to various forest and grassland ecosystems. The types of these ecosystems vary among the regions, so for example, the ecosystem types considered in the South and Southeast Asia region included tropical moist forest, tropical seasonal forest, and open forest while the ecosystem types considered for Canada were temperate evergreen forest, temperate deciduous forest, boreal forest, temperate grassland and tundra.

The carbon stock data along with estimates of the extent of various land use conversions are used to calculate the carbon released from the land use conversions.   In the Searchinger et al. analysis, the assumption is made that all of the carbon in biomass and 25 % of the carbon in soil is released in land use conversions from forests or grassland to cropland.

6.4.3 Comparison of Woods Hole data with Winrock data

Since the regions considered and the ecosystem types considered differ between the two data sets, there are only a limited number of comparisons that can be made.   Three areas the studies have in common are the US, Europe, and Russia. The Excel spreadsheet includes figures for the average carbon content of forests and grasslands in each region so those data can be compared to the average carbon stocks in forests and grasslands from Table 16 of the 2008 Winrock report. As shown in Table 6-1, the carbon (in Mg or tons C per hectare) stored in forests and grasslands in the Woods Hole data is substantially

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[33] Supporting on-line material for T. Searchinger, R. Heimlich, R. Houghton, F. Dong, A. Elobeid, J. Fabiosa, S. Tokgoz, D. Hayes, T-H. Yu, "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases through Emissions from Land-Use Change.", www.sciencemag.org/cgi/content/full/1151861/DC1.

greater than that estimated by Winrock.

Table 6-1. Comparison of Winrock and Woods Hole Forest and Grassland Emissions				
Region	Winrock Forest	Woods Hole Forest	Winrock Grassland	Woods Hole Grassland
Europe	57	123	6	7
U. S.	61	170	4	10
Russia	44	150	4	7

Although China and India are included separately in the Winrock report and China, India and Pakistan are included as a combined area in the Woods Hole data, the Searchinger et al. study did not include estimates of carbon stocks in forests in these countries since they made the simplifying assumption that no forests would be converted to cropland in these countries. The carbon stocks in grassland for this region are similar (7 in Woods Hole and 8 in Winrock).

There are also some comparisons that can be made for the carbon in soil, as shown in Table 6-2. The comparisons are not as direct as for forest or grassland biomass, since the Winrock data is for soil carbon averaged over the five ecosystem types they used and the Woods Hole data is aggregated over only the ecosystem types and areas that Searchinger et al. estimated for any given region. Despite this limitation, the Woods Hole data clearly estimates higher carbon stocks in soil than the Winrock data.

Table 6-2. Comparison of Winrock and Woods Hole Soil Data		
Region	Winrock Soil	Woods Hole Soil
Europe	81	139
U. S.	50	112
Russia	89	169

6.4.4   Discussion

To determine possible reasons for the differences between the two data sources, the primary references in the documents and the IPCC guidelines for determining emissions from land use change were evaluated. While there are many factors involved, there was one major reason for the different biomass carbon estimates and another major reason for the different soil carbon estimates.

While Winrock used recent estimates of biomass carbon for various regions, Woods Hole relies on estimates of carbon in undisturbed vegetation and soil for the various ecosystem types. The footnotes to Table D-1 of the Searchinger et al. supporting material document that the estimates of carbon in vegetation and soil are for undisturbed ecosystems. The same carbon stock estimates that are in the Searchinger et al. supporting information are

found in Table 1 of Houghton's 1999 Tellus article[34] and were used as the 1850 baseline for his bookkeeping model calculation of carbon emissions from land use changes.

Since current forests around the world have been logged extensively and many are highly managed, most are not undisturbed ecosystems. An example of the impact of human activity on forest carbon stocks is actually given in Houghton and Hackler 1999,[35] one of the references in Searchinger et al. Houghton and Hackler use a bookkeeping model to estimate biomass carbon and soil carbon from 1750 to 1995 in tropical Asia. The baseline biomass and soil carbon estimates for 1750 pre-disturbance ecosystems (moist forest, seasonal forest, and dry forest) in Houghton and Hackler are the same as the estimates in the Searchinger et al. supporting material for current carbon stocks in South and Southeast Asia. However, Houghton and Hackler estimated that the carbon biomass per hectare in moist forest in 1995 was 196 tons C per hectare compared to the 250 tons C per hectare baseline, and the biomass in seasonal forest was reduced from 150 tons C per hectare in the 1750 baseline to 120 in 1995. There was an even larger reduction in soil carbon for these forest types from 1750 to 1995. Houghton and Hackler ascribe the changes over time to shifting cultivation, logging, fuelwood extraction, and associated regrowth.

For soil carbon, the major difference is that the Woods Hole data is for the carbon in soil in the top 100 cm whereas Winrock uses data on the carbon in soil in the top 30 cm. There is evidence summarized in Figure 5 of Guo and Gifford[36] indicating that the carbon in soil below 60 cm is not affected by the conversion of forests to cropland. For other transitions, the impact on soil may differ. In addition, the IPCC default recommendation is to use the 30 cm data when inventorying greenhouse gas emissions from land use changes.

> 6.5   A Comparison of Winrock data with other data sources

Although there is a substantial difference between the Winrock and Woods Hole datasets, the Winrock data is, for the most part, in general agreement with other estimates of carbon stocks for individual countries and regions. Russia is the largest political unit in the Northern Hemisphere and contains the largest stocks of terrestrial carbon. Winrock used data from Houghton et al. 2007 for Russia. As shown in Table 2 of Houghton et al., the average forest biomass in Mg carbon per hectare is within the range of other estimates, although the extent of estimated forest area with the MODIS data is the smallest of nine estimates in the literature.

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[34] R. Houghton, "The annual net flux of carbon to the atmosphere from changes in land use 1850–1990," Tellus, **51B**, 298 –313, 1999.

[35] R . Houghton and J . Hackler, "Emissions of carbon from forestry and land-use change in tropical Asia," Global Change Biology, **5,** 481–492 (1999).

[36] L. Guo and R. Gifford, "Soil carbon stocks and land use change: a meta analysis," Global Change Biology (2002) 8, 345-360.

The average forest biomass in Table 16 of the 2008 Winrock report is very similar to the estimates in Table 3 of Houghton 2005[37] for the U. S. Russia and the EU.   The carbon biomass in forest in the Winrock analysis for the U. S. from Blackard et al. 2008 is also similar to the estimates in the EPA's National Greenhouse Gas Inventory.

A comparison that is not as direct can be made for south and southeast Asia by comparing the forest biomass data for India, Indonesia, Malaysia, and the Philippines from Table 16 of the 2008 Winrock report with Table 3 in Houghton and Hackler 1999 which has five estimates of the average carbon content of tropical Asian forests.   The comparison is not exact because the Houghton and Hackler data refers to 15 Asian countries in the aggregate, while the Winrock report has data for four of the 15 countries. Nevertheless, the Winrock data that ranges from 111 to 179 Mg C per hectare are similar to the range of 73 to 144 Mg C per hectare in Houghton and Hackler.

6.6   Additional concerns with using carbon stock data

There are two types of uncertainty that need to be considered in using the Winrock (or any other data) on carbon stocks. The first is uncertainty in establishing the base case or current condition for national or sub-national administrative units. The second relates to whether the land converted is typical of the administrative unit or is systematically different from the average land in that classification.

6.6.1   Uncertainty in the base case

While the Winrock carbon stock estimates are taken from what the authors considered the best available sources for each country, there is still considerable uncertainty in the estimates.   Many estimates are grounded in systematic sampling of forest plots in developed countries. However, this is not a probability-based sample. It typically is a sample that was developed with forest production and management in mind and focused on providing information useful to the forest products industry and forest management interests. Remote sensing data plays a major role in many of the recent analyses, but, as noted above in these comments, there are a series of issues with collecting and interpreting satellite-based remote sensing data.

Local agricultural and forestry management practices differ across the globe and these practices can impact carbon stocks. Forests in some European countries tend to be highly managed. In some areas of the world, collection of fuel wood is extensive. The fraction of carbon in understory biomass differs depending on the age of the forest and whether the canopy is closed or not. The fate of slash, stumps and roots left on cleared land differs from region to region and this can affect carbon stocks. The impact of natural disturbances such as fire can also vary. The type of logging both historically and currently can differ. Grazing and over-grazing, differences in fertilizer use, and different cultivation practices all can affect carbon stocks. While the greatest changes in carbon

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[37] R. Houghton, "Aboveground Forest Biomass and the Global Carbon Balance," Global Change Biology (2005) 11, 945–958.

storage per hectare result from the conversion of forests to cultivated land and the reverse, abandonment of croplands to forests, there are many other activities that change the carbon content without changing the area devoted to agriculture or forests. Although the peer reviewers were generally supportive of the Winrock choices for carbon stocks, Dr. Houghton pointed out that the estimates may not be correct and may change based on future work.

6.6.2   Potential for systematic biases

Houghton[38] points out that if the forests cleared, logged, or burned are systematically different in biomass from 'average' forests, the use of average values will bias the calculated sources and sinks of carbon.   This issue arises for all the conversions considered by Winrock.   Since many conversions typically occur at the edges or transitions between ecosystems or at the edges and transitions between built-up areas and natural areas, it is likely that the "average" carbon stock data may not apply.   In addition, for large countries like the U. S. with highly varying ecosystems, and hence highly varying forest carbon stocks in different areas of the country, land use conversions that take place in one portion of the country will likely not be well represented by using country average figures.

There are also issues of economics that come into play. Differences in the cost of land, the value of land for other uses, and the cost of making a conversion will influence where investments are made in land conversions and where they occur. Differences in local land management practices or government regulation will also influence where land conversions occur. All of these considerations may introduce bias into the GHG impacts calculated using country average factors.

6.7   Carbon stored in building products

When managed forest is converted to other uses such as cropland or pasture, the forest is undoubtedly harvested first before the land is plowed for crops. Even unmanaged forests are probably harvested before conversion. The harvested wood is used in a variety of uses including building products, and eventually end up landfills. Landfills in the U.S. and other developed countries are carefully managed to reduce the interaction of oxygen with organic products to reduce CO_2 that is generated as a result of heterotrophic respiration. Decomposition takes place instead by anaerobic digestion, but this process is also extremely slow. Building products can remain intact in landfills for many decades.

The DRIA indicates that:

> "Initial changes in biomass carbon stocks reflect gross emission rather than net emission; harvested wood products, including long-term storage and retirement, were not considered in this analysis. Based on consultation with Winrock we determined that including IPCC default GHG credits for harvested wood products

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[38] R. Houghton, "Aboveground Forest Biomass and the Global Carbon Balance," Global Change Biology (2005) 11, 945–958.

(HWPs) would have an insignificant impact on our estimates of land use change emissions, as there is limited evidence that trees cleared from converted forestland is converted to wood products…..However, we intend to analyze the impact of wood product credits for the final rule"

Overall, we believe the fraction of forest converted to cropland or pasture due to biofuels is small, due to higher conversion costs relative to pasture, and the abundance of pasture which is already cleared. We believe that EPA's assumption not to credit storage of building products stems from its primary belief that nearly all forest conversion due to biofuels occurs internationally, and not domestically. However, in the FASOM modeling for the draft rule, the FASOM forest module was turned off, thus, this eliminated a major inventory of land in the U.S. that would be available for increasing cropland (as indicated earlier, the FASOM model also did not include 61 million acres of cropland pasture, 6 million acres idle land, and almost 250 million acres of pasture/rangeland, none of which is forested). And, any forest that would be cleared in the U.S. would be managed, where the wood would be harvested at the conversion.

FASOM itself does include carbon sequestered in building products;

"Harvesting timber will cause a reduction in carbon sequestration, although some of the carbon that was in the harvested trees will continue to be stored in forest products for some time afterward….(Page A-26)

"When timber is harvested FASOM tracks the fate of the carbon that had been sequestered on the harvested land…..To calculate carbon in harvested logs, cubic feet of roundwood is converted into metric tons of carbon using factors reported in Skog and Nicholson. These factors vary by regions and are reported for logs coming from an aggregate softwood and hardwood stand. They exclude carbon in logging residue left onsite. (A-29)

"Skog and Nicholson assumed that 67% of carbon leaving the wood product pool and 34% of carbon leaving the paper product pool goes to landfills. The remainder of the carbon leaving the wood and paper product pools goes into CO_2 emissions to the atmosphere. (A-32)

"In addition, FASOM tracks the fate of mill residue using two different pools. The first is for mill residue that is used as an intermediate input in the production of wood and paper products. This carbon in tracked using the appropriate product category as described above. The second pool is for carbon in mill residue that is burned for fuel, with the fraction burned in each region based on Smith et al. it was assumed that one-third of all mill residue burned is used to offset fossil fuels. Harvested fuel logs and the associated carbon are used to produce energy at mills. For fuel wood, FAASOM assumes that 100% of fuel wood burned in the sawtimber and pulpwood production process is used to offset fossil fuels. (A-33 and A-34)

Once EPAA turns the forest module on in FASOM, any forest converted in the U.S. should follow these well-established and documented procedures for accounting for carbon sequestered in forest productions outlined in FASOM and the associated references. Fifth, if there is any forest converted outside the U.S., it could use these same procedures, perhaps discounted by a percentage that EPA thinks is appropriate given timber harvesting and landfill practices in other regions.