Par Pacific

Par Pacific's Comments on the 15-Day Package

August 27, 2024

Mr. Matt Botill
Chief, Industrial Strategies Division
California Air Resources Board
1001 I Street Sacramento, California 95812

Ms. Rajinder Sahota
Deputy Executive Officer
Climate Change & Research
California Air Resources Board
1001 I Street Sacramento, California 95812

Dear Mr. Botill and Ms. Sahota,

We appreciate the opportunity to provide comments on the proposed modifications to the text of the LCFS amendment issued August 12, 2024 (the "15-Day Changes").

Par Pacific Holdings, Inc. (NYSE: PARR), headquartered in Houston, Texas, is a growing energy company providing both renewable and conventional fuels to the western United States. Par Pacific owns and operates 219,000 bpd of combined refining capacity across four locations in Hawaii, the Pacific Northwest and the Rockies, and an extensive energy infrastructure network, including 13 million barrels of storage, and marine, rail, rack, and pipeline assets. In addition, Par Pacific operates the Hele retail brand in Hawaii and the "nomnom" convenience store chain in the Pacific Northwest. Par Pacific also owns 46% of Laramie Energy, LLC, a natural gas production company with operations and assets concentrated in Western Colorado. More information is available at www.parpacific.com.

Par Pacific has announced a $90 million investment at its Kapolei, Hawaii refinery to convert an existing distillate hydrotreater unit to produce renewable fuels. The 61 million gallon per year project is expected to produce renewable diesel, sustainable aviation fuel, renewable naphtha, and renewable light-end products. The project is expected to be completed during the second half of 2025.

The 2025 Step-Down and Auto-Adjustment Mechanism (AAM)

We support the increase in the step-down from 5% to 9% in 2025. We also support the inclusion of the AAM but are concerned that its first potential triggering remains, as in the 45-day package, with 2028 being the first year for which it can amend CI reduction targets. Instead, we recommend that 2025 performance should be able to trigger the AAM, which would then be able to impact CI targets in 2027.

In short, the AAM should be allowed to trigger as early as possible, to guard against the case where the step down is not sufficient to address the current credit bank oversupply. This is especially the case since CARB did not include the more aggressive step-down in 2025 as recommended by ICF and as advocated for by many stakeholders in comments on the 45-day package.

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The Cap on Credits on Biomass-Based Diesel ("BBD") from Soy and Canola Feedstocks

We were surprised and disappointed that CARB included major changes from the current regulation and the 45-day package in the 15-Day Changes related to caps on credits for soy and canola. We do not believe that it is appropriate to include impactful revisions without the supporting science and an adequate public process**.**

Caps on credits for BBD pathways with soybean oil and canola feedstocks were added in the 15-Day Changes despite these matters not being workshopped, and being contrary to CARB's position as expressed in its April 10, 2024 workshop (the "Workshop"), including as set forth in staff's presentation for it.

CARB has only provided stakeholders 15 days to submit comments on these major changes, however they include provisions that may cause some biofuels producers to go out of business and leave stranded assets. This potential outcome is inconsistent with CARB's guiding principles for the LCFS and may result in reduced renewable diesel and biodiesel in the California fuel pool.

In short, to include such drastic changes at this juncture is bad public policy and is unfair to stakeholders, including those living in disadvantaged communities

1. The 20% cap on credits for BBD from soy and canola feedstocks is unnecessary and will result in higher GHG emissions and tailpipe emissions for Californians, especially those in disadvantaged communities.

    a. As CARB made clear in the Workshop, soybean oil BBD will become deficit generating by 2033 at the latest and perhaps 2030 if the AAM mechanism is triggered twice. The use of soybean oil as a feedstock will then phase out, rendering the cap unnecessary.

    b. Furthermore, as CARB explained in the Workshop, the science does not exist to justify a cap on crop-based biofuels at this time.

    c. CARB also made clear in the Workshop, the LCFS already contains guardrails that disincentivize the use of crop-based feedstocks through the inclusion of an indirect land use change ("iLUC") Carbon Intensity ("CI") penalty and sustainability requirements. The amended LCFS will contain stringent sustainability requirements including certification by an internationally recognized body and third-party verification.

    d. As the 2022 Scoping Plan sets forth, and CARB has reiterated in the amendment proceeding, including in the Workshop, internal combustion engines will be on California roads for years to come and the heavy-duty fleet is expected to transition slowly. Heavy-duty trucking is extremely difficult to electrify, and it is projected that there will not be enough hydrogen production or refueling infrastructure in the foreseeable future.

       As the Scoping Plan noted, the answer in the transition period is the use of low carbon liquid fuels like BBD for the heavy-duty trucking sector.

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The LCFS incentivizes the use of waste-based feedstocks to make BBD due to the iLUC penalty on crop-based feedstocks, however there are clear signs that there will not be enough of these feedstock streams by 2030 to supply the market. This will be especially true as renewable diesel production continues to grow.

The EPA recently announced that it is investigating at least two biofuel producers amid concerns they are using virgin palm oil disguised as used cooking oil ("UCO") as feedstocks to generate RINs. The EU is also investigating the same issue. Without valid Chinese UCO, there will not be sufficient feedstocks for the necessary RD production unless producers can generate LCFS credits on the crop-based RD they produce. In addition, we expect the unintended consequence of more Chinese UCO being imported into the US to meet the CARB requirements and further incentive to blend virgin palm oil into the UCO pool, running counter to CARB's intentions.

2. **The possible end of BBD fuel pathways**. We were also surprised by the inclusion of a provision in the 15-Day Changes allowing for the possibility of CARB not accepting fuel pathway applications for BBD starting on January 1, 2031. This provision was not workshopped or discussed before the 15-Day Changes.

   If CARB insists on this provision, the triggering mechanism should be limited to the number of ZEV or near-ZEV classes 7 & 8 vehicles, i.e., the heavy-duty trucking categories, since these are the vehicles that are difficult to electrify.

3. **The 15-Day Changes reflect out-of-date databases to determine iLUC**

   On p. 10 of the Notice, CARB describes its proposed changes to Table 6, Land Use Change Values for Use in CI Determination as follows:

   In section 95488.3(d), Table 6, staff proposes to add specification of the geographic region to Table 6, identifying where land use change (LUC) carbon intensity was modeled for specific feedstock/fuel combinations. **Table 6 LUC values were estimated through the GTAP and AEZ-EF modeling framework developed by CARB with input from an expert working group in 2010 and were updated during CARB's re-adoption of the LCFS program in 2015.** [Emphasis added.]

   It was at this time that CARB assessed the iLUC for soy BBD at its current value of 29.1. However, as Dr. Farzad Taheripour et al explain in their June 2023 report entitled *Biodiesel induced land use changes: An assessment using GTAP-BIO 2014 data base,* appended hereto and incorporated by this reference, CARB's assessments of LUC value were made using an earlier version of the GTAP-BIO model than is used today, as well as a 2004 database. However, the 2004 database has been updated twice since then, once in 2011 and again in 2014. In addition to updating the database, the Purdue GTAP team has also greatly improved the GTAP-BIO model to take into account intensification due to multiple cropping and/or conversion of idled land to crop production.

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Therefore, the 2004 data base and model CARB has been using was out-of-date, and CARB will be compounding the issue in the upcoming amendment by continuing to use them. The Scoping Plan requires CARB to use "the best available science" when computing emissions from crop-based feedstocks. Therefore, we request that CARB use the current GTAP-BIO model and 2014 database to calculate iLUC for such feedstocks.

Furthermore, we request that CARB continue to accord an equivalent iLUC value to Argentine soybean oil as the iLUC value for US soybean oil-based BBD. In addition to the same iLUC value, we also request that CARB continue to accord Argentine soy farming emissions an equivalent value to those of US soy.

4. **Eliminating fossil jet fuel as a deficit generator**. In the 45-day text, fossil jet from in-state jet fueling was added as a deficit generator. Again, without prior discussion, CARB removed the provision from the 15-Day Changes.

In closing, we note that there is sufficient time before the November Board meeting for CARB to issue a second 15-day package. We urge CARB to do so.

Sincerely,

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Biodiesel induced land use changes: An assessment using GTAP-BIO 2014 data base

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Report: June 2023

This research was funded by Clean Fuels Alliance America

Biodiesel induced land use changes: An assessment using GTAP-BIO 2014 data base

Farzad Taheripour, Omid Karami, and Ehsanreza Sajedinia

1. Introduction

Biofuel production and policy may Induce Land Use Change (ILUC) emissions. However, the extent to which these emissions may occur needs more attention. Biofuel production started to grow in the early 2000s for several reasons, including but not limited to: major surpluses in crop markets leading to low crop prices, high crude oil prices, and environmental concerns about the expansion in consumption of fossil fuels (Taheripour et al., 2022). In the late 2000s, in the absence of actual observations, some papers argued that biofuel production will largely increase demand for new cropland, generate major deforestation, and cause large GHG emissions (Tilman et al., 2006; Fargione et al., 2008, Searchinger et al., 2008; Plevin et al., 2010). Since then, major efforts have been made to re-evaluate these early assessments. These efforts have concluded that the early research in this area had significantly overstated the land use implications of biofuels (Zilberman et al., 2018). Some of these efforts are highlighted in the following.

More than a decade ago, Searchinger et al. (2008) used the CARD/FAPRI model and argued that producing corn ethanol in the U.S. will generate more than 100 grams of CO_2 emissions equivalent per megajoule (gCO_2e/MJ). Over time, this model has been modified and improved by various authors. As an example, in a more recent paper, Carriquiry et al. (2019), using an improved version of this model, have estimated that the land use emissions associated with U.S. corn ethanol could vary between 9.7 gCO_2e /MJ and 23.9 gCO_2e/MJ. These values are substantially lower than the estimated ILUC value by Searchinger et al. (2008).

In the late 2000s, the GTAP-BIO model was developed at Purdue University to assess the economic and environmental impacts of biofuels production and policy. Since then, this model has been frequently improved and used to evaluate the land use emissions due to biofuels. In the earlier stages of this process, the California Air Resources Board (CARB) adopted and used this model to assess ILUC emission values for various biofuel pathways. The early improvements in this model were made based on a set of recommendations suggested by an expert group assembled by CARB. Using the improved model, CARB (2015) has assessed that corn ethanol and soybean biodiesel generate about 19.8 gCO_2e/MJ and 29.1 gCO_2e/MJ emissions, respectively. Those assessments were made using the GTAP-BIO model and its 2004 benchmark data base.

In addition to the improvements mentioned above, several new efforts have been made to further improve the GTAP-BIO model since 2015. Taheripour et al. (2017) made two lines of modifications in this model. They first used an updated benchmark data base. Unlike the CARB assessment that was based on benchmark data for 2004, Taheripour et al. (2017) used a newer GTAP-BIO data base to represent the global economy in 2011. In addition, they improved the model to take into account intensification due to multiple cropping and/or conversion of idled land to crop production. They also made it possible to take into account the fact that yield to price response varies by region. With these modifications, Taheripour et al. (2017) have shown that induced land use emissions due to corn ethanol and soybean biodiesel would be about 12 gCO_2e /MJ and 18.3 gCO_2e /MJ emissions, respectively.

The estimated ILUC values for corn ethanol and soybean biodiesel have generally followed declining trends over time. For example, Figure 1 provides an overview of several estimated ILUC emissions for soybean biodiesel obtained from various modeling approaches.

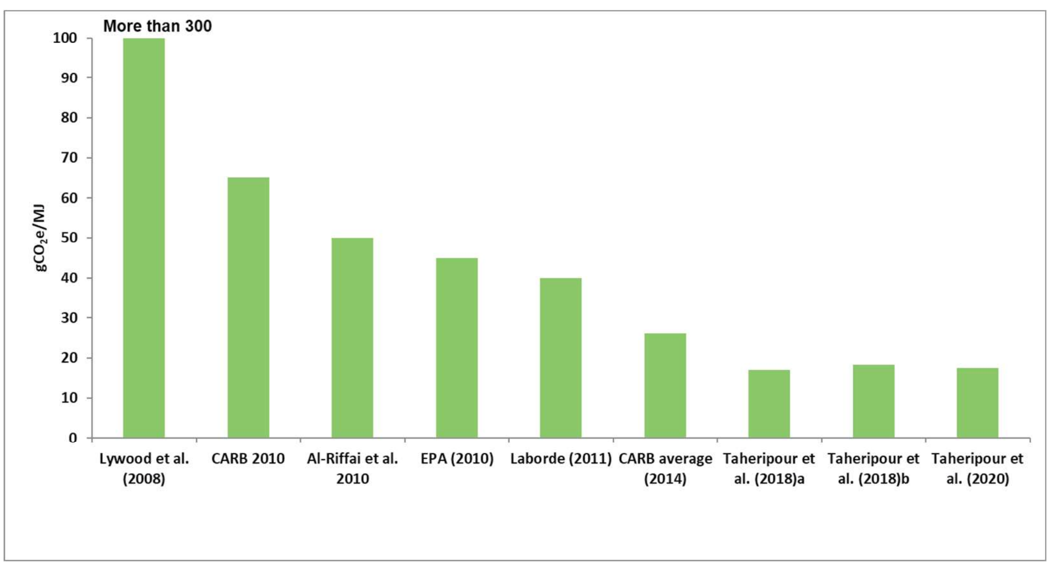


Figure 1. Some estimated ILUC values for soybean biodiesel.

As shown in Figure 1, the estimated ILUC values for soybean biodiesel has declined over time from more than 300 gCO_2e/MJ (estimated by Lywood et al., 2008) to 17.5 gCO_2e/MJ (estimated by Taheripour et al., 2020). Various factors, including model and data improvements, productivity increases, intensifications, and tuning modeling practice to actual observations, explain the observed declining trend in ILUC emissions for soybean biodiesel.

In a recent effort, a new data base has been developed for use in the GTAP-BIO data base. This new data base represents the global economy in 2014. This research uses this new data base and provides new assessments for ILUC emissions values for the U.S. soybean biodiesel and rapeseed biodiesel pathways. This report uses the modeling framework developed and reported by Taheripour et al. (2017) to provide these assessments. The rest of this research report provides the following sections. First, the 2014 GTAP-BIO data base is introduced. Then a brief summary of the GTAP-BIO model used in this study is provided. The examined scenarios are outlined in the next section. The last section provides the results.

2. 2014 GTAP-BIO data base

The standard GTAP data bases which trace production, consumption and trade of all goods and services by country at the global scale do not explicitly represent biofuels and their by-products. In a pioneer practice and for the first time, Taheripour et al. (2007) introduced biofuels into the 2001 GTAP data base and generated the first GTAP-BIO data base. In 2001, only a few countries (mainly Brazil, U.S., and some EU members) were producing limited amounts of biofuels. The global biofuel production was about 5 billion gallons in 2001. Since then, major efforts have been made to provide GTAP-BIO data bases for 2004 (Taheripour and Tyner, 2011) and 2011 (Taheripour et al., 2016). However, as the number of biofuel-producing countries and quantities of biofuels produced in each country grew over time, introducing biofuels into GTAP data bases turned to a challenging and time-consuming task. For example, it took a long time to introduce about 23 billion gallons of ethanol and 6 billion gallons of biodiesel produced from different feedstock across the world into the 2011 GTAP-BIO data base.

While introducing biofuels into a new version of GTAP-BIO data bases is an important task to accomplish, more steps are required to develop one of these data bases. In addition to biofuels, these data bases trace land cover, land use, harvested area, and crop production across the world. Furthermore, compared to the standard GTAP data bases, the GTAP-BIO data bases split various original GTAP sectors to better understand and establish the links between biofuels, agricultural, non-agricultural, and energy sectors. For additional steps needed to generate a new GTAP-BIO database, see Taheripour et al. (2016).

During the past three years, major efforts have been made to update the GTAP-BIO data base to represent the global economy in 2014. This data base is developed based on the standard GTAP data base for this year (Aguiar et al. 2022). To accomplish this task, data on biofuels produced and consumed around the world by feedstock were collected and introduced into the Input-Output table of each biofuel-producing country. The monetary values for crops and food products for each country are matched with the corresponding data provided by the Food and Agricultural Organization (FAO). Following Taheripour et al. (2016), the following standard GTAP sectors are divided into new sectors:

- Coarse grains (gro) is divided into: corn and other coarse grains,
- Oilseeds (osd) is divided into: Soybeans, rapeseed, palm, and other oilseeds,
- Vegetable oil (vol) is divided into: vegetable oil soy, vegetable oil palm, vegetable oil rapeseed, vegetable oil other, and their corresponding meals,
- Food (ofd) is divided into: Food and feed,
- A dummy sector is introduced for cropland pasture (this version includes cropland pasture for all countries around the world).

In addition to the above changes, a new sector is added to blend biofuels with conventional transportation fuels. Furthermore, following Baldoset al. (2020), land cover, land use, and crop production by Agro Ecological Zones are added to the data base for 2014.

In what follows, we compare a few key differences between the 2011 and 2014 GTAP-BIO data bases. Figure 2 compares ethanol and biodiesel produced across the world in these two data bases. The global supplies of ethanol and biodiesel were about 22.8 billion gallons and 6.1 billion gallons in 2011, respectively. The corresponding figures in 2014 were about 24 billion gallons for ethanol and 5.6 billion gallons for biodiesel. The largest ethanol producers in these two years are the U.S. and Brazil at the global scale. The EU region is the largest biodiesel producer in both years. In general, ethanol production has increased in most regions across the world in 2014 compared to 2011. However, in the case of biodiesel, the global supply has declined in 2014 compared to 2011 with some fluctuations across the world.

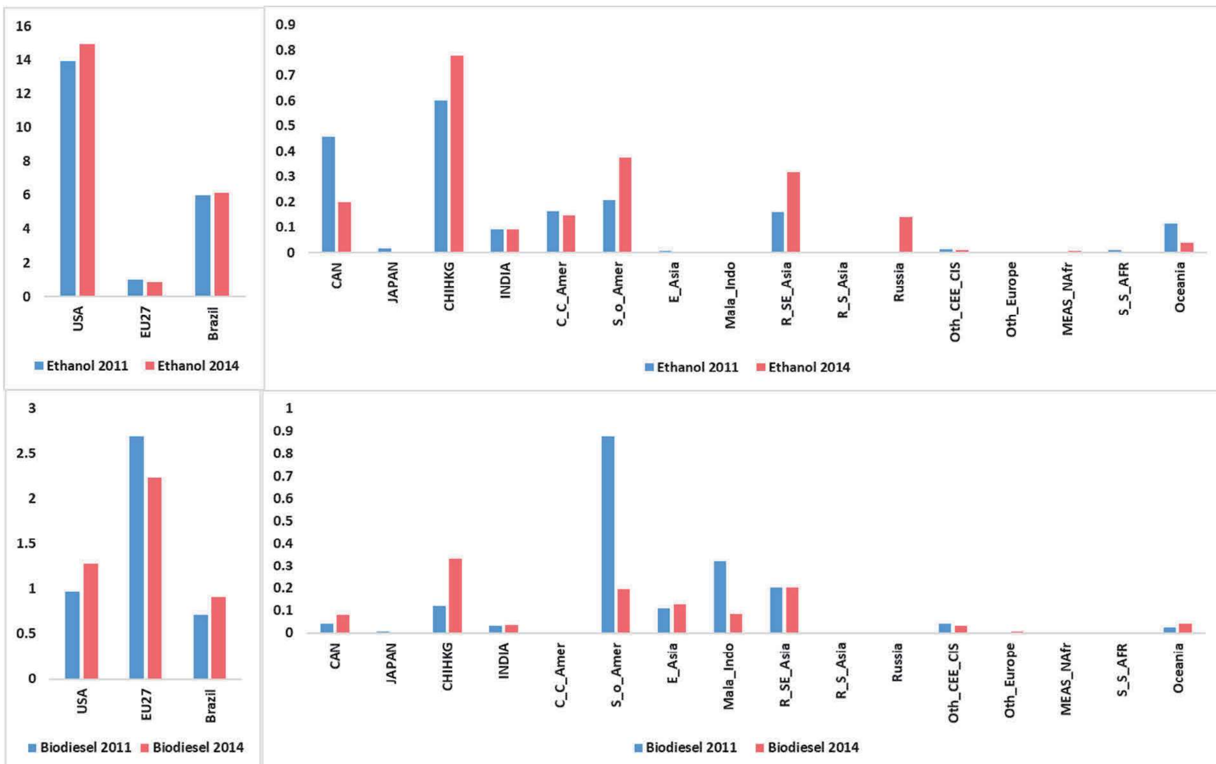
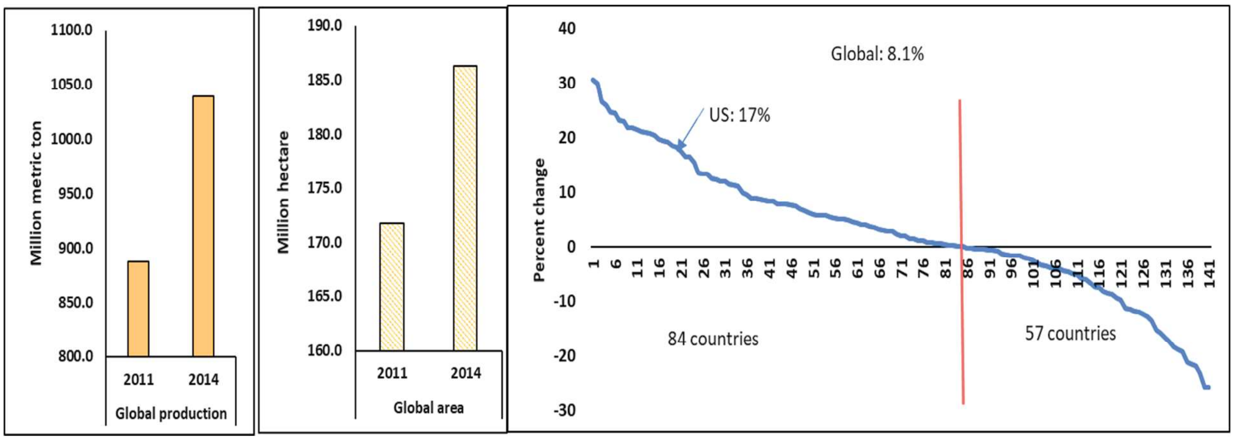


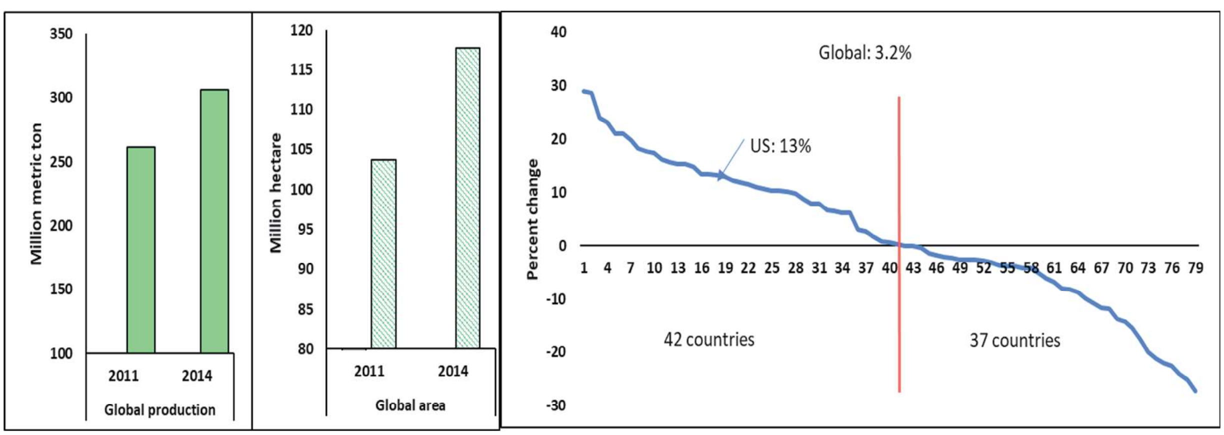
Figure 2. Biofuels produced across the world: 2011 and 2014 GTAP-BIO data bases

Figures 3 and 4 highlight a key difference between the 2011 and 2014 data bases. These figures mainly compare changes in corn and soybean yields by country between 2011 and 2014. For example, Figure 3 shows that between 2011 and 2014 the area of corn and its production have increased at the global scale. In addition, this figure shows that between 2011 and 2014 corn yield has increased in 84 countries and decreased in 57 other countries with an average increase of 8.1% at the global scale. The corresponding yield increase for U.S. corn was about 17%. Figure 4 provides a similar pattern for the case of soybeans between 2011 and 2014. For the case of soybean, yield has increased in 42 countries and declined in 37 countries, with an average increase of 3.2% at the global scale. Between 2011 and 2014, the U.S. soybean yield has increased by 13%. In general, crop yields were higher in 2014 compared to 2011 in many countries because in this year drought conditions occurred in many countries.



Panel A: Area   Panel B: Production   Panel C: Yield

Figure 3. Global corn area and production in 2011 and 2014 and regional percentage changes in corn yield between these years



Panel A: Area   Panel B: Production   Panel C: Yield

Figure 4. Global soybean area and production in 2011 and 2014 and regional percentages change in soybean yield between these years

The differences between the 2011 and 2014 data bases go beyond the differences just between the biofuel and agricultural sectors. Rather, they cover a wide range of changes across many economic activities that could directly or indirectly affect the biofuel analyses. While any element of the new data base is different from its older version, reflecting the state of the global economy in that year, the extent to which any of these differences could affect the ILUC results could be insignificant.

3. Implemented GTAP-BIO model

We use the GTAP-BIO model developed and reported by Taheripour et al. (2017). Compared to the earlier version of this model used by CARB, this version takes into account multiple cropping and conversion of unused cropland to active cropland. This model has been adopted by the Carbon Offset and Reduction Scheme for International Aviation (CORSIA) of the International Civil Aviation Organization (ICAO) of the United Nations (Zhao et al., 2021) as well. However, this is the first research that uses the 2014 GTAP-BIO data base in combination with this model.

In summary, this model includes and carries all properties and developments made in the GTAP-BIO model to date. The implemented modifications are augmented in this model to take into account market-mediated responses that occur in real world due to biofuels. Among these market-mediated responses are interactions between agricultural (crops and livestock), forestry, biofuel, and energy sectors with other industries and services. For example, it takes into account land transition among land cover items considering opportunity costs of land conversions. It also allows crop switching among alternative crops due to changes in relative crop prices. Endogenous yield improvements due to higher crop prices are included as well. It also considers yield differences between the new and existing croplands. In addition, it allows conversion of cropland pasture (a sub-category of cropland used by livestock) to cropland. The model also takes into account multiple cropping and the use of unused cropland for crop production. Lastly, the model considers substitution among animal feed rations and allows substitution between conventional transportation fuels and biofuels. As noted in the data base section, unlike the earlier versions, the model now incorporates land classified as cropland pasture for all regions.

We use the AEZ-EF emission module Plevin et al. (2014) to convert the estimated GTAP-BIO land conversions to land use emissions. Note that currently the AEZ-EF module follows the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. An update in this module according to the new IPCC 2019 refinement could alter the ILUC results provided in this report.,

4. Examined scenarios

In this research, we assess ILUC emission values for the following various soybean biodiesel demand shocks to evaluate the extent to which ILUC values may respond to shock sizes:

i) An expansion in soybean oil biodiesel by 1.05 billion gallons off of 2014
ii) An expansion in soybean oil biodiesel by 1.35 billion gallons off of 2014
iii) An expansion in soybean oil biodiesel by 1.81 billion gallons off of 2014
iv) An expansion in soybean oil biodiesel by 2.22 billion gallons off of 2014
v) An expansion in soybean oil biodiesel by 2.51 billion gallons off of 2014
vi) An expansion in soybean oil biodiesel by 3.22 billion gallons off of 2014

In addition, we calculate ILUC emission values for the following shocks in rapeseed biodiesel:

i) An expansion in rapeseed oil biodiesel by 0.06 billion gallons off of 2014
ii) An expansion in rapeseed oil biodiesel by 0.47 billion gallons off of 2014
iii) An expansion in rapeseed oil biodiesel by 0.03 billion gallons off of 2014

5. Results

5.1. ILUC values

Figure 5 shows the ILUC emission values for the implemented soybean biodiesel shock sizes. This figure shows an ILUC value of 9.11 gCO_2e/MJ for an increase in soybean biodiesel by 1.05 billion gallons. The ILUC value slightly increases to 9.78 gCO_2e/MJ for the largest implemented shock size of 3.22 billion gallons. The results presented in Figure 5 suggest that the soybean ILUC values do not significantly change with shock size. That basically shows that the model results are linear and are not sensitive to the shock size of soybean biodiesel.

As noted in the introduction section, using the 2011 GTAP-BIO data base, Taheripour et al. (2017) estimated an ILUC value of 18.3 gCO_2e/MJ for soybean biodiesel. However, the results provided in Figure 5 indicate that the 2014 data base provides a significantly smaller ILUC value than using the 2011 data base for this type of biodiesel, even with the largest implemented shock size (9.78 gCO_2e/MJ for 3.22 billion gallons). Three factors mainly contribute to this result: (1) Higher soybean yields in 2014 than 2011; (2) including cropland pasture in all regions of the model, and (3) a larger crop production base in 2014 compared to 2011. Regarding the first factor, ceteris paribus, the higher the yield, the lower the ILUC value. The second factor helps to use cropland pasture across the world instead of higher demand for conversions of pasture and forest to cropland, leading to lower land use emissions. Finally, the last item refers to saving in the existing uses of various related items due to biofuel demand. For a given change in demand for soybean biodiesel, a portion of the additional demand will come from the savings in current consumptions of oilseeds, vegetable oils, tallow, and animal fats. Hence, ceteris paribus, the larger uses of oilseeds and vegetable oils in the 2014 data base (compared to 2011)provides more savings in the existing uses of oilseeds, vegetable oils, tallow, and animal fats, leading to less demand for land conversions and hence a lower ILUC value. Also, it is important to note that the 2014 area of soybeans provides more feedstock due to yield improvements, which leads to lower demand for land conversion.

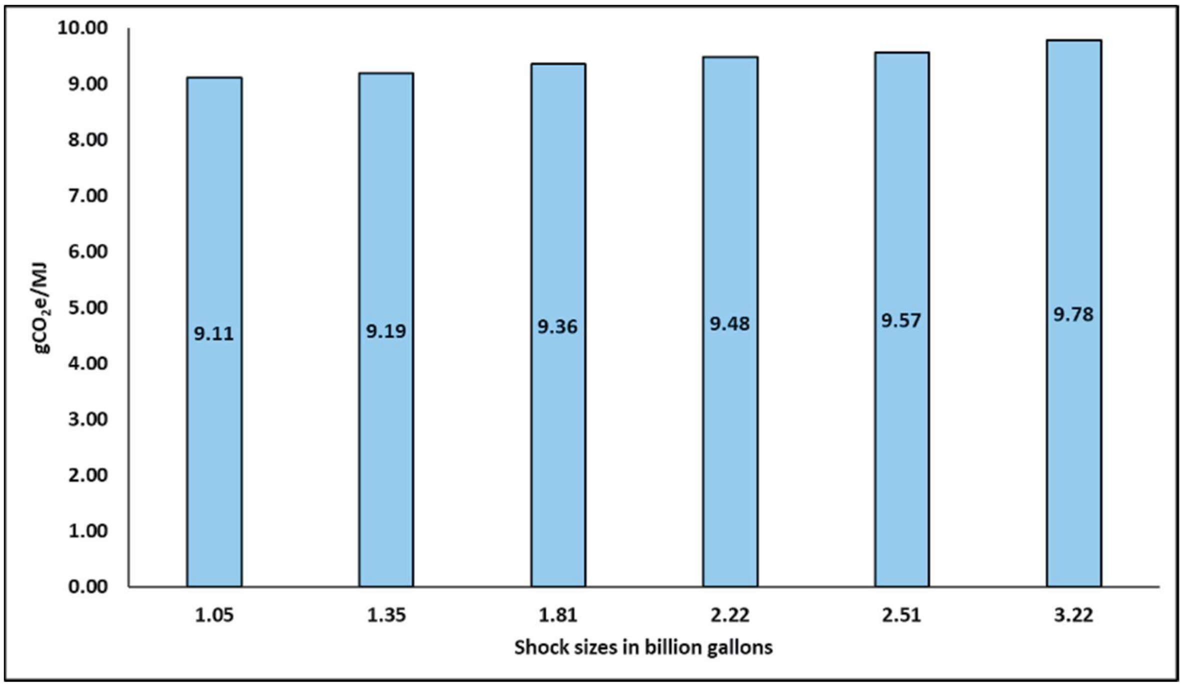


Figure 5. Soybean biodiesel ILUC emission values for various levels of shock sizes using the GTAP-BIO 2014 data base.

Figure 6 shows the ILUC values for the three examined small levels of increased rapeseed biodiesel demand. This figure shows that an increase in this type of biodiesel by 0.03 billion gallons generates an ILUC emission value of 14.07 gCO_2e/MJ. The ILUC emission value for this biodiesel increases to 14.22 gCO_2e/MJ for a shock size of 0.06 billion gallons and to 15.06 gCO_2e/MJ for a shock size of 0.47 billion gallons. These results suggest that the size of ILUC grows slightly as the shock size grows for this type of biodiesel. That is because the U.S. rapeseed and rapeseed oil sectors are small, so yield increases result in relatively less increased supply of rapeseed oil than would occur in the case of soy. Increases in demand for this biofuel necessitate either domestic land conversion or increased imports of imported feedstock which can trigger land conversion in other rapeseed-producing countries.

Note that, regardless of the shock size, the rapeseed ILUC value is larger than the soy ILUC value. Several factors explain this observation. Unlike soybean biodiesel, a big portion of feedstock for rapeseed biodiesel comes from other countries. The nature of land use and land cover and their corresponding emissions factors in countries that produce rapeseed are different from the U.S. The markets and uses of rapeseed and rapeseed oil are different from soybeans and soybean oil markets. As an example, implementing a similar shock in soybean biodiesel and rapeseed biodiesel will generate different responses in the oilseeds and oil market at the global scale. Compared to the cases of soybean biodiesel, since a big portion of feedstock for rapeseed biodiesel comes from other countries, a shock in this biofuel will generate more effects (e.g., substitutions among oilseeds and oils) outside the U.S. Substitutions among oils in many countries are significantly higher than the U.S. Yield responses are different across the two crops. It is also important to note that the links between rapeseed and palm markets are different than the links between soybeans and palm markets. An expansion in rapeseed demand could relatively induce more land use changes (adjusted to the shock size) in Malaysia and Indonesia than an expansion in soybeans demand.

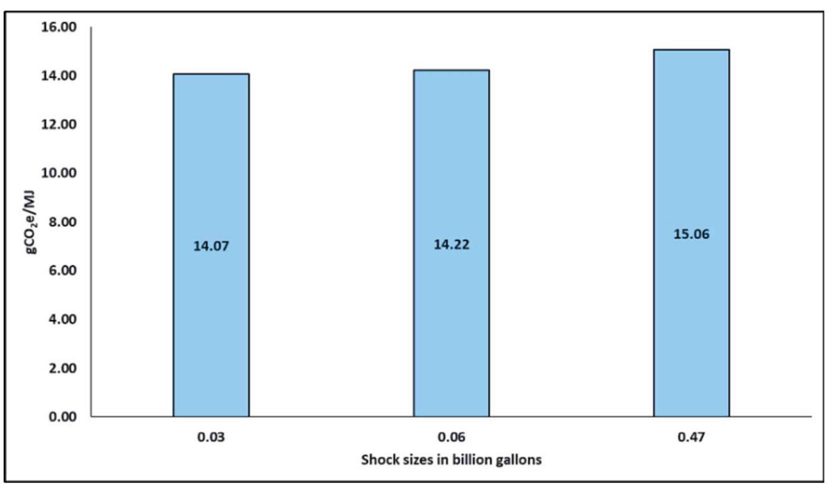
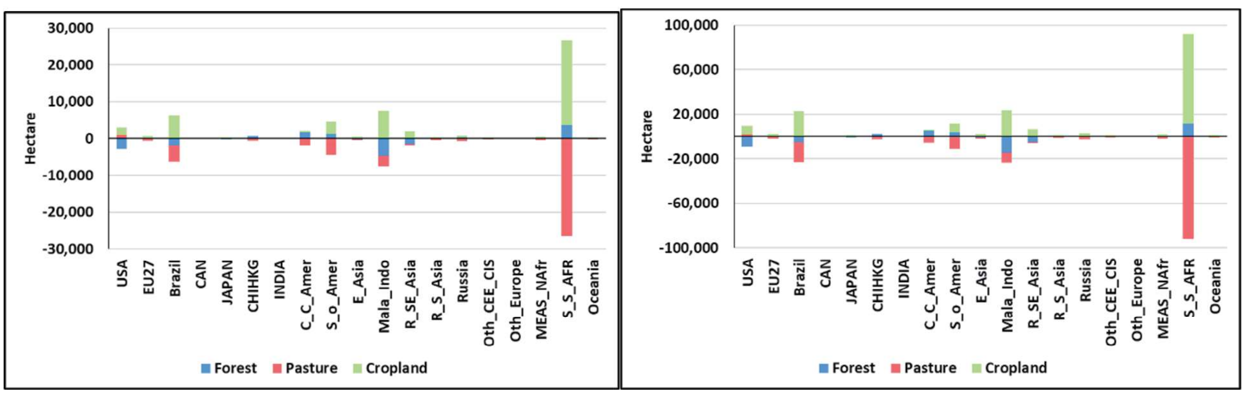


Figure 6. Rapeseed biodiesel ILUC emission values for various levels of shock sizes using the GTAP-BIO 2014 data base.

5.2. Land use changes

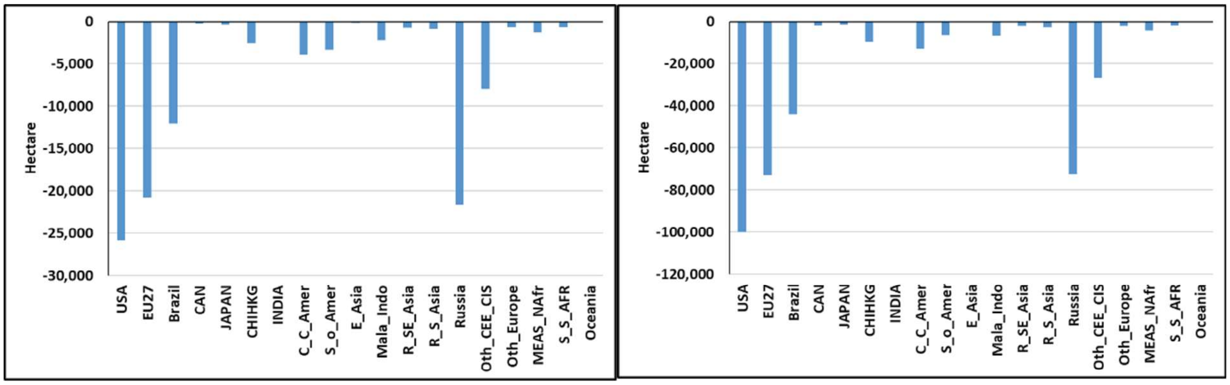
Figure 7 shows the global changes in land cover items (forest pasture and cropland for the smallest (1.05 billion gallons in panel A) and largest (3.22 billion gallons in panel B) shock sizes in the soybean biodiesel examined in this research. The largest shock size represents larger land conversion in panel B, following in a linear scale. Regardless of the shock size, Figure 7 shows that the examined expansion in soybean biodiesel generates the largest land conversions in Sub Saharan Africa. This region is a large producer of various grains, oilseeds, and many other crops at the global scale. It is also a U.S. trade partner in several agriculture markets. Cropland has historically increased in this region due deforestation as well. According to these actual observations, which are embedded in the model data base, the model projects that this region provides land conversion to satisfy the increased feedstock demand and/or demand for soy oil substitutes in other markets. After that, more land conversions occur in the main oilseed producers' regions, such as Malaysia-Indonesia, Brazil, and Central and South America.



Panel A Panel B

Figure 7. Land conversion due to soybean biodiesel shocks: Panel A for 1.05 billion gallons shock and Panel B for 3.22 billion gallons

In addition to the land conversion among land cover items, expansion in soybean biodiesel provides incentives to convert cropland pasture from livestock use to crop production across the world, as shown in Figure 8. The conversion of cropland pasture for the smallest and largest shocks are presented in panels A and B of Figure 8.



Panel A Panel B

Figure 8. Conversion of cropland pasture from the use by livestock to crop production due to soybean biodiesel shocks: Panel A for 1.05 billion gallons shock and Panel B for 3.22 billion gallons

Finally, Figure 9 illustrates land conversions due to the largest shock (0.34 billion gallons) in rapeseed biodiesel. As shown in this figure, expansion in this type of biodiesel (as for the case of soybean biodiesel) causes larger land conversions in Sub-Saharan Africa relative to other regions. However, for this pathway, land conversion occurs in more regions than in the cases of soybean biodiesel. That said, given the implanted small shocks in rapeseed biodiesel, the scale of land conversion for this pathway is relatively small compared to all soybean biodiesel shocks which are significantly larger. As shown in Figure 10, the expansion in rapeseed biodiesel triggers the conversion of cropland pasture from livestock to crop production as well.

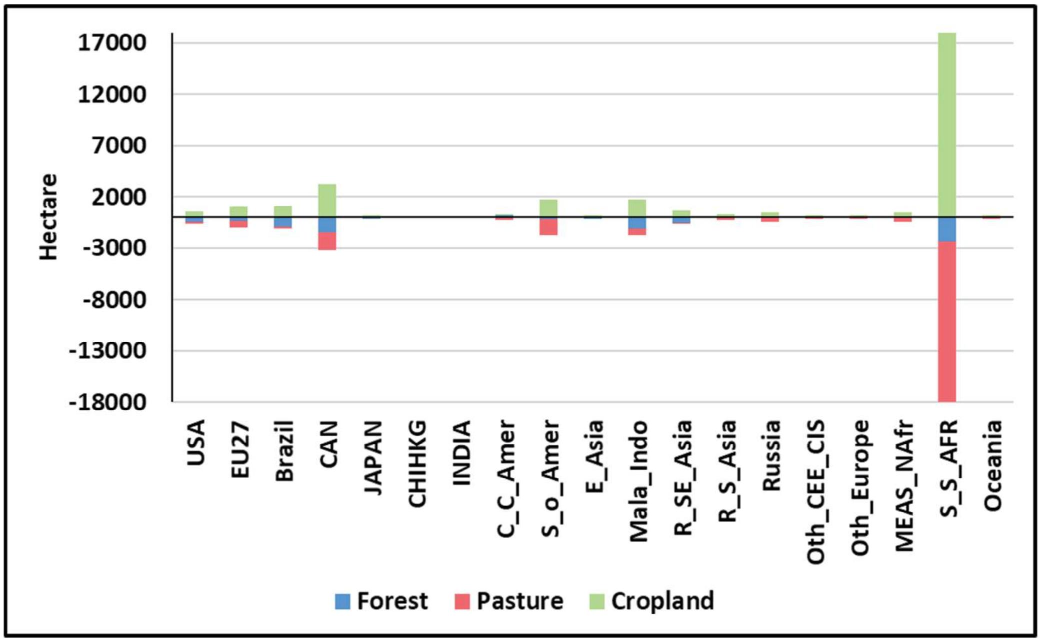


Figure 9. Land conversion due to rapeseed biodiesel shock by 0.47 billion gallons shock

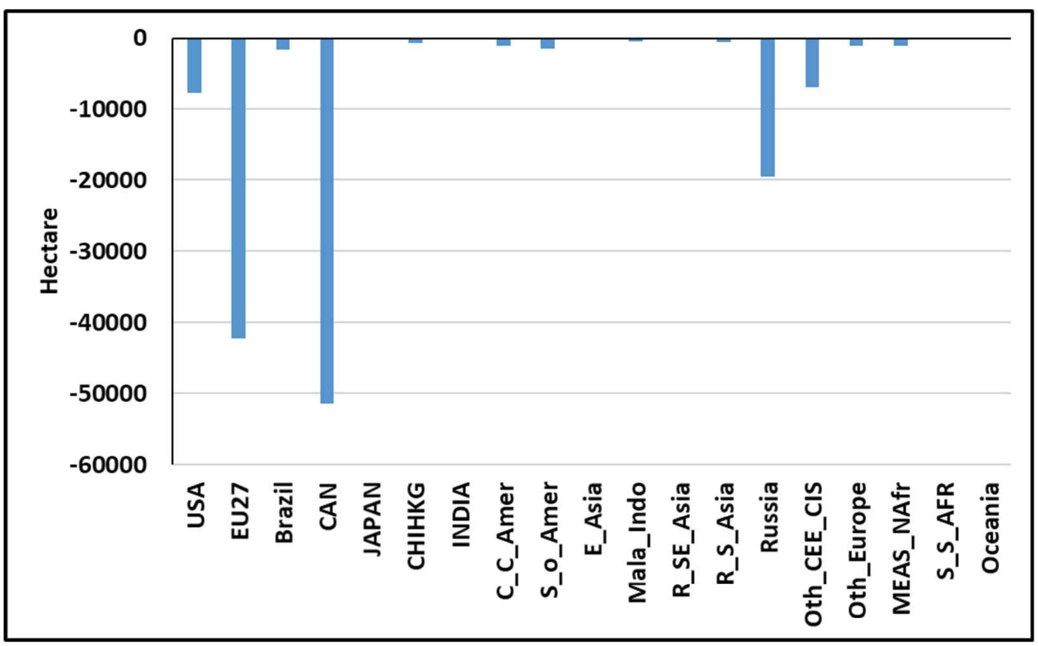


Figure 10. Conversion of cropland pasture from the use by livestock to crop production due to rapeseed biodiesel shock by 0.47 billion gallons shock

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