Comments on

Ethanol's Broken Promise by the Environmental Working Group (May 2014)

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Summary

In their recent report,[1] the Environmental Working Group (EWG) posited that the life-cycle emissions of corn ethanol are greater than those of gasoline. EWG concluded that lowering the ethanol mandate under the Renewable Fuel Standard (RFS) by the United States Environmental Protection Agency (EPA) would reduce greenhouse gas (GHG) emissions by 3 million tons of CO_2 equivalents (CO_2e) in 2014.

The EWG report was organized into three sections. First, EWG maintained that a significant amount of grasslands and wetlands were converted to corn farming between 2008 and 2012. This conclusion was based on two EWG earlier reports[2,3] that used U.S. Department of Agriculture's (USDA's) Cropland Data Layer (CDL) and satellite data. EWG then applied the emission factors of land conversions from earlier work by Plevin et al.[4] to estimate total emissions associated with conversion of grasslands and wetlands to corn farms. The land areas EWG estimated to have been converted to wetlands and grasslands are high compared to earlier detailed studies[5,6] and modeling results.[7] Further, the emission factors they applied are high compared to those in other reports and studies that take into account important variations in initial and final land states. Most importantly, the emission factor EWG applied to wetland-to-corn agriculture transitions reflects emissions from conversion of peat- and carbon-rich tropical wetlands rather than from conversion of temperate wetlands found in the United States.[8] Conversion of U.S. temperate wetlands should be less carbon-intensive.

Second, EWG used EPA's land-use change (LUC) GHG emissions results for corn ethanol for year 2012 to calculate high life-cycle GHG emissions for corn ethanol. EPA's intent for including corn ethanol LUC GHG emissions results for 2012 and 2017, however, seems to have been mostly for sensitivity analyses because these emissions were not discussed in the RFS final rule or its Regulatory Impact Analysis (RIA). Further, 2012 emissions were not calculated for all biofuel pathways included in RFS. In their report, EWG picked the EPA 2012 GHG emissions for corn ethanol and applied them to the EPA-proposed reduced volume for corn

ethanol in 2014 to make the erroneous conclusion that the proposal resulted in 3 million tonnes of CO_2 reduction in 2014.

Finally, EWG stated that Argonne National Laboratory's Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET™) model uses unrealistic assumptions in estimating LUC associated with increased corn ethanol production. EWG confused parameters in GREET with those in an economic model, the Global Trade Analysis Project (GTAP). The particular parameter EWG discussed, the yield-price elasticity, in the GTAP model is supported by a recent analysis.[9]

In the discussion below, we address in detail each of these three areas and several other issues in the EWG report.

Lands Converted for Corn Farming through 2011 and Resulting LUC Emissions

For its analyses of LUC, EWG relied on the USDA CDL. Table 1 summarizes land areas converted to general or corn agriculture in EWG reports from 2012, 2013, and 2014. Notably, in developing these estimates, EWG used a pixel-by-pixel approach which they stated may overestimate their estimates of converted lands.[2] It is important to note that the CDL depends upon the National Land Cover Data (NLCD) that the U.S. Geological Survey (USGS) develops. The CDL uses the NLCD to help identify non-agricultural land covers such as grasslands and wetlands. The NLCD, however, is explicitly not designed to be used for pixel-by-pixel or localized analyses. Rather, as the USGS describes, the NLCD is best used for national- or regional-level analyses.[10] Additionally, in their 2013 report, EWG used the National Wetlands Inventory (NWI) to identify wetlands that had been converted. A key point, however, is that the NWI is based on aerial photos taken largely in the 1970s and 1980s, which have received only minor updates.[5] The LUC EWG reports could therefore be based on data that is decades old, reflecting wetland conversion over a much longer time horizon. A number of factors have driven wetlands conversion in the Prairie Pothole Region over the past several decades, one of which is increased prices and demand for corn.[5] More recent NWI data as well as efforts to ground-truth these data would improve estimates of wetland conversion and allow these conversions to be associated with a particular time period.

Table 1. Land areas (million acres) converted to agriculture in three different EWG reports

EWG report year	USDA CDL data	Grasslands, shrublands, and wetlands converted		Wetland and wetland buffers converted to row crops	Highly erodible lands converted to row crops	Wetlands converted to corn	Grasslands and shrublands converted to corn
		Total	To corn				
2012[2]	2008-2011	23.68	8.43				
2013[3]	2008-2012			1.9[a]	5.3		
2014[1]	No original analysis reported					0.306[b]	8.1[c]

[a] Total wetland area converted. EWG reports that, in hotspot counties, 228,000 acres of converted lands were reverted to wetlands. The area of reverted wetlands in counties that EWG did not classify as hotspots was not reported. The net conversion is then at most 1.67 million acres.

[b] This value was not reported in previous EWG reports, and the CDL data used to obtain it is not specified. The timeframe given for the conversion of these wetlands to corn agriculture is 2008 to 2012.

[c] This value seems to have been calculated as the difference between the 8.43 million acres of grasslands, shrublands, and wetlands converted to corn as EWG reported in 2012 and the 0.306 million acres of wetlands converted to corn as EWG reported in 2014 with no supporting information about the data source. The timeframe for the 8.43-million-acre conversion is 2008-2011, which does not match the reported timeframe for the wetland conversion, 2008 to 2012.

The EWG results in Table 1 can be evaluated and compared to other analyses and data sources. For example, Johnston[5] concluded in a comprehensive study that wetland conversion to croplands in the Prairie Pothole Region of North and South Dakota amounted to 332,200 acres between 1980 and 2011, or 153,600 acres between 2001 and 2011. In 2013, EWG wrote that a similar region, the two Dakotas and Minnesota, accounted for about 40% of their estimated wetland conversion. It is therefore notable that EWG's estimated area of wetland conversion <u>between 2008 and 2012</u>, 122,400 (306,000 × 40%) acres to corn, is similar to Johnston's result for a similar region <u>over a quarter century</u>. Overall, EWG may have overestimated wetland conversion, especially for the conversion of wetlands to corn farms. EWG's inclusion of wetland buffers in estimates of converted wetland areas and the pixel-by-pixel approach they took could account for their seeming overestimation of converted wetland areas. If EWG released results for wetlands converted in the Dakotas alone, that would facilitate direct comparison with Johnston and validation of EWG's results.

Wright and Wimberly[6] authored another study that serves as a point of comparison to EWG's results. These authors estimated grassland conversion to corn and soybean farms between 2006 and 2011 in the six-state Western Corn Belt. They estimated a net loss of grassland to corn/soybean farms of 1.3 million acres in the region between 2006 and 2011. This is far less than the 8.1 million acres of grass/shrub lands converted to corn farms EWG estimated.[1] Admittedly, the six-state Western Corn Belt is a smaller land area than EWG considered and does not cover all of the regions in the United States with the potential for conversion to corn farming. But the Belt has been the major region for corn farming expansion, as acknowledged by Wright and Wimberly[6] and EWG.[2,3] Furthermore, Wright and Wimberly sought to avoid errors in the NLCD that could exist between different categories of grass-dominated land cover and used a broad definition of grassland that included native grassland, grass pasture, grass hay, fallow/idle cropland, and pasture/hay. Their estimate of grassland conversion may therefore be too high. Lastly, while Wright and Wimberly estimated conversion to corn and soybeans, EWG estimated conversion only to corn.

Other data from, for example, the USDA National Agricultural Statistics Service Quick Stats database[11] can also serve as a comparison. Figure 1 plots USDA data for U.S. farm acres for different crops including corn, soybeans, and wheat. The figure shows that, while corn acreage has increased in parallel with the build-up of the corn ethanol industry between 2004 and 2013, total principal crop acreage has remained fairly constant and constitutes 311 million acres in 2013. These observed trends are consistent with Taheripour and Tyner,[12] who analyzed land cover data from the Food and Agriculture Organization of the United Nations. These authors, in line with the trend in Figure 1, did observe crop shifting (e.g., wheat fields converted to corn agriculture) in the United States in this time period as a key mechanism for additional corn production. Another mechanism is likely the conversion of grasslands, wetlands, and other lands. In particular, the USDA data in Figure 1 show that, between 2008 and 2012, corn acreage increased by 11.2 million acres (together with 1.48 million acres for soybeans), while other crop acreages decreased: wheat by 7.8 million acres, hay by 3.8 million acres, sorghum by 2 million acres, barley by 609,000 acres, and oats by 487,000 acres.

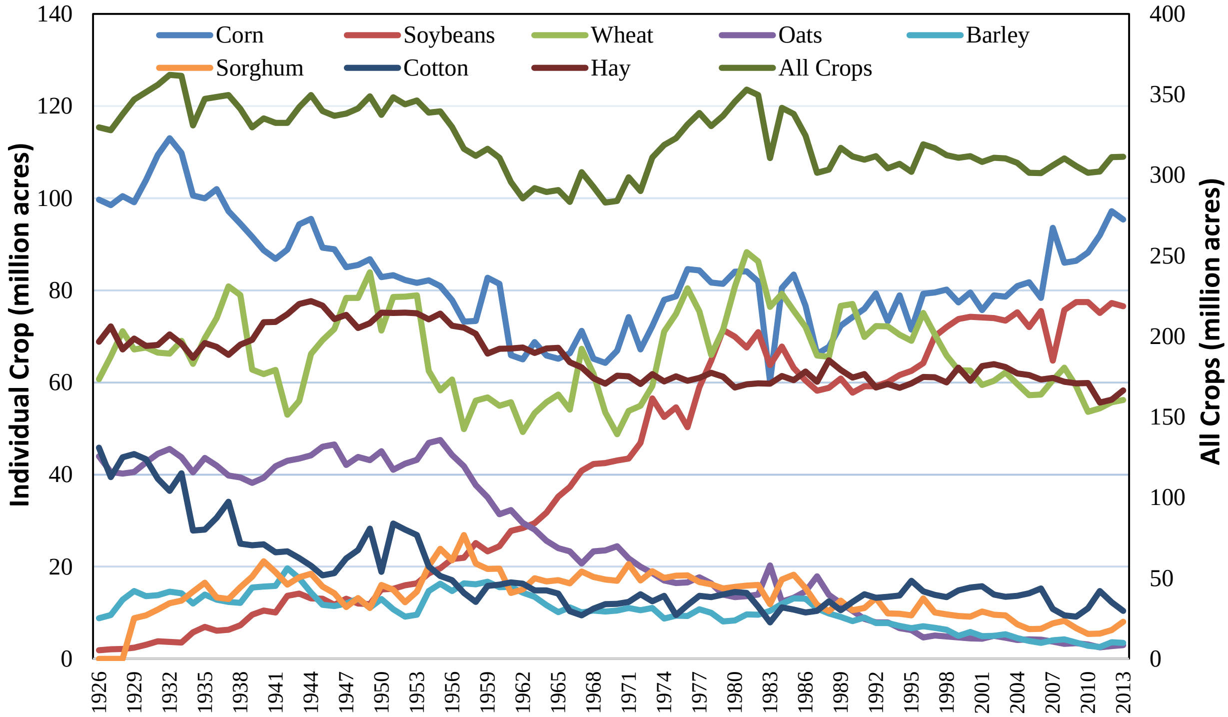

Figure 1. Annual acreage of principal crops in the United States[11]

The above observed increased acres for corn farming are driven by the significant increase in corn prices since 2005. However, several key factors cause corn price increases, including U.S. corn ethanol production, recent grain demand increases, and dietary changes in emerging economies.

Another point of comparison to the EWG results are results from economic models, which can be used to estimate corn ethanol-induced LUC. Using Purdue University's Global Trade Analysis Project (GTAP) model for this purpose predicted a price-induced land conversion of 5.3 million acres in the United States to meet an increase in corn ethanol production from its 2004 level (3.41 billion gallons) to 15 billion gallons.[7] These 5.3 million acres amount to 1.7% of the 2013 principal cropland of 311 million acres. The GTAP-estimated 5.3 million newly converted acres to grow corn for ethanol production is smaller than the EWG-estimated conversion of 8.4 million acres of wetlands, grasslands, and shrublands to corn farms.

Thus, EWG's estimate of 306,000 acres of wetlands and 8.1 million acres of grasslands and shrublands converted to corn seems too high when compared with estimates in other studies and data sources. Better statistics, updated remote sensing data, and ground-truthing of results are necessary so that land conversions can be accurately assessed. This is especially important if agencies desire to prevent adverse land conversions for biofuel production.

Another point of consideration is the emission factors EWG selected for use in their 2014 analysis. These emission factors are from Plevin et al.[4] as published in 2010. However, Plevin et al. revised land conversion emission factors significantly in 2014.[13] Table 2 reproduces the EWG emission factors and provides alternative emission factors from both GREET[14,15] and Searchinger et al.[8] as well as the recent grassland-to-cropland emission factors from Plevin et al. The alternative wetland-to-cropland emission factors are especially important because the wetland conversion emission factors that EWG adopted from Plevin et al.[4] were based on an overview of studies that included only tropical wetlands,[8,16,17] which are irrelevant to temperate climate wetland conversion in the United States as estimated in the EWG report. As Searchinger et al.[8] pointed out on the basis of an Intergovernmental Panel on Climate Change (IPCC) report,[18] emissions from conversion of tropical wetlands are significantly higher than those from conversion of wetlands elsewhere in the world. Searchinger et al. provided an emission factor of 460 Mg CO_2e/acre for tropical wetlands in Southeast Asia (see Table 2). This emission factor is less than the maximum wetland conversion emission factor value EWG used. Searchinger et al. presented a wetland conversion emission factor of 300 Mg CO_2e/acre for wetlands worldwide. This emission factor is indeed below the minimum value EWG used. With the alternative wetlands emission factors in place of the EWG ones, total average emissions from wetland conversion drop by more than half.

One complicating factor regarding the conversion of wetlands to agriculture is that upon conversion, CH_4 emissions from wetlands, which can be significant,[19] will diminish. Analyses focusing on climate change impacts of wetland conversions should consider both carbon emissions and the elimination of CH_4 emissions from wetland conversion. The latter could play an important role in net GHG effects, if the levels of carbon-rich peat in the converted wetlands are low. Overall, carbon-rich peatlands tend to be concentrated outside of the United States.[20]

Another concern about the emission factors EWG used is that the final land state is general cropland rather than specifically corn agriculture. It is well understood that spatially specific factors such as precipitation, soil type, and land use history influence CO_2 emissions upon land transitions. But the emission factors used by EWG are very general and do not consider these factors. Taking these variables into account, we have developed grassland-to-corn emission factors at a U.S. county level using the CENTURY model over a 30-year time horizon.[15,21] The range of grassland-to-corn agriculture emission factors we calculated are presented in Table 2 (labeled GREET values). They are on average nearly 70% less than the emission factors EWG used. Furthermore, both the recent Plevin et al.[13] and GREET emission factors are for an initial land state of grasslands, whereas EWG characterized the 8.1 million converted acres as grasslands and shrublands. Shrublands could have different carbon stocks than grasslands (e.g., potentially higher above ground carbon but potentially lower soil carbon). EWG did not provide a split between these two land types to improve estimates of GHG emissions from this land transition.

In conclusion, EWG seemingly overestimated LUC GHG emissions from lands converted to corn farming between 2008 and 2012 because of two factors. First, based on an analysis of the methodology EWG used and a comparison of their results to those in the literature, from models, and from other data sets, EWG appears to have overestimated the amount of land converted for corn farming between 2008 and 2012. Second, EWG used emission factors that appear too high.

The carbon stocks of different land types significantly affect LUC GHG emissions for biofuel. Models such as CENTURY provide insight into soil organic carbon (SOC) changes from different land conversions. However, more real-world SOC data can help improve modeled estimates of SOC changes upon land transitions.

Table 2. Comparison of emission factors for land conversions to corn farming and total emissions

Land category	Emission factor (tonne CO_2e/acre)		Years of land conversion in EWG report	Annual emissions (million tonne CO_2e/acre/yr)	
	Min.	Max.		Min.	Max.
Grasslands					
EWG[1]	30	81	4	60	162
GREET + Searchinger et al.[a]	–5.0	40	4	–10	80
Plevin et al.[13]	6.5	50	4	13	100
Wetlands					
EWG[1]	405	1,215	5	25	74
Searchinger et al.[8]	300 (worldwide)	460 (tropical moist forest of S.E. Asia)	5	18	28

[a] Emissions take into account loss of vegetation based on Searchinger et al.'s value of 15 tonnes of CO_2e/acre. SOC emissions are based on a 30-year time horizon for grassland-to-corn transitions for which conventional tillage was assumed and no stover was removed as a biofuel feedstock.[14,15,21]

EWG's Use of EPA's 2012 LUC GHG Emissions Results for Corn Ethanol

In their report, EWG used life-cycle GHG results that EPA reported in their RIA that accompanied the RFS final rule. EPA provided in the docket accompanying the RIA (docket EPA-HQ-OAR-2005-0161-3173) a spreadsheet that calculates GHG emissions from corn ethanol plants that use different process fuels and from LUC over a 30-year period beginning in 2012, 2017, or 2022. Similar spreadsheets exist for some other fuel pathways included in the RIA. EWG's report included EPA life-cycle GHG emissions results for corn ethanol using each of the three possible LUC results. EPA, in the RIA and in the final rule itself, however, used only the 2022 results and did not explain or mention the 2012 and 2017 results that were presented only in the spreadsheet. A memo in the docket with the subject, "Fuel-Specific

Lifecycle Greenhouse Gas Emissions Results," described the 2022 base year as the case used in the calculation of life-cycle GHG emissions for the regulation. This memo indicated that only some of the spreadsheets for the different fuel pathways in the RIA include LUC GHG emissions results for base years 2012 and 2017. For example, the spreadsheets for corn stover ethanol and switchgrass ethanol did not include results for 2012.

An examination of GHG emissions results from the corn ethanol spreadsheet with the three different base years reveals that EPA's predicted GHG emissions from corn ethanol plants would decline with time (Figure 2), which is a logical conclusion, given expected efficiency improvements and other factors.[22] The trend in international LUC emissions, however, is puzzling. The figure shows that LUC GHG emissions from international land conversions decrease with increasing base year, which is neither logical nor intuitive. As corn ethanol production volume goes up from 2012 to 2017 and stabilizes at the 2022 production level, one may expect that additional marginal land with less productivity will be brought into farming, resulting in increased LUC GHG emissions per unit of fuel produced. Thus, it seems illogical that the LUC emission factor in 2012 is more than double the 2022 emission factor. Because EPA did not discuss LUC results with base years 2012 and 2017 in the RIA or regulation, we interpret that the results for base year 2022 are the most reliable. We further hypothesize that EPA included 2012 and 2017 base year LUC modeling results in some of the docket materials to document sensitivity analyses they conducted while developing the LUC modeling technique used in the final rule.

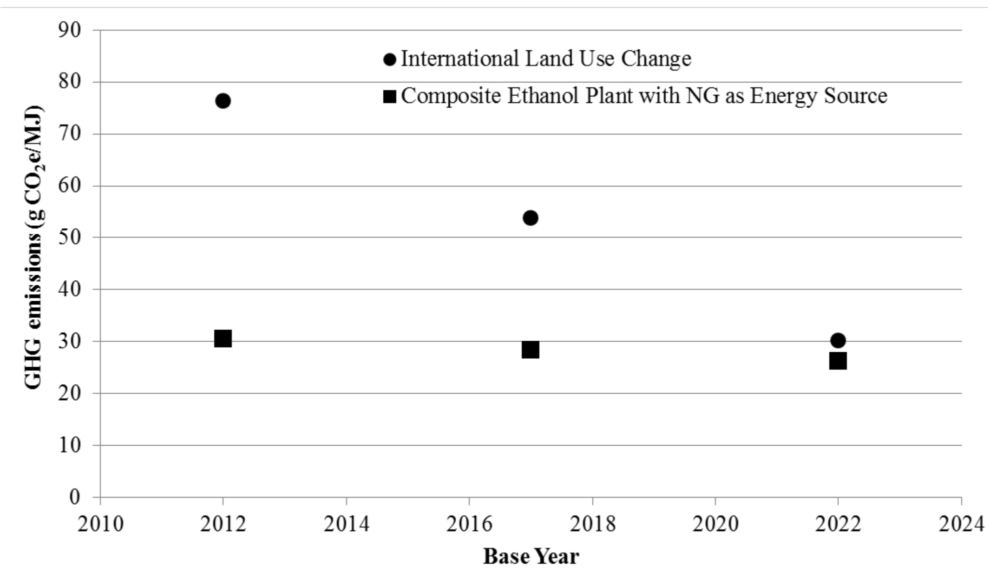

Figure 2. International LUC and ethanol plant GHG emissions for different base years in the RFS RIA (The baseline composite ethanol plant that uses natural gas (NG) as an energy source represents a weighted average of dry mill plants producing 63% of dry distillers' grains solubles (DGS) and 37% of wet DGS.)

Without delving into details in EPA's RIA and final rule, it appears that EWG misunderstood EPA's GHG emissions for years 2012 and 2017. The absence of an explanation from EPA in both documents certainly contributed to this misunderstanding. In the end, EWG picked the EPA 2012 GHG emissions for corn ethanol and applied them to the EPA's proposed reduced volume for corn ethanol in 2014 to make the erroneous conclusion that the proposal resulted in 3 million tonnes of CO_2 reduction in 2014.

Since 2009, when EPA conducted corn ethanol LUC GHG modeling with the FAPRI and FASOM models, significant efforts have been made to improve economic models and soil carbon models to better estimate biofuel LUC GHG emissions. EPA and other federal agencies should consider updating RFS LUC modeling so that up-to-date LUC results can be used for biofuel policy making.

EWG Critique of LUC Modeling Assumptions in GREET and GTAP Models

EWG raised a concern about the yield price elasticity assumption used in economic models such as GTAP to estimate LUC stemming from biofuels production. Contrary to EWG's statement that the GREET model conducts LUC modeling, GREET incorporates LUC results from the GTAP model, a computable general equilibrium (CGE) model. The GTAP model contains many parameters related to the response of the agricultural sector and interlinked sectors to an increase in biofuel production, including the yield-price elasticity, or YDEL, as it is called in the GTAP code. EWG stated that the YDEL value of 0.25 used in GTAP is too high. That is, EWG posited that a YDEL of 0.25 overestimates yield increases upon rising corn prices. The organization maintained that this high YDEL value would overpredict corn yields and underestimate LUC and biofuel LUC GHG emissions.

YDEL needs to be understood in an appropriate context. The underlying rationale of the YDEL parameter is that over the medium- to long-term (the time horizon of GTAP), the agricultural sector will respond to increases in net returns to crops with appropriate investments to improve crop yields. These investments include off-farm investments as well as on-farm investments. In fact, a major portion of investments may occur off-farm, including those by seed companies to produce higher yielding seeds, by chemical companies to produce better herbicides/pesticides, by farm equipment companies to produce more efficient machinery for cultivation and harvest, and by farmers to improve drainage and other soil properties, among other productivity enhancing investments. In other words, YDEL attempts to capture responses throughout the agricultural sector to higher returns in given crops. YDEL does not measure changes over one crop year. In fact, any YDEL estimate done over one year would be totally inappropriate for GTAP and other economic models.

Mathematically, YDEL is the *percentage change in intensive yield* (yield at existing croplands with intensive activities) over the percentage changes in *relative price of a crop over input* *prices*. In other words, it is the intensive yield change with respect to change in variable returns of a crop. A YDEL value of 0.25 means that the change of 10% in variable returns of a crop will result in a change of 2.5% in intensive yield for the crop. This value was estimated by Keeney and Hertel.[23]

A recent analysis provides evidence that a YDEL value of 0.25 is reasonable. Using econometric models with various assumptions regarding the representation of price changes and using data from the 1996-2010 period, Goodwin et al.[9] estimated a range of interseasonal and intraseasonal price-yield elasticities from 0.15 to 0.46. They find empirical support for a corn price-yield elasticity of 0.25 in the major corn producing states. An important component of this research effort involved a "focus group" type of meeting with growers and seed dealers. Producers and those with direct interest in the timing of production were queried about the timing of their input decisions. The focus group revealed the complexity of grower decisions in response to price signals, including actions that will likely impact their realized yield after planting. It is notable that nitrogen application occurs in March and April and side dressing and the application of chemical inputs continue through June. It is also relevant to note that longer-run production decisions, such as the purchase of seeds and fertilizer, may occur in the fall months that preceded planting.

Besides intensive yield changes, yields can be changed by extending croplands to new lands (extensive yield changes). As noted in Hertel et al.,[24] there are *two* important sources that affect the extensive margin of yields. The first source is due to *shifting among crops*. For example, shifting from a corn-soybean rotation to a corn-corn rotation could affect yield. The second source of change in extensive yield is due to land conversion from less productive forest or pasture acres to croplands. In the first case, if there is a corn ethanol shock applied to GTAP, more corn will be demanded, and there likely will be both crop switching and land cover changes to accommodate the higher demand for corn. With crop switching, there will be more acres of corn and fewer acres of other lower yielding crops. In the second case, land cover changes from pasture or forest typically tend to reduce yields because new land could be less productive than existing agricultural lands. Because GTAP is a CGE model, yields can also be influenced by a myriad of other changes such as changes in variable costs. In summary, yields can be and are affected by many factors working in GTAP, including, but not limited to, YDEL.

Additional Comments on the EWG Report

We discuss below several additional issues in the EWG report. First, EWG mistakenly stated that EPA projected that corn ethanol plants would be biomass-powered in 2022 and that this is one reason behind EPA's GHG reduction for corn ethanol of 21% in 2022. To the contrary, EPA derived this GHG emission reduction based on a dry mill ethanol plant with natural gas as the energy source. This baseline plant dries 63% of the DGS produced and fractionates the corn oil. EPA examined sensitivity cases with coal and biomass as energy sources. When coal was the energy source, GHG emissions for corn ethanol exceeded those of gasoline by 1%. Biomass-powered dry mill ethanol plants were shown with a reduction of 38%.

Second, EWG discussed the effect of a yield ceiling on the diminishing ability of improvements in corn yield to reduce LUC. They further stated that GREET assumes that rising demand for corn would be met largely through increased corn yields. To reiterate, GREET does not model LUC. It relies on GTAP results in its calculation of LUC GHG emissions. GTAP uses historical data on corn yields to project yields into the future by considering corn price change together with YDEL (see discussion above). In fact, a significant amount of additional corn for ethanol production, as simulated in GTAP, was from the 5.3 million acres that were converted to corn agriculture from grasslands and forest lands in response to increased corn ethanol demand.[7,25] While biotechnology holds strong promise to continue the uptrend in corn yields over time,[26] EWG correctly pointed out that yield limitations due to irrigation water availability and other factors should be considered in LUC modeling.[27] Adapting LUC modeling to reflect this physical limitation and other factors in CGE models since the California Air Resources Board and EPA produced their modeling results in support of the Low Carbon Fuel Standard and RFS2, respectively, should help these agencies update LUC results.[28]

Additionally, EWG cited the work of Crutzen et al.[29] to posit that fertilizer-derived N_2O emissions could be up to five times greater than many analyses report. The 3-5% N-to-N_2O conversion rate Crutzen et al. derived was based on a global N_2O balance. Such a top-down approach is reasonable when applied as a check and verification of results derived from a bottom-up approach (e.g., IPCC method).[30] Data for the top-down approach, however, need to be closely examined for generating reliable N_2O conversion factors for specific applications such as N_2O conversion factors in fertilized soils. Crutzen et al. combined a 2001 global N_2O emissions balance and nitrogen inputs from a separate 2004 study in deriving N_2O conversion factors. Additionally, their estimate did not account for agricultural subsystems, such as crop farming, animal waste management, and crop residue burning, all of which need to be taken into account for generating N_2O conversion rates for nitrogen inputs into crop farming.[31] Although Crutzen et al. subtracted industrial N_2O emissions from an estimate of aggregate N_2O emissions, their approach could overestimate N_2O conversion rates from nitrogen inputs into crop farming systems.

In conclusion, EWG's estimated LUC and resulting GHG emissions between 2008 and 2011 appear too high, considering other LUC estimates and data sources and EWG's use of high LUC emission factors. Furthermore, EWG's use of EPA's LUC GHG emissions for base year 2012 seems to be irreconcilable with EPA's intent and context for reporting 2012 base year emissions. Finally, EWG's critique of the YDEL value of 0.25 used in GTAP may not be supported by recent analyses.

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