RENEWABLE FUELS ASSOCIATION

April 1, 2022

Attention: Docket ID No. EPA-HQ-OAR-2021-0921

The Honorable Michael Regan
Administrator
U.S. Environmental Protection Agency
EPA Docket Center
Office of Air and Radiation Docket
Mail Code 28221T
1200 Pennsylvania Ave NW
Washington, DC 20460

Via: www.regulations.gov

Re: Comments on *Virtual Meeting on Biofuel Greenhouse Gas Modeling* (86 Fed. Reg. 73757; December 28, 2021)

Dear Administrator Regan,

The Renewable Fuels Association (RFA) appreciates the opportunity to submit these comments in response to the U.S. Environmental Protection Agency's (EPA) Workshop on Biofuel Greenhouse Gas Modeling, which was held Feb. 28 – Mar. 1. EPA, *Announcing Upcoming Virtual Meeting on Biofuel Greenhouse Gas Modeling* (86 Fed. Reg. 73757; December 28, 2021).

RFA is the leading trade association for America's ethanol industry. Its mission is to drive expanded demand for American-made renewable fuels and bioproducts worldwide. Founded in 1981, RFA serves as the premier organization for industry leaders and supporters. With over 300 members, we work every day to help America become cleaner, safer, and more economically vibrant.

From its beginning, the Renewable Fuel Standard (RFS) has been a tremendously successful energy, carbon reduction, and economic development policy. Moving forward, expanding the use of low-carbon renewable fuels like ethanol is the most immediate and effective strategy for meeting the Administration's carbon reduction goals. Under the RFS program, biofuels use has resulted in the avoidance of nearly 1 billion metric tons of greenhouse gas (GHG) emissions from the transportation sector. In addition, growth in renewable fuels production has stimulated the farm economy and rural communities, supporting job creation, increased tax revenue, and heightened household incomes.

RFA commends the EPA for holding the recent workshop and soliciting related comments. The Agency's last analysis of the GHG emissions associated with corn ethanol was conducted in 2010, as part of the rulemaking process for the RFS after it was revised by the Energy Independence and Security Act of 2007. Over the ensuing 12 years, the RFA has consistently urged the EPA to update its analysis to reflect the efficiencies that have been gained in ethanol production and the advances that have been made in life cycle analysis.

The attached comments address the specific questions asked by the EPA in connection with the workshop and provide additional relevant information. Thank you again for the opportunity to comment on this important matter, and please do not hesitate to contact me should you have questions.

Sincerely,

Geoff Cooper

Geoff Cooper
President & CEO

COMMENTS OF THE

RENEWABLE FUELS ASSOCIATION (RFA)

IN RESPONSE TO THE

EPA WORKSHOP ON BIOFUEL GREENHOUSE GAS MODELING

DOCKET ID NO. EPA-HQ-OAR-2021-0921

86 FED. REG. 73757 (DECEMBER 28, 2021)

The Renewable Fuels Association (RFA) appreciates the opportunity to submit these comments in response to the U.S. Environmental Protection Agency's (EPA) recent Workshop on Biofuel Greenhouse Gas Modeling. EPA, *Announcing Upcoming Virtual Meeting on Biofuel Greenhouse Gas Modeling* (86 Fed. Reg. 73757; December 28, 2021).

RFA commends the EPA for holding the workshop and soliciting related comments. The Agency explained the purpose of the event by saying, "The information gathered as part of this workshop will be used to inform a range of current and future actions, including EPA's methodology for quantifying the greenhouse gas emissions under the Renewable Fuels Standard."[1] The Agency's last analysis of the greenhouse gas (GHG) emissions associated with corn ethanol was conducted in connection with the 2010 rulemaking to implement modifications that the Energy Independence and Security Act of 2007 (EISA) made to the Renewable Fuel Standard (subsequently referred to as RFS2). Over the ensuing 12 years, the RFA has consistently urged the EPA to update its analysis to reflect the efficiencies that have been gained in ethanol production and the advances that have been made in life-cycle analysis (LCA).

In its announcement of the workshop, the EPA sought comment on three questions about biofuel GHG modeling. Each question is addressed below, and additional information directly relevant to the Agency's request is provided.

I. What model(s) are available to evaluate the lifecycle GHG emissions of land-based biofuels, and do the model(s) meet the Clean Air Act requirements for quantifying the direct and significant indirect emissions from biofuels?

The Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) model developed by the Department of Energy's Argonne National Laboratory is considered the gold standard for estimating the GHG emissions from transportation fuels,

[1] 86 Fed. Reg. 73757

including both direct and indirect emissions. GREET has been utilized extensively by federal, state, and international agencies. Most notably, the EPA used GREET emission factors in the LCA that was conducted for the 2010 RFS2 rulemaking, and the model has been adapted by the California Air Resources Board for the state's Low Carbon Fuel Standard (CA-GREET3.0) and by the Oregon Department of Environmental Quality for its Clean Fuels Program (OR-GREET3.0).

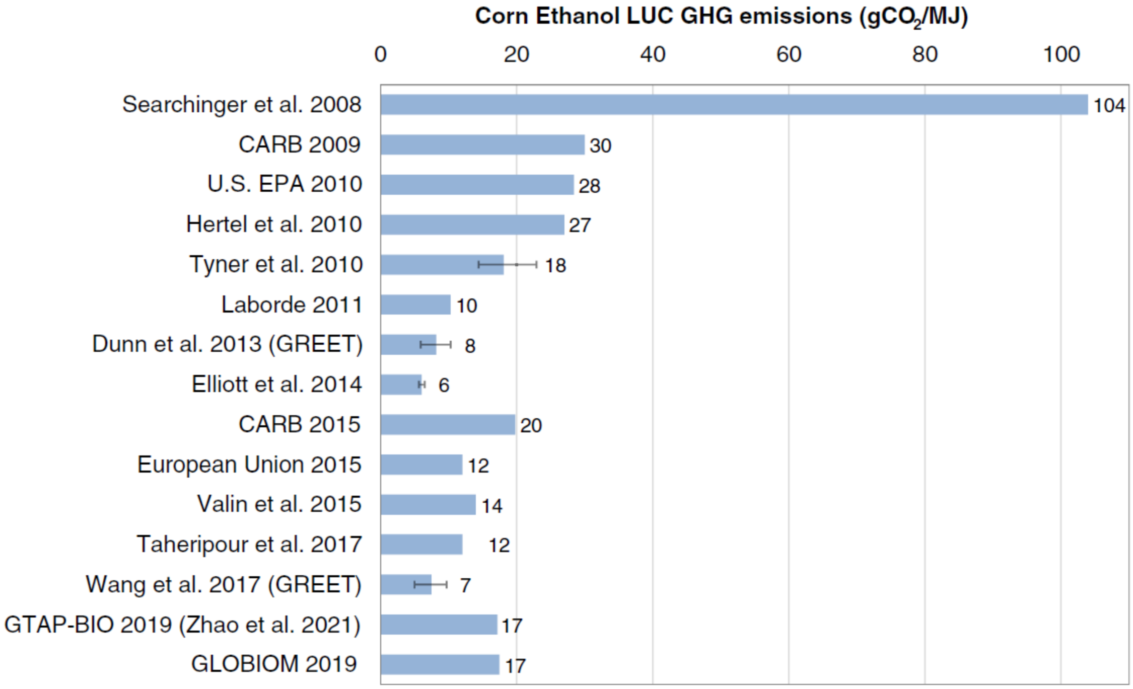
RFA understands that for LCA related to RFS2, EPA must consider "significant indirect emissions" as required by EISA. However, RFA strongly emphasizes that (1) significant indirect effects should be considered for all fuels, including petroleum-based fuels, which is consistent with EISA's references to the lifecycle GHG emissions of gasoline and diesel and to the "full fuel lifecycle, including all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through the distribution and delivery and use of the finished fuel to the ultimate consumer," (2) the EPA should not give undue consideration to anomalous allegations about indirect land use change (ILUC) associated with corn ethanol, given that ILUC emissions estimates have converged into a fairly well-defined range over time, and (3) EPA should clarify how it interprets the term "significant," as the most recent estimates of ILUC emissions are relatively small and are a minor component of the total lifecycle carbon intensity estimate.

While ILUC remains a hypothetical concept, the most scientifically robust model-derived estimates of corn ethanol ILUC emissions are integrated into GREET. The Carbon Calculator for Land Use Change from Biofuels Production (CCLUB) is used to estimate ILUC emissions within the GREET/CCLUB/Global Trade Analysis Project (GTAP) modeling array. The use of CCLUB within this array has advantages over other approaches since CCLUB's LUC estimates are taken from the latest version of Purdue University's GTAP model and its emission factors are based on actual field measurements incorporated into the CENTURY/DAYCENT tools for measuring site-level carbon (C) fluxes.

Based on these enhancements, the latest version of GREET/GTAP/CCLUB estimates that ILUC emissions from corn ethanol are approximately 5.4 grams of carbon dioxide equivalent per megajoule (g CO2e/MJ), while total emissions from LUC (including domestic LUC) are 7.4 g CO2e/MJ.

As researchers from Argonne explained in a 2021 study, "The LUC GHG emissions from large-scale corn production for corn ethanol have been simulated since 2008. Early studies showed extremely high LUC emissions (*e.g.*, Searchinger et al.), and recent studies show significantly lower LUC emissions. The downtrend in simulated LUC emissions is a result of better developed and calibrated economic models and better modeling of GHG emissions from LUC. Economic models such as [GTAP] are much improved in addressing land intensification (i.e., existing lands are managed to be more productive) versus land extensification (i.e., croplands extend into new areas of pasture and forest), crop yield increases over time, crop yield differentials in existing croplands and in newly cultivated croplands, double cropping in regions such as Asia, availability and restriction of certain land conversions (e.g., restriction of public forest land for conversion to croplands), price elasticities for crop yield responses, and food demand responses to price changes."[2] The paper included a timeline summarizing LUC emissions estimates that have appeared in the literature since 2008 (Exhibit 1). The 10 most recent estimates result in an average of 12 gCO2/MJ, roughly 60% lower than EPA's 2010 estimate, which the agency still relies upon.

Exhibit 1: Trend of Simulated LUC GHG Emissions for U.S. Corn Ethanol



Source: Argonne National Laboratory (Lee *et al.*)
For GTAP-BIO 2019 and GLOBIOM 2019, LUC values calculated for corn ethanol-derived jet fuels in ICAO were converted into per-MJ of ethanol. The error bars reflect maximum and minimum values in individual studies.

Any ILUC values used by EPA should reflect impacts that are estimated to have occurred in response to the expansion of multiple biofuels simultaneously, not based on an attempt to isolate an individual fuel, since increases in the volumes of corn ethanol, biomass-based diesel and other biofuels have actually occurred concomitantly under RFS2 and the California Low Carbon Fuel Standard (LCFS).

More broadly, the principles of lifecycle analysis (e.g., ISO 14040) require that consistent analytical boundaries be used when evaluating and comparing the relative attributes of competing products. It is inarguable that all forms of energy have associated indirect economic effects, many of which have implications for a fuel's lifecycle GHG emissions. Thus, assuming the EPA includes ILUC in LCAs for biofuels, the Agency must

[2] Lee, U., Kwon, H., Wu, M. and Wang, M. (2021). Retrospective Analysis of the U.S. Corn Ethanol Industry for 2005–2019: Implications for Greenhouse Gas Emission Reductions. *Biofuels, Bioprod. Bioref.* https://doi.org/10.1002/bbb.2225

also take into account the additional emissions that petroleum-based fuels induce through indirect economic effects at the resource margin. Otherwise, a comparison of GHG emissions from biofuels and petroleum-based fuels would not be on an "apples-to-apples" basis. Still, regulators should only quantify indirect effects in a manner that is scientifically defensible and driven by consensus-based methods.

II. What sources of data exist, and how can they be used to inform the assumptions that drive GHG estimates?

Models used for LCA incorporate a large amount of data from multiple sources. As such, it is not possible to summarize the existing sources of data briefly. As a general principle, whenever possible, data should come from public sources, the methods used to collect the data and develop associated estimates should be transparent and follow best practices, and the accuracy of the data should be understood.

Additionally, it is important that the data be updated on a regular basis. In the case of ethanol, corn yields per acre and ethanol yields per bushel of corn have increased significantly over time, while energy usage per gallon of ethanol has declined.

To the extent that some of the data needed for LCA are not available from public sources, they can be supplemented with data from private sources that meet the other criteria. Ethanol production estimates are available from the Energy Information Administration, and estimates of feedstock usage and the output of some coproducts are available from the U.S. Department of Agriculture (USDA). Additionally, Argonne, government agencies (e.g., USDA), and academic researchers have conducted surveys of ethanol plant operations from time to time. Still, to ensure that data are up to date and are part of a consistent historical series, it could be beneficial to use select data from private sources (e.g., aggregated operational data developed by companies that conduct accounting and benchmarking services across a significant number of ethanol plants) to populate certain input parameters in LCA models.

Any datasets that cannot meet these criteria should be avoided unless there is no usable alternative, in which case any known issues or limitations should be clearly documented if the data are significant to the LCA results.

III. How can the sources of uncertainty associated with quantifying the GHG emissions associated with biofuels best be characterized?

While uncertainty in LCA should be recognized and addressed, it should not be used as an excuse to avoid taking action to confront environmental problems or manipulated to promote a preconception or undermine specific biofuels. In recent years, some observers have placed an outsized emphasis on uncertainty, rather than using it to provide context around the scientific consensus that has been established through more than a decade of extensive research and model refinements regarding the GHG emissions of biofuels.

In its *Guidance on Data Quality Assessment for Life Cycle Inventory Data*, the EPA states, "Uncertainty is defined as a lack of knowledge, or the level of confidence in a value being true or false. For uncertainty, the actual value of a quantity is unknown and described by a probability distribution. This distribution is based on the information or metadata about the value and can be reduced by improving the metadata."[3]

As discussed above and reflected in Exhibit 1, researchers from Argonne compiled estimates of LUC emissions from corn ethanol based on 15 models and assessments. They showed that the emissions estimates have decreased over time and converged into a range.

The EPA guidance document goes on to differentiate between uncertainty and variability, saying, "Variability refers to the observed differences due to diversity, and is represented with a frequency distribution derived from the observed data and can usually not be reduced with further measurement or study. … It is important to distinguish differences between variability and uncertainty and if possible to capture both. Variability in LCA context is the natural fluctuation that occurs within a process or data set."

GREET addresses these issues by allowing users to assign probability distribution functions to input variables and run simulations, including Monte Carlo analyses (it also supports other sampling techniques). Additionally, the associated CCLUB calculator, which estimates LUC emissions, allows users to choose among scenarios and change certain variables.

While it is important to incorporate such practices into LCA, their use related to ILUC merits a note of caution. Occasionally, papers are published that use flawed methods to generate anomalous findings about ILUC, and some of these purport to address uncertainty by utilizing Monte Carlo analysis. This might give the appearance of credibility, but if the base values around which Monte Carlo analysis is performed are arbitrary or inaccurate, then the resulting distributions around those values will be meaningless.

IV. Supplemental information: GHG emissions from corn ethanol versus gasoline

The scientific consensus is that corn ethanol reduces GHG emissions by nearly half, on average, compared to gasoline. The 2021 Argonne study noted above estimated that typical corn ethanol provides a 44% GHG savings compared to gasoline, including LUC emissions. Similarly, researchers affiliated with Harvard University, MIT, and Tufts

[3] Edelen, A., & Ingwersen, W. (2016). *Guidance on Data Quality Assessment for Life Cycle Inventory Data*. U.S. Environmental Protection Agency. https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=528687

University concluded that corn ethanol offers an average GHG reduction of 46% versus gasoline.[4]

In addition, the California Air Resources Board (CARB) found that ethanol used in the state in 2020 reduced emissions by 41%, on average, compared to gasoline, even when the 2015 CARB LUC emissions penalty shown in Exhibit 1 is included. From 2011 to 2020, CARB data show that the use of ethanol cut GHG emissions from the California transportation sector by 27 million metric tons of CO_2e—more than any other fuel used to meet the state's LCFS requirements.[5]

V. Supplemental information: LUC emissions

It is necessary to address the recent paper by Lark *et al.*, "Environmental outcomes of the US Renewable Fuel Standard,"[6] since the EPA invited Seth Spawn-Lee of the University of Wisconsin-Madison to make a presentation at the biofuel GHG modeling workshop, Spawn-Lee was a coauthor of the paper, and previous work by Lark involving similar methods was mentioned by the EPA in *Biofuels and the Environment: Second Triennial Report to Congress*.

The RFA issued a preliminary rebuttal issued shortly after the paper was released.[7] A more detailed assessment, which is attached to these comments, reveals a number of fundamental flaws and serious questions associated with the assortment of models and methods that Lark *et al.* strung together, including:

- The analysis covers the period 2008-2016, but the proper starting year would have been 2007. For renewable fuel to qualify toward RFS2, the feedstock from which it is produced must be grown on land cleared or cultivated prior to Dec. 2007, when EISA was enacted. The area planted to corn fell by 7.5 million acres (mil. ac.) from 2007 to 2008, so Lark *et al.* stacked the deck by using 2008 as the starting year.
- Lark *et al.* claim that the RFS has caused cropland to expand. However, this is inconsistent with EPA's annual estimates of U.S. agricultural land, which in recent years have been 20-25 mil. ac. (5-6%) lower than the 2007 level.

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[4] Scully, M. J., Norris, G. A., Alarcon Falconi, T. M., & MacIntosh, D. L. (2021). Carbon Intensity of Corn Ethanol in the United States: State of the Science. *Environmental Research Letters.* https://iopscience.iop.org/article/10.1088/1748-9326/abde08

[5] California Air Resources Board. *Low Carbon Fuel Standard Reporting Tool Quarterly Summaries.* https://ww2.arb.ca.gov/resources/documents/low-carbon-fuel-standard-reporting-tool-quarterly-summaries

[6] Lark, T. J., Hendricks, N. P., Smith, A., Pates, N., Spawn-Lee, S. A., Bougie, M., Booth, E. G., Kucharik, C. J., & Gibbs, H. K. (2022). Environmental Outcomes of the US Renewable Fuel Standard. *Proceedings of the National Academy of Sciences*. https://doi.org/10.1073/pnas.2101084119

[7] https://ethanolrfa.org/media-and-news/category/blog/article/2022/02/setting-the-record-straight-on-the-environmental-outcomes-of-the-renewable-fuel-standard-

- The method used to determine the volume of ethanol production attributable to the RFS is overly simplistic and contains errors.
- The commodity price projections in the no-RFS scenario are unreasonably low, and the findings come with the caveat of wide confidence intervals. The authors admit in the Supplementary Information document, "Our [business as usual] projections become less credible as time passes."
- Lark *et al.* claim that "native" grassland with high carbon storage has been converted to corn production, but they use satellite imagery in an attempt to determine what types of land were converted, an approach that has been shown to be fundamentally flawed. Lark *et al.* used the USDA-NASS Cropland Data Layer (CDL) in their analysis; however, the USDA issued a warning about using the CDL for assessments involving non-agricultural land cover categories, stating, "Unfortunately, the pasture and grass-related land cover categories have traditionally had very low classification accuracy in the CDL."
- In addition to misidentifying land use change, Lark *et al.* simplistically attribute purported cropland expansion to corn ethanol, ignoring other drivers.
- They overestimate the GHG emissions that would be associated with hypothesized land use change.
- They miss the fact that as ethanol production has grown under the RFS program, the additional corn needed has come primarily from increased yields, not from expanding cropland.
- The bottom-line estimate of GHG emissions associated with ethanol is an outlier. The scientific consensus is that today's corn ethanol reduces emissions by roughly half, on average, compared to gasoline.

Separately, a group of experts from Argonne, Purdue University, and the University of Illinois system conducted an extensive assessment of the Lark *et al.* paper.[8] They determined, "After a detailed technical review of the modeling practices and data used by Lark et al., we conclude that the results and conclusions provided by the authors are based on several questionable assumptions and a simple modeling approach that has resulted in overestimation of the GHG emissions of corn ethanol." A number of problems with the study by Lark *et al.* were pointed out, including:

- The land use changes that were identified likely reflect the conversion of fallow or idle land to crops, rather than permanent grasslands.
- Lark *et al.* likely overestimated soil organic carbon (SOC) loss by a factor of two to eight as a result of the incorrect application of carbon response functions. The reviewers noted that "the validation of the SOC emissions model used by Lark et al. … showed remarkably poor fit to measured SOC changes."

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[8] Taheripour, F., Mueller, S., Kwon, H., Khanna, M., Emery, I., Copenhaver, K., & Wang, M. (2022). *Comments on "Environmental Outcomes of the US Renewable Fuel Standard."* https://greet.es.anl.gov/publication-comment_environ_outcomes_us_rfs

- Lark *et al.* appeared to have double-counted the emissions of nitrous oxide from the use of fertilizer in corn production by adding them in while overlooking the fact that they are already included in the corn farming-related emissions in the main LCA models.
- They attributed 5.5 billion gallons of ethanol per year to RFS2 between 2008 and 2016 by comparing the volume under RFS2 to the requirements that had been established for the original RFS in 2005, without considering other significant drivers of ethanol production.
- The validity of picking the limited time period of 2006-2010 to assess price impacts associated with RFS2 is questionable. This does not align with the 2008-2016 timeframe for the study by Lark *et al.*, and significant price increases occurred during the earlier period.

ATTACHMENT:

RFA REBUTTAL TO THE REPORT BY LARK *ET AL.*

"ENVIRONMENTAL OUTCOMES OF THE U.S. RENEWABLE FUEL STANDARD"

REBUTTAL TO THE LARK *ET AL.* REPORT "ENVIRONMENTAL OUTCOMES OF THE U.S. RENEWABLE FUEL STANDARD"

April 1, 2022

A paper published in February in the *Proceedings of the National Academy of the Sciences*, which was funded by the National Wildlife Federation, purports to examine the "environmental outcomes" of the Renewable Fuel Standard (RFS).[1] The authors precariously strung together a series of worst-case assumptions, cherry-picked data, and disparate results from previously debunked studies to create a completely erroneous account of the environmental impacts of the RFS—and particularly corn ethanol. Following up on the Renewable Fuels Association's (RFA) preliminary rebuttal[2] issued shortly after the paper was released, the following is a more detailed assessment of the deficiencies of the *Lark et al.* report.

Executive Summary

There are number of fundamental flaws and serious questions associated with the daisy chain of models and methods used by Lark *et al.*:

- The analysis covers the period 2008-2016, but the proper starting year would have been 2007. For renewable fuel to qualify toward RFS2, the feedstock from which it is produced must be grown on land cleared or cultivated prior to Dec. 2007, when the Energy Independence and Security Act of 2007 was enacted. The area planted to corn fell by 7.5 million acres (mil. ac.) from 2007 to 2008, so Lark *et al.* stacked the deck by using 2008 as the starting year.
- Lark *et al.* claim that the RFS has caused cropland to expand. However, this is inconsistent with EPA's annual estimates of U.S. agricultural land, which in recent years have been 20-25 mil. ac. (5-6%) lower than the 2007 level.
- The method used to determine the volume of ethanol production attributable to the RFS is overly simplistic and contains errors.

[1] Lark, T. J., Hendricks, N. P., Smith, A., Pates, N., Spawn-Lee, S. A., Bougie, M., Booth, E. G., Kucharik, C. J., & Gibbs, H. K. (2022). Environmental Outcomes of the US Renewable Fuel Standard. *Proceedings of the National Academy of Sciences*. https://doi.org/10.1073/pnas.2101084119

[2] Renewable Fuels Association. (2022, February 14). *Preliminary Rebuttal to PNAS Report: "Environmental outcomes of the U.S. Renewable Fuel Standard" (Lark et al.)*. https://files.ctctusercontent.com/a8800d13601/e2f451f3-0231-4946-a8dc-33556297da63.pdf

- The commodity price projections in the no-RFS scenario are unreasonably low, and the findings come with the caveat of wide confidence intervals. The authors admit in their Supplementary Information document, "Our [business as usual] projections become less credible as time passes."
- Lark *et al.* claim that "native" grassland with high carbon storage has been converted to corn production, but they use satellite imagery in an attempt to determine what types of land were converted, an approach that has been shown to be fundamentally flawed. Lark *et al.* used the USDA-NASS Cropland Data Layer (CDL) in their analysis; however, the USDA warned, "Unfortunately, the pasture and grass-related land cover categories have traditionally had very low classification accuracy in the CDL."
- In addition to misidentifying land use change, Lark *et al.* simplistically attribute purported cropland expansion to corn ethanol, ignoring other drivers.
- They overestimate the greenhouse gas (GHG) emissions that would be associated with hypothesized land use change.
- They miss the fact that as ethanol production has grown under the RFS program, the additional corn needed has come primarily from increased yields, not from expanding cropland.
- The bottom-line estimate of GHG emissions associated with ethanol is an outlier. The scientific consensus is that today's corn ethanol reduces emissions by roughly half, on average, compared to gasoline.

In summary, the work by Lark *et al.* does not stand up when subjected to scrutiny.

Stacking the Deck Through the Choice of Starting and Ending Years for the Analysis

The Energy Independence and Security Act (EISA), which expanded the RFS (subsequently referred to as RFS2), was enacted in December 2007.[3] For renewable fuel to qualify toward RFS2, the feedstock from which it is produced must be grown on land cleared or cultivated prior to that date. EISA defined renewable fuel as "fuel that is produced from renewable biomass and that is used to replace or reduce the quantity of fossil fuel present in a transportation fuel." It further defined renewable biomass to include "[p]lanted crops and crop residue harvested from agricultural land cleared or cultivated at any time prior to the enactment of this sentence that is either actively managed or fallow, and nonforested."

[3] Energy Independence and Security Act of 2007, 42 U.S.C. § 7545 (2007).https://www.govinfo.gov/content/pkg/PLAW-110publ140/pdf/PLAW-110publ140.pdf

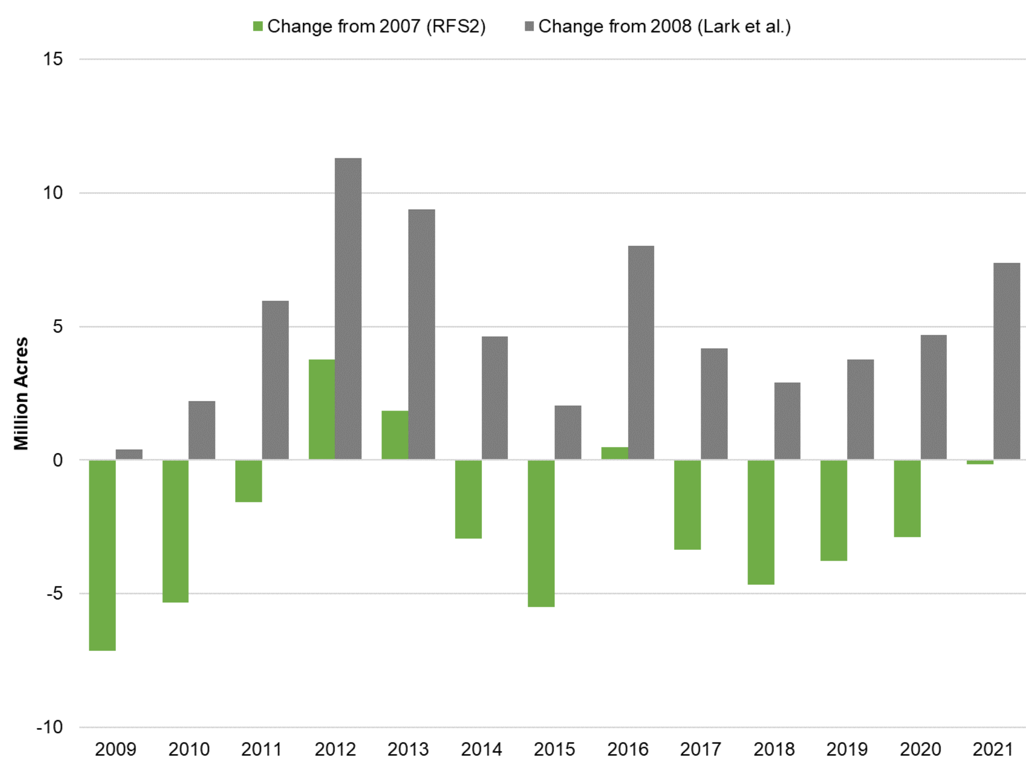
However, the analysis by Lark *et al.* addressed the period 2008-2016. Notably, the area planted to corn fell by 7.5 mil. ac. from 2007 to 2008, according to USDA (Exhibit 1). As a result, using 2008 as the starting year of the analysis results in the appearance of a greater change in corn area.

Measured from 2008 to 2016, the area planted to corn in the U.S. increased by 8.0 mil. ac. However, if 2007 had been used as the starting point, corn planted area would have been only 0.5 mil. ac. higher in 2016. Moreover, planted area each year from 2017 to 2021 has been lower than in 2016. Area rose last year as a result of weather-related production issues that had occurred in the preceding years, but it was still 0.2 mil. ac. less than in the spring of 2007 before RFS2 was adopted.

As can be seen, Lark *et al.* stacked the deck by choosing 2008 as the starting year for the analysis and 2016 as the ending year, which would have affected their findings related to corn and therefore ethanol.

It is also worth noting that the amount of land dedicated to corn production today is well below long-term historical levels and is 18% below the peak level of 113 mil. ac. planted in 1932, according to USDA data.

Exhibit 1: Change in Corn Acres Planted vs. Base Year



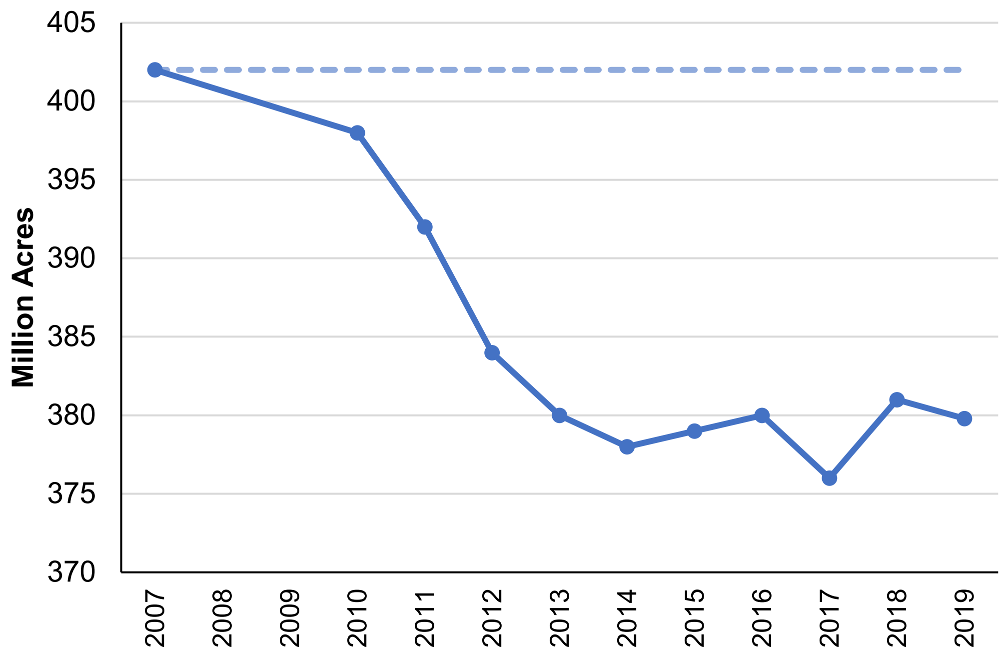
Source: RFA analysis of USDA-NASS data

Findings Regarding Cropland Area Changes Are Inconsistent with EPA Assessments

More broadly, Lark *et al.* claim that RFS2 has caused cropland to expand. In the Supplementary Information (SI) document, they acknowledge that "cropland area had been trending downward from 1982-2007."[4] They then assert that "cropland area increased nationally by 3.0 [million hectares (Mha)] from 2007-15, in part due to the RFS, but also due to several other factors."

However, when EPA initially implemented RFS2, it determined that 402 mil. ac. of U.S. agricultural land were available in 2007 for production of crops and crop residue that would meet EISA's definition of renewable biomass; this encompasses total cropland (including fallow cropland), pastureland and Conservation Reserve Program (CRP) land. The agency conducts annual assessments to ensure this number of acres is not exceeded, which clearly show that **U.S. agricultural land has receded since passage of EISA. In recent years, it has been 20-25 mil. ac. (5-6%) lower than in 2007** (Exhibit 2).[5]

Exhibit 2: U.S. Agricultural Land Area



Source: EPA

[4] Lark, T. J., Hendricks, N. P., Smith, A., Pates, N., Spawn-Lee, S. A., Bougie, M., Booth, E. G., Kucharik, C. J., & Gibbs, H. K. (2022). Supplementary Information for Environmental Outcomes of the US Renewable Fuel Standard. *Proceedings of the National Academy of Sciences*. https://www.pnas.org/doi/10.1073/pnas.2101084119#supplementary-materials

[5] Data for 2020 and 2021 have not yet been published by EPA.

Specific to their study period, Lark *et al.* stated at the outset of their paper that they found the RFS resulted in an increase in "total cropland by 2.1 Mha (2.4%) in the years following policy enactment (2008 to 2016)." However, this is misleading, as they actually "found that cropland expansion increased by 1.8 Mha." The remainder was a reduction in cropland abandonment versus what they *hypothesized* would have happened absent the RFS.

<u>The Method Used to Estimate the Increase in Ethanol Volumes Attributable to RFS2 Is Deficient</u>

The method used by Lark *et al.* to determine the volume of ethanol production attributable to RFS2 is overly simplistic and contains errors. They state, "We found that the RFS stimulated 20.8 billion L (5.5 Bgal) of additional annual ethanol production, which requires nearly 1.3 billion bushels of corn after accounting for coproducts that can be fed to animals." This assumption actually appears to have been taken from another paper, given that the citation for the sentence is to a 2017 paper by Carter, Rausser and Smith and that the SI document indicates, "Carter et al. (2017) estimate that the 2007 RFS increased mandated ethanol use by 5.5 billion gallons (20.8 GL) per year."[6]

However, Carter *et al.* simplistically defined the impact as the difference between the volume requirements in RFS2 (specifically the implied conventional biofuel requirement toward which corn ethanol can be used) and those in the original 2005 RFS (referred to as RFS1). There was no analysis behind whether this reflected the real-world impact of the passage and implementation of RFS2 on ethanol production and consumption. Rather, this method and the related calculations by Carter *et al.* were erroneous in multiple ways.

Most importantly, Carter *et al.* calculated the differential over the period 2008-2015. However, RFS1 specified volume requirements only through 2012, after which the applicable volume for each calendar year was to be determined by the EPA Administrator based on a range of criteria including "the expected annual rate of future production of renewable fuels." Since RFS2 preempted RFS1, the actual RFS1 volumes that would have been required from 2013 to 2015 are unknown. Carter *et al.* attempt to get around this by using estimates based on a 2013 paper by Schnepf and Yacobucci, which assumed that RFS1 requirements would have been 7.6 billion gallons (BG) in 2013 and would have increased to 7.8 BG in 2015.[7]

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[6] Carter, C. A., Rausser, G. C., & Smith, A. (2017). Commodity Storage and the Market Effects of Biofuel Policies. *American Journal of Agricultural Economics*, 99(4), 1027–1055. https://doi.org/10.1093/ajae/aaw010

[7] Schnepf, R. & Yacobucci, B. (2013). *Renewable Fuel Standard (RFS): Overview and Issues.* Congressional Research Service. https://sgp.fas.org/crs/misc/R40155.pdf

It is not clear how Schnepf and Yacobucci developed these estimates, but they appear to be based at least in part on an assumption that gasoline consumption would fall in future years. They noted, “Instead of growth, EIA projects gasoline consumption to fall to about 120 billion gallons by 2022.” However, gasoline consumption actually increased from 133 BG in 2012 to 141 BG in 2015 and reached 143 BG over the following few years. Moreover, according to EIA, ethanol consumption was 12.9 BG annually from 2010 to 2012. It seems highly unlikely that the EPA Administrator would have set 2013-2015 requirements more than 5 BG below the levels of ethanol usage that had actually been occurring, especially at a time when gasoline consumption was rising.

Separately, the RFS2 requirements used by Carter *et al.* to calculate a 5.5 BG impact were the statutory levels in EISA and did not reflect the fact that the EPA used its general waiver authority to reduce the implied conventional biofuel requirement by 0.8 BG in 2014 and 0.9 BG in 2015. Additionally, the volume of ethanol used toward RFS2 from 2012 to 2015 was less than the implied conventional biofuel requirement (after adjusting for the EPA’s use of general waiver) by 0.1-0.6 BG annually, as carryover RINs and other biofuels were used to meet a portion of companies’ obligations. Both the waivers and the ethanol usage volumes were known at the time of final publication of the paper by Carter *et al.* The combination of the two would have reduced their assumed RFS2 impact on ethanol to less than 5.2 BG and would have cut corn usage accordingly. (This ignores the much larger effect of the unrealistic assumptions used for RFS1 requirements in estimating the 5.5 BG impact.)

If Carter *et al.* had retained their simplistic method but had used actual ethanol consumption as the RFS2 quantity and assumed the EPA would have set RFS1 requirements at 12.9 BG annually from 2013 to 2015, **their estimated RFS2 impact would have been 3.3 BG over the full period studied—41% less than what they assumed and what Lark *et al.* subsequently adopted**. This would have made a significant difference in the findings by Lark *et al.* related to land use change (LUC), since the chain of causality in their study was that RFS2-induced biofuel demand drove feedstock demand, which in turn drove feedstock prices, which ultimately drove land use and conversion. They postulate “the RFS increased corn prices by 30% and the prices of other crops by 20%, which, in turn, expanded US corn cultivation by 2.8 Mha (8.7%) and total cropland by 2.1 Mha (2.4%) in the years following policy enactment (2008 to 2016).”

The issue of how much of U.S. ethanol production and consumption is attributable to the Renewable Fuel Standard as opposed to other drivers (e.g., market forces and such factors as octane needs) is beyond the scope of this review. However, a recently published study by Taheripour *et al.* asserts, "While the existing literature has successfully identified the key drivers of the growth in biofuels, it basically has failed to properly quantify the impacts and contributions of each of these drivers separately. This paper develops short- and long-run economic analyses … to differentiate the economic impacts of the RFS from other drivers that have helped biofuels to grow."[8] It goes on to note, "One of the main contributions of this research is to demonstrate that biofuels production growth that is often attributed to the RFS is actually due to energy and agricultural market conditions and key drivers." The authors examined the 2004-2016 period and found that the RFS increased ethanol consumption by 0.7 BG annually from 2004 to 2011 and 1.5 BG annually from 2011 to 2016, concluding that the RFS was binding on ethanol usage during the latter period. This is not necessarily a consensus among researchers, but it is an example of a much more rigorous attempt at attribution than was done by Lark *et al.*

The Commodity Price Projections in the No-RFS2 Scenario Are Unreasonable

"[T]o assess the effects of the RFS on US crop prices," Lark *et al.* state, "Our approach closely follows that of Carter et al." This is the same study from which the RFS2 volume impact was apparently taken. Lark *et al.* explain, "For all estimates, we compare outcomes under the 2007 RFS to a business-as-usual (BAU) counterfactual scenario in which ethanol production satisfies only the volume required by the initial 2005 version of the policy." However, the method that they use results in unreasonably low estimates of commodity prices in the BAU scenario and thereby overstates the impact of RFS2 on commodity prices (even before accounting for problems with their estimate of the impact of RFS2 on ethanol volumes).

In the BAU case, corn prices appear to be approximately $1.50/bu in 2015, and soybean and wheat prices appear to be around $2/bu; the confidence intervals indicate they could be even lower, with corn prices below $1/bu in 2015 and 2016 (Exhibit 3). Such prices simply would not have been tenable, especially for more than a year. **As the SI document admits, "Our BAU projections become less credible as time passes."**

Perhaps this is why the SI also indicates, "We estimated the effects of the RFS on corn, soybean, and wheat prices by comparing observed prices in the 2006-10 crop years to the BAU projections for those years." However, the 2006-2010 time period for the price analysis is misaligned with the 2008-2016 timeframe for the overall Lark *et al.* study.

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[8] Taheripour, F., Baumes, H., & Tyner, W.E. (2022). Economic Impacts of the U.S. Renewable Fuel Standard: An Ex-Post Evaluation. *Front. Energy Res.* https://doi.org/10.3389/fenrg.2022.749738

Exhibit 3: Lark *et al.* Crop Price Projections Under the Business-as-Usual Case

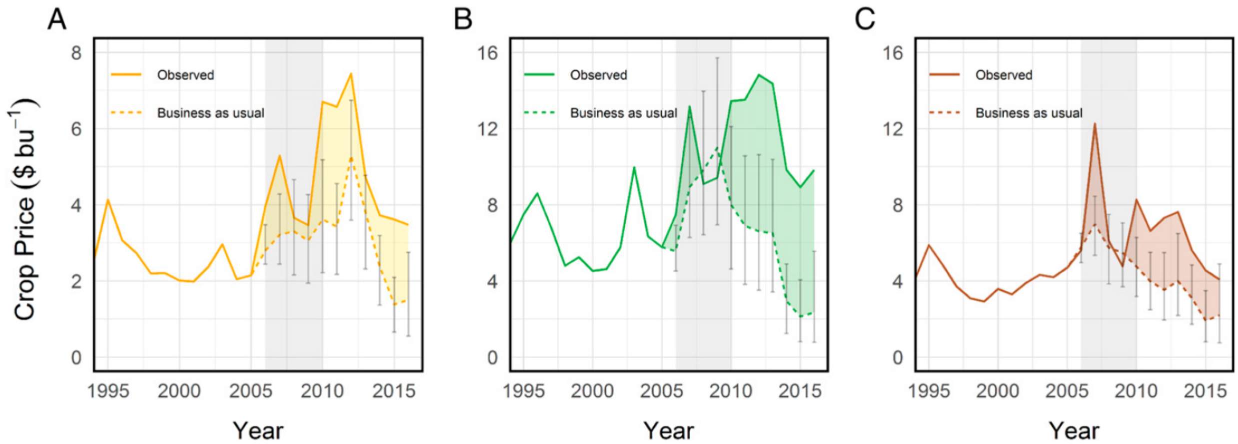

Fig. 1. Observed and BAU estimates for crop prices. (*A*) Corn. (*B*) Soybeans. (*C*) Wheat. Vertical bars represent the 95% CIs for each BAU spot price. Each year denotes a crop year; e.g., 2006 is September 2006 to August 2007 for corn and soybeans and June 2006 to May 2007 for wheat. Averages for 2006 to 2010 (highlighted in gray) were used to derive the estimates in the text, although long-run persistent impacts were consistent with these results (46).

Source: Proceedings of the National Academy of Sciences

These issues are important since the RFS2 price impact analysis is the starting point for the daisy chain of models and methods that were strung together by Lark *et al.* It is used in subsequent analyses of crop rotations and, most notably, LUC. As explained in the paper, “The model [of cropland area changes] uses point-level land use transition data based on observed annual land use transitions in the National Resources Inventory (NRI) from 2000 to 2012. We then used the model to predict the change in transitions between 2008 and 2016 based on changes in prices.”

The findings regarding price impacts also come with the caveat of wide confidence intervals. The paper starts out by saying, “We find that the RFS increased corn prices by 30% and the prices of other crops by 20%.” However, the SI document acknowledges the range within which the actual price impacts could fall: “These estimates include 95% confidence intervals of [5%, 70%] for corn, [-8%, 72%] for soybeans, and [2%, 60%] for wheat. Thus, there is a wide range of plausible price effects in the model, but the point estimates round to 30% for corn and 20% for soybeans and wheat.”

It is telling that they did not incorporate this range of potential price impacts in their uncertainty analysis. They say, “Except for the price impacts, we propagated the uncertainty results throughout the connected components—from the land use models through to all subsequent environmental outcomes.” This is a considerable omission.

Additionally, following the questionable method that Carter *et al.* used, Lark *et al.* should have arrived at a 41% smaller estimate of the impact of RFS2 on ethanol volumes, as discussed in the preceding section. If they had incorporated this into the price analysis, prices in the BAU case would not have been as low, and the estimated impact of RFS2 on prices would have been smaller. Again, this would have flowed through to the LUC analysis by Lark *et al.*

Finally, while it is beyond the scope of this review to address the merits of the vector auto-regression (VAR) approach that was used to estimate the price impacts of RFS2, it is worth mentioning that Lark *et al.* did not use a model that was designed to parse out the differential effects of RFS2 from other drivers of ethanol volumes or the differential effects of ethanol from other significant factors driving the corn market during the study period. Additionally, as noted in a thorough review of the Lark *et al.* study by Taheripour *et al.*, the uniform increase in prices that was projected by over time "is contrary to findings by other recent work developed by Filip et al. (2019) who reviewed the existing literature in this area and estimated the price impacts of biofuels for eight commodities in the U.S., the EU, and Brazil using the VAR approach and detailed weekly data (instead of annual data). Filip et al. (2019) concluded that 'price series data do not support strong statements about biofuels uniformly serving as main leading source of high food [commodity] prices.'"[9]

The Method Used to Determine Types of Land Purportedly Converted to Crop Production Is Fundamentally Flawed

Despite the fact EPA data show that the amount of agricultural land meeting the EISA definition has declined since 2007, Lark *et al.* claim that "native" grassland with high carbon storage has been converted to corn production because of RFS2. They tout the use of NRI data (from 2000 to 2012) in the study, but in the end they utilize satellite imagery to attempt to determine what types of land were converted, an approach that has been used in previous studies conducted by Lark and others and that has been shown to be fundamentally flawed. This undermines the foundation of the findings by Lark *et al.* about LUC-related environmental impacts.

As they describe, "We then mapped observed LUC at field-level resolution during our study period following the general approach of [a 2015 study by Lark, Salmon and Gibbs]. … [T]he high-resolution field data were used only to identify the possible locations and characteristics of converted land. … This hybrid approach thereby combined the high certainty and long-term temporal coverage (prior to any RFS price signals) of the NRI data with the field level specificity of the satellite-based land conversion observed during the study period."[10]

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[9] Taheripour, F., Mueller, S., Kwon, H., Khanna, M., Emery, I., Copenhaver, K., & Wang, M. (2022). *Comments on "Environmental Outcomes of the US Renewable Fuel Standard."* https://greet.es.anl.gov/publication-comment_environ_outcomes_us_rfs

[10] An interview with Lark that was published the same day as the study was released in PNAS claimed, "The current study used the survey-based USDA National Resources Inventory (NRI), which had been endorsed previously by the Renewable Fuels Association, a trade association for the ethanol industry, to

Additionally, Lark *et al.* "estimated the ecosystem carbon emissions associated with RFS-related LUC using the methods of Spawn et al." The 2019 study by Spawn *et al.* that is referenced hypothesized that cropland expansion predominantly occurred on former grasslands, and it found, "Grasslands conversion was the primary source (87%) of LUC emissions."[11] (It should be noted that Spawn-Lee was a coauthor of the current study, and Lark was a coauthor of the paper by Spawn *et al.*)

For example, if a satellite image from 2008 appeared to show a particular parcel of land was covered in grass, but a satellite image from 2016 appeared to show that same parcel was planted to corn, the authors would treat this as a conversion of "native" grassland to corn. Using an opaque methodology, they then assign that "new" corn acreage to ethanol and allocate the assumed emissions from land conversion to ethanol.

There are multiple problems with this approach. Most notably, the Lark *et al.* SI document indicates that the USDA-NASS Cropland Data Layer was used in agroecosystem modeling for the 2008-2016 period, which in turn was used to estimate GHG emissions from LUC. However, the **USDA issued a warning** about using the CDL for assessments involving non-agricultural land cover categories, stating, **"Unfortunately, the pasture and grass-related land cover categories have traditionally had very low classification accuracy in the CDL."**

Using the CDL, it is often not possible to differentiate among wheat, alfalfa hay, grass, and other land cover types. And even if the tools could identify land covered in grass with a high degree of certainty, they cannot distinguish between grass pastureland, grass hay, land enrolled in the CRP, and "native" grassland. Of course, these land cover types would have considerably different carbon storage profiles. Yet, Lark *et al.* treat all these land cover types (sometimes also including wheat, alfalfa and other crops) as "native" grassland.

The authors also attempt to characterize these supposed land cover changes as "empirical" and "observed," suggesting that they actually verified these supposed conversions with their own eyes and were able to discern that the cause of the purported conversion was the RFS. This is not the case. Rather, they are relying on highly uncertain and error-prone satellite images for their purported "empirical observations" of LUC and

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quantify cropland expansion area and the portion attributable to corn ethanol." The RFA has not endorsed any specific data set. Rather, the EPA in its *Second Triennial Report to Congress* in 2018 suggested that the NRI is better suited for temporal analysis than other sources of data on land cover and land use because it does not suffer from methodological changes over time.

[11] Spawn, S. A., Lark, T. J., & Gibbs, H. K. (2019). Carbon emissions from cropland expansion in the United States. *Environmental Research Letters*. https://doi.org/10.1088/1748-9326/ab0399

are then using supposition and questionable methods to suggest the RFS was the driving factor.

The satellite imagery-based methods used by Lark and affiliated researchers in similar studies has been rejected after rigorous critique by the scientific community. The fundamental flaws were detailed in reviews conducted by the GeoSpatial Mapping, Applications, and Research Center (GeoMARC) at Southern Illinois University Edwardsville (SIUE) in 2019 and 2021.[12] [13] The more recent paper examined a 2020 study led by Lark and a 2021 study by Zhang *et al.* (on which Lark was a coauthor) regarding the environmental impacts of purported cropland expansion in the Midwest between 2008 and 2016. The SIUE authors noted that the "researchers have attempted to develop a framework to increase the accuracy of the CDL-based assessment" but pointed out the "inability of these methods to increase the CDL's accuracies." They determined, "Therefore, the cropland expansion claimed by Lark et al. (2020) and adopted by Zhang et al. (2021) has a high potential of being false change due to poor classification certainty in the earlier CDL." The SIUE authors concluded, **"The CDL suffers from accuracy and certainty issues that severely hinder its use for estimating change over time."**

In their 2019 paper, the SIUE researchers provided an example of how misclassification of land cover in satellite-based imagery has remained an issue for the CDL. They compared the CDL with a randomly selected panel of aerial imagery from the National Agricultural Imagery Project (NAIP) in southern Iowa in 2017. As can be seen in Exhibit 4, the CDL misclassified a water body as deciduous forest and grassland, showing that the CDL still has issues with misclassification.

More information about the flaws in Lark's satellite imagery-based methods is available from the following sources:

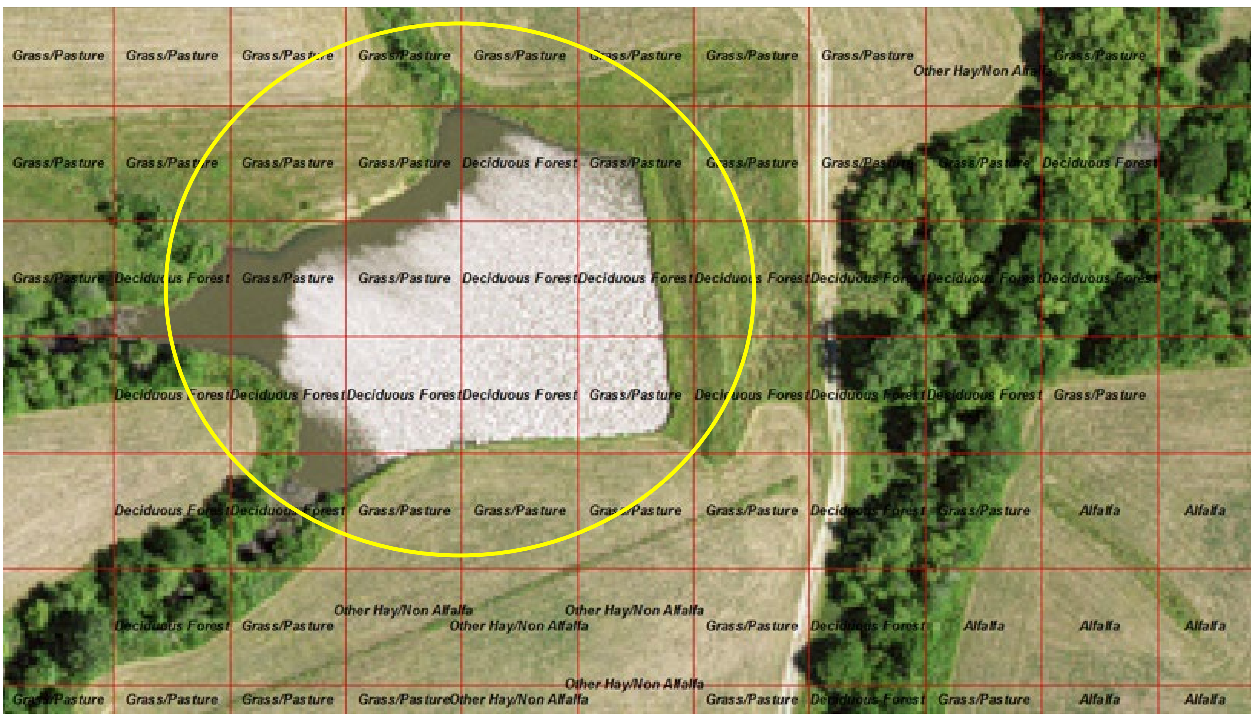
- Energy economists and life cycle analysis experts from Northwestern University, the Dept. of Energy's Argonne National Laboratory and Oak Ridge National Laboratory, the University of Illinois-Champaign/Urbana, and the University of Illinois-Chicago:
  - https://ethanolrfa.org/file/2005/ijgi-10-00281.pdf
  - https://ethanolrfa.org/file/807/Measured-extent-of-agricultural-expansion-depends-on-analysis-technique_Dunn-et-al_2016.pdf

[12] Pritsolas J. and R. Pearson. (2019). *Critical Review of Supporting Literature on Land Use Change in the EPA's Second Triennial Report to Congress.* https://ethanolrfa.org/wp-content/uploads/2019/07/SIUE-Review-of-Land-Use-Change-Literature-07-2019.pdf
[13] Pritsolas J. and R. Pearson. (2021). *A Cautionary Tale: A Recent Paper's Use of Research Based on the USDA Cropland Data Layer to Assess the Environmental Impacts of Claimed Cropland Expansion.* https://ethanolrfa.org/file/1833/SIUE-Rebuttal-on-USDA-CDL-Use.pdf

- ➢ https://ethanolrfa.org/file/1447/1373e8a3f091431ad5_g0m6ibjcr.pdf
- ➢ https://ethanolrfa.org/file/2001/LUC-Ethanol-Plant-Proximity-Crop-Prices_Li-et-al_2018-12.pdf

- Economists at the Renewable Fuels Association:
  - ➢ https://ethanolrfa.org/file/1932/USDA-Data-Show-Cropland-Reductions-in-Counties-with-Ethanol-Plants-from-1997-2012.pdf
  - ➢ https://ethanolrfa.org/media-and-news/category/news-releases/article/2015/04/university-of-wisconsin-study-based-on-shaky-foundation-of-faulty-data-and-conclusions
  - ➢ https://ethanolrfa.org/file/1814/Wisconsinethanolresponse11.15.pdf

Exhibit 4: Misclassification of Water as Grass/Pasture and Deciduous Forest in the 2017 CDL

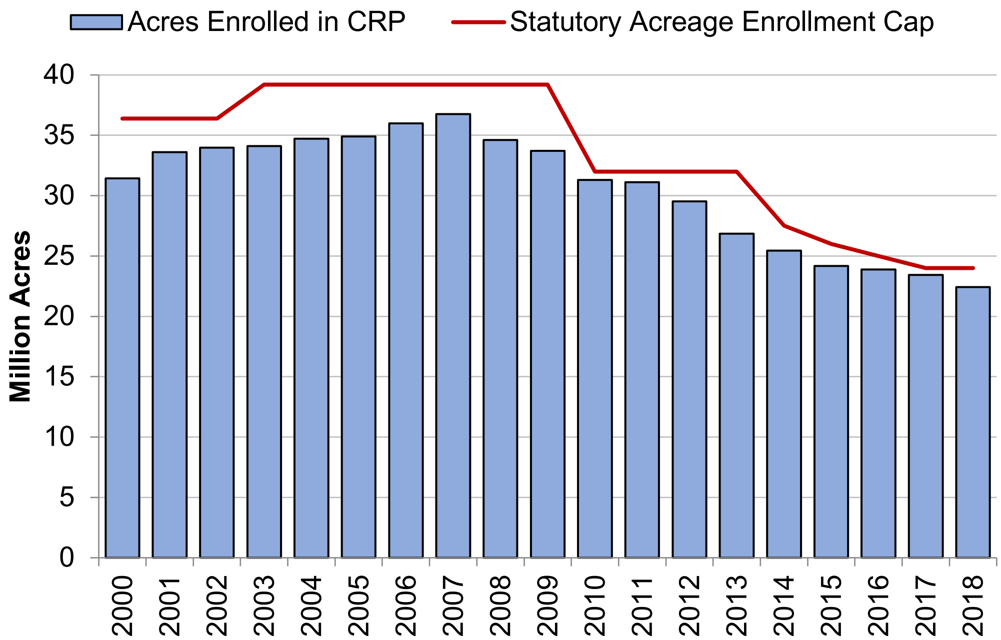


Source: SIUE GeoMARC

Additionally, any transitions into cropland from other (non-crop) land that have occurred since RFS2 was adopted are most likely explained by expired CRP land (which was previously used for agriculture) returning to cropland, not conversion of "native" grassland. Yet, from a carbon emissions standpoint, the Lark *et al.* methodology treats a transition of CRP ground back to cropland the same as a conversion of native grassland to cropland. In any case, it is incorrect to argue that the return of some former CRP land to crop production is solely due to the RFS. Rather, Congress repeatedly lowered the cap on the amount of land eligible for enrollment in CRP, dropping the limit from 39 mil. ac. in

2008 to 25 mil. ac. in 2016, the time period used in the Lark *et al.* study (Exhibit 5). Thus, it should be no surprise that some of the land no longer eligible for CRP enrollment returned to crop production.

Exhibit 5: Land in the Conservation Reserve Program



Source: USDA

The Attribution of Land Use Change to Ethanol Is Overly Simplistic

In addition to misidentifying LUC, Lark *et al.* simplistically attribute it to corn ethanol. In addition to using a "back-of-the-envelope" calculation to dismiss any potential role of other biofuels, they don't even mention urban development in the paper or SI. The American Farmland Trust estimates that 10.9 mil. ac. of agricultural land were developed or compromised from 2001 to 2016, including 4.1 mil. ac. of land converted to urban and highly developed land use and 6.8 mil. ac. converted to low-density residential land use.[14] Yet, Lark *et. al* didn't consider how such development results in pressure to convert other land to cropland. Only ethanol was in their sights.

Estimates of GHG Emissions Are Grossly Exaggerated

Lark *et al.* exaggerate LUC-related GHG emissions in two ways. First, they overstate the conversion of other land (primarily grassland) to cropland and hypothesize that additional cropland would have been abandoned if not for RFS2, and they then overestimate the GHG emissions that would be associated with these changes.

[14] American Farmland Trust. (2020). *Farms Under Threat: The State of the States.* https://farmlandinfo.org/statistics/farms-under-threat-the-state-of-the-states/

Lark *et al.* estimated that total GHG emissions associated with RFS-induced conversion to cropland were 320.4 Tg (million metric tons) CO2e or 181 Mg (metric tons) CO2e per ha. They also estimate that reduced rates of cropland retirement have reduced carbon sequestration that would have otherwise occurred by 77.3 Tg CO2e.

However, despite the fact that the Lark *et al.* modeling approach utilized carbon response functions (CRFs) that were developed by Poeplau *et al.* in a meta-analysis that encompassed 95 studies, the Lark *et al.* estimates of soil organic carbon (SOC) losses per ha. were considerably larger than those found by Poeplau *et al.*[15] In the paper that describes the methods that were used, Spawn *et al.* note, "When training the CRFs used in this analysis, Poeplau *et al* (2011) were careful to only consider data from sites where the natural landcover had not been previously disturbed by human activity. **By applying these CRFs to soils that may have been previously cultivated, our approach may over-estimate the sensitivity of some soils to conversion.**"

Additionally, the modeling efficiencies (EF) used by Poeplau *et al.* as a measure of the overall precision of the CRFs were distinctly worse for grassland-to-cropland conversion than for other types of land conversions. The grassland-to-cropland efficiency was 0.19 for the specific function used by Lark *et al.*, whereas it was 0.63 for cropland-to-grassland conversions. Poeplau *et al.* commented on this, saying, "Despite the highest number of sites among the investigated LUCs, the EF of the [specific CRF] (0.19) was low, which indicates that **the available explanatory variables cannot explain the variance of the data points sufficiently.**"

As discussed in a blog post by Alverson, the 181 Mg CO2e/ha estimated by Lark *et al.* "is equivalent to a 49.4 megagram SOC loss per hectare before SOC stocks reached a new equilibrium. … However, the Poeplau et al. global meta-analysis (cited by Lark) found that total SOC losses when grasslands were converted to croplands … were 36 megagrams SOC before reaching a new equilibrium."[16] He further points out that the "studies cited by Poeplau et al. represented grassland conversions to cropland that occurred decades ago when crop production practices and yields (intense tillage and low yields/carbon returns to soil from crop residues and roots) were a fraction of today. …

[15] Poeplau, C., Don, A., Vesterdal, L., Leifeld, J., Van Wesemael, B., Schumacher, J., & Gensior, A. (2011). Temporal Dynamics of Soil Organic Carbon After Land-Use Change in the Temperate Zone - Carbon Response Functions as a Model Approach. *Global Change Biology*. https://doi.org/10.1111/j.1365-2486.2011.02408.x

[16] Alverson, R. (2022, March 2). Ethanol Study Rebuttal – Correcting Misrepresentations with Data. *American Coalition for Ethanol.* https://ethanol.org/news/blog/2022/03/02/ethanol-study-rebuttal-%E2%80%93-correcting-misrepresentations-with-data/.

When grasslands are converted to cropland in recent years, SOC losses are minimal due to reduced tillage and higher yields/residue and root carbon additions."

Furthermore, as noted in the review by Taheripour *et al.*, "[T]he validation of the SOC emissions model used by Lark et al., which was published in a previous paper (Spawn et al. 2019), showed remarkably poor fit to measured SOC changes. … [T]he model tends to overestimate SOC emissions by about 20 MgC/ha at lower observed values and is poorly correlated with observations in general." They concluded, "**The apparent result of our re-analysis is that the SOC emissions model used by Lark et al. may overestimate soil carbon loss by a factor of two to eight** for lands with smaller changes in soil carbon … particularly those not managed using conventional tillage."

Lark *et al.* also hypothesized that an additional 354,000 ha. (875,000 ac.) of cropland would have been abandoned from 2008 to 2016 if not for higher crop prices attributed to the RFS. However, they "assumed that any abandoned land would have been retired to the CRP and sequestering carbon for the duration of its contract." This overstates the estimated emissions reduction per ha., as it is highly unlikely that all of the land would have returned to the CRP. There were 23.9 mil. ac. enrolled in the CRP in 2016, so the area that Lark et al. hypothesized would have been abandoned would have represented 78% of the remaining space under the statutory cap, and there would have been constraints related to program structure and eligibility. In announcing CRP enrollment in 2016, the USDA noted, "This was one of the most selective sign-up periods in CRP's 30-year history, with a record high Environmental Benefits Index cut-off and the lowest-percentage of applications accepted."[17]

A second way that Lark *et al.* exaggerate LUC-related GHG emissions is through the apparent double-counting of nitrous oxide (N20) emissions. Taheripour *et al.* determined, "**Lark et al. appeared to have double-counted the N2O emissions with fertilizer use for corn farming** by adding 9 gCO2e/MJ of ethanol to the remaining LCA results of corn ethanol and **overlooked that these were already included in the corn farming related emissions as is the case in most LCA calculations."** They noted that Lark *et al.* "used these rates to calculate additional nitrogen usage (synthetic fertilizer and animal manure) associated with the change in crop rotation or cropland area due to RFS2, followed by the modeling of the changes in N2O emissions from the additional fertilizer usage." However, the main lifecycle analysis models, such as GREET, already include N2O emissions associated with fertilizer usage in their estimates of the carbon intensity of ethanol.

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[17] U.S. Department of Agriculture. (2016, May 5). *USDA Announces Conservation Reserve Program Results.* https://www.usda.gov/media/press-releases/2016/05/05/usda-announces-conservation-reserve-program-results

<u>Additional Corn for Ethanol Production Has Come Primarily from Yield Increases and Secondarily from Crop Switching—Not from Acreage Expansion</u>

What Lark *et al.* miss is that as ethanol production has grown under the RFS program, the additional corn needed has come primarily from increased efficiency—not from expanding cropland. This can be seen in corn production and usage statistics for the period since 2008, the starting year for the analysis by Lark *et al.*

In 2008, the first year of the Lark *et al.* study period, U.S. farmers planted 86 mil. ac. of corn and harvested 78.6 mil. ac. (Exhibit 6). (As noted previously, legislation establishing RFS2 was enacted in 2007, and planted area fell by 7.5 mil. ac. between 2007 and 2008.) The average yield was 153.3 bu/ac, and production was 12.04 billion bu. In 2018, the record-high year for ethanol production, farmers planted 89.1 mil. ac. of corn, the average yield was 176.4 bu/ac, and production was 14.42 bil. bu.

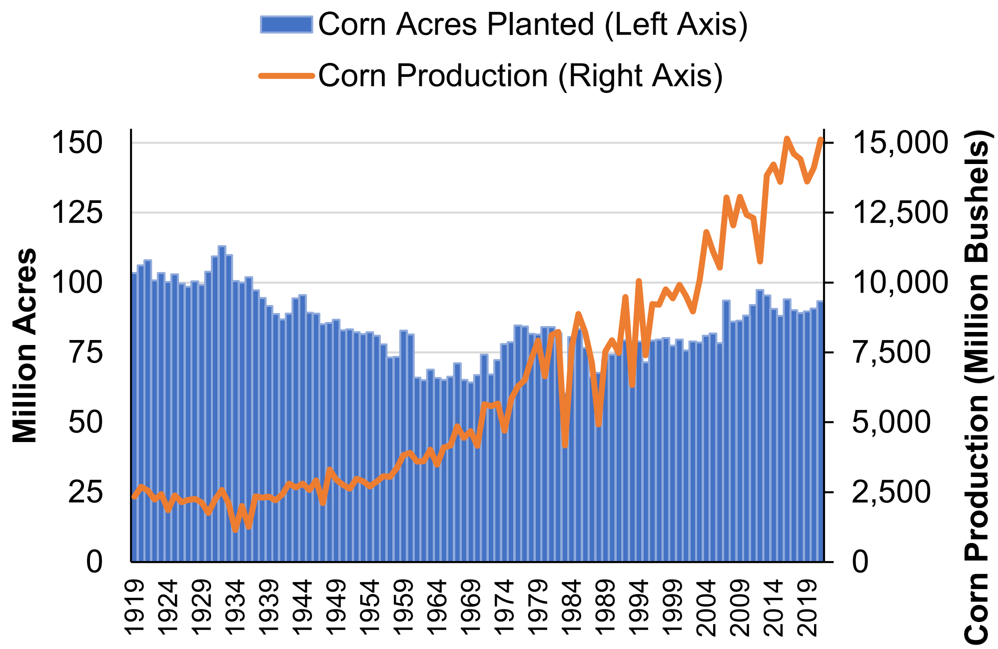
Exhibit 6: Corn and Ethanol Production and Associated Metrics

	2008	2018	Change	% Change
Total Agricultural Cropland (m. acres)[1]	402.0	381.0	-21.0	-5.1%
Corn Acres Planted (m. acres)[2]	86.0	89.1	3.1	3.6%
Corn Acres Harvested (m. acres)	78.6	81.3	2.7	3.4%
Yield per Acre (bu. per acre)	153.3	176.4	23.1	15.1%
Corn Production (m. bu.)	12,043	14,420	**2,377**	19.7%
Ethanol Production (m. gal.)[3]	9,309	16,091	6,782	72.9%
Corn Use for Ethanol & Co-products (m. bu.)[4]	3,325	5,646	**2,321**	69.8%

1. EPA
2. USDA
3. EIA
4. RFA based on average ethanol yield per bushel

Corn use for ethanol and co-products was 2.32 bil. bu. higher in 2018 than in 2008, which was slightly less than the 2.38 bil. bu. (20%) increase in corn production. Importantly, the area planted to corn expanded by less than 4%, and the additional acreage came from reductions in the area of other crops (like wheat and cotton), not from expanding cropland. Yield growth alone accounted for about 80% of the corn production increase between 2008 and 2018. This is consistent with the long-term trend of increased corn production on an acreage base that is stable or smaller (Exhibit 7).

Exhibit 7: U.S. Corn Planted Acreage and Production



Source: USDA

<u>The Lark Study's Estimate of Ethanol's GHG Emissions Is an Outlier</u>

The scientific consensus is that today's corn ethanol reduces GHG emissions by roughly half, on average, compared to gasoline. Using the GREET model, which is considered the gold standard for life cycle analysis, researchers from Argonne National Laboratory estimate that typical corn ethanol provides a 44% GHG savings compared to gasoline, including land use change emissions.[18] Similarly, researchers affiliated with Harvard University, MIT, and Tufts University concluded that corn ethanol offers an average GHG reduction of 46% versus gasoline.[19]

In addition, the California Air Resources Board (CARB) found that ethanol used in the state in 2020 reduced emissions by 41%, on average, compared to gasoline, including LUC. From 2011 to 2020, CARB data show that the use of ethanol cut GHG emissions from the California transportation sector by 27 million metric tons of CO_2e, more than any other fuel used to meet the state's Low Carbon Fuel Standard requirements.[20]

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[18] Lee, U., Kwon, H., Wu, M. and Wang, M. (2021). Retrospective Analysis of the U.S. Corn Ethanol Industry for 2005–2019: Implications for Greenhouse Gas Emission Reductions. *Biofuels, Bioprod. Bioref.* https://doi.org/10.1002/bbb.2225

[19] Scully, M. J., Norris, G. A., Alarcon Falconi, T. M., & MacIntosh, D. L. (2021). Carbon Intensity of Corn Ethanol in the United States: State of the Science. *Environmental Research Letters.* https://iopscience.iop.org/article/10.1088/1748-9326/abde08

[20] California Air Resources Board. *Low Carbon Fuel Standard Reporting Tool Quarterly Summaries.* https://ww2.arb.ca.gov/resources/documents/low-carbon-fuel-standard-reporting-tool-quarterly-summaries

Conclusion

As is apparent from this review, there are number of fundamental flaws and serious questions associated with the methods used by Lark *et al.* Their paper overtly contrasts their findings to those of Argonne and CARB. However, those mainstream analyses have been refined over a decade or more, and it is the work by Lark *et al.* that does not stand up once it is subjected to scrutiny.