RESPONSE TO NEW FUELS ALLIANCE AND DOE ANALYSTS CRITICISMS OF *SCIENCE* STUDIES OF GREENHOUSE GASES AND BIOFUELS

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(February 26, 2008)

The New Fuels Alliance (NFA) and two biofuel analysts at the Department of Energy (Michael Wang and Zia Haq) have issued press releases or open letters criticizing new studies in *Science* magazine incorporating land use change into the greenhouse gas calculations of biofuels. I was lead author of the study, "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Land Use Change." While further research could certainly refine our study, these criticisms are off the mark.

SUMMARY

Misrepresentations of the Study

1. Claim: The study assumes no increases in crop yields. Answer: The study assumes that yields both in the U.S. and the rest of the world will continue to increase at present trends based on detailed analysis.

2. Claim: The study assumes that all new cropland conversion will use pristine lands, a worst case scenario. Answer: The study calculates that new cropland conversion will come from a wide variety of land uses, many far from pristine, including many re-growing forests and even many existing croplands that would revert to grassland or forest but for increased biofuel use. More generally, the study incorporates many beneficial assumptions for biofuels, including an assumption that converting grassland now used for livestock forage will not trigger any deforestation to replace that forage, and that no new croplands will use wetlands except in Southeast Asia. Overall, there are at least as many reasons to believe estimated emissions from land use change are too low as too high.

3. Claim: The analysis is irrelevant because it calculates emissions from a far higher use of corn-ethanol that mandated under the most recent Energy Bill. Answer: The study calculates a rate of emissions from each gallon of corn ethanol, not a total level of emissions. This rate varies somewhat but tells the same story at any level of ethanol just as automobile mileage does not greatly change between a car's first 25,000 miles and the next. Prices could also push corn ethanol well above the mandated minimum level.

4. Claim: The study incorrectly predicts that even at today's corn ethanol level, U.S. corn exports would decline by 62% compared to the past. Answer: The study actually predicts that corn experts would decline by 62% only at 30 billion gallons of corn ethanol, four times today's ethanol level, and not in comparison to existing exports but only in comparison to what they would otherwise by in 2016.

Economic and Related Errors:

5. Claim: Because U.S. corn exports have slightly increased this year, corn ethanol is not having any impact on exports or world grain production. Answer: To supply ethanol, the U.S. planted 20% more corn acres this year than in 2004, switching acres from soybeans, wheat and cotton. Ethanol had major impacts on exports through reductions in soybeans, and even so, corn and soybean exports this year relied on large reductions in domestic stocks, which can only continue temporarily.

6. Claim: The study gave insufficient credit to distillers' grains, a feed by-product of corn ethanol, because the study does not credit their increased protein content. Answer: Distillers grains have some proteins but not all, and their use by livestock is complex and varies by livestock type. Focusing only on energy or protein would be simplistic, and the study used an elaborate analysis of livestock uses that is also consistent with USDA economic analysis.

7. Claim: The study is one-sided because it omits land use emissions from oil production. Answer: They are likely to be very small per gallon of gasoline.

Logical Errors:

8. Claims: The study is wrong because many factors influence deforestation, because some activities abroad may reduce deforestation rates and because much larger yield increases are possible and could make more land available for biofuels. Answer: It is true that many factors influence deforestation, and dramatic increases in yields or new government policies could reduce the world's deforestation overall. But these factors would change the world with or without biofuels – in other words, they would change the baseline -- and it is not proper to attribute to biofuels either the benefits or harms from independent factors. Each acre of biofuels that uses productive cropland still leads to more deforestation and related land use changes.

9. Claim: By incorporating land use change, the study arbitrarily incorporates just one of many possible additional factors that influence greenhouse gas effects of biofuels. Answer: Prior studies all assign to biofuels the benefit of using land to take carbon out of the atmosphere by growing feedstocks, but fail to acknowledge that using land in this way has carbon costs because it sacrifices other carbon benefits of land. Our study simply rounds out an otherwise one-sided accounting of the use of land.

True Statements Consistent with Study

Claims: Different feedstocks using different lands and different refining efficiency could improve greenhouse gas effects. Answer: True, as the paper states, but corn ethanol would remain a net source of greenhouse gas emissions over 30 years even with widely varying assumptions. The most promising alternatives would use waste products or possibly generate high volumes of biomass on unproductive lands.

RESPONSES TO NEW FUELS ALLIANCE

1. The Greenhouse Gas Emissions Per Gallon of Ethanol Remain Comparable at Any Level of Ethanol.

NFA claims that the indirect land use study has no real significance for existing, or contemplated, corn-based ethanol because the study is based on an analysis of an expansion in ethanol from 15 to 30 billion gallons (56 to 111 billion liters), which is much larger than that now contemplated by the new U.S. Energy Bill.

This criticism could be valid if the study focused on the total increase in emissions from expected increases in corn-based ethanol. Obviously, total emissions would be wrong if based on an excessive amount of ethanol. But the study focuses on the rate of emissions for ethanol, in other words, the level of greenhouse gas emissions per gallon (unit of energy) of ethanol. A car that gets 25 miles to the gallon is likely to get roughly the same mileage when driven the first 25,000 miles as the next 25,000 miles. Similarly, the rate of emissions from land-use change will be comparable.

The NFA's criticism could also be valid if the agricultural model used by the study calculated that more land use change would occur per gallon of ethanol at higher levels of ethanol than at lower levels. In that event, the study would attribute to today's ethanol the greater land-use change likely with tomorrow's ethanol. (Analogously, an analysis might calculate than an older car burns more gas as it drives more miles than a younger car.) But the agricultural analysis used for our study does no such thing. The results vary somewhat at different levels of ethanol but tell a comparable story. For example, the study explains that at 22 billion gallons of ethanol, emissions from land use change per gallon of ethanol would be 10% less.

We also examined impacts in 2011 that would result from increases in corn ethanol from 14,830 billion gallons to 16,631 billion gallons. We analyzed this increase because it was the first time baseline conditions and higher corn ethanol scenarios differed by more than 1 billion gallons in analyses performed by CARD based on different oil prices. In this scenario, land use change emissions per gallon were more than 30% higher than in the higher ethanol scenario we analyzed for the study. In this lower ethanol scenario, proportionately more of the increase in U.S. corn acres occurs through reduced plantings of wheat rather than soybeans. When countries replace wheat acres, they need more proportionately more land than when they replace U.S. soybean acres because wheat acres in many foreign countries are proportionately lower than U.S. yields although the acres converted tend to be somewhat less carbon rich. This result shows that, under our model, different predictions about the kinds of crop responses to increased ethanol will have somewhat different results, but they will not significantly change the overall picture.

Why did the study analyze an increase from 15 to 30 billion gallons by 2016? This analysis, completed before Congress passed the 2007 Energy Independence and Security Act, was based on projections that corn ethanol would rise to 30 billion gallons if the price of gasoline remains high, existing tax credits remain in place, and cars are adjusted to be able to burn more than 10% ethanol. Contrary to common understanding, while the Energy Bill has the practical effect of requiring close to 15 billion gallons of corn ethanol, it does not prohibit corn ethanol above 15 billion gallons. The new law might discourage those increases in corn ethanol because it requires that gasoline distributors purchase many other biofuels, and distributors might resist purchasing both them and even more corn ethanol. But if gasoline prices remain high and existing tax credits remain in effect, corn ethanol could still be cheaper than gasoline and could therefore rise well above 15 billion gallons per year.

It is hard to determine exactly what level of corn ethanol to analyze, and results will also vary depending on increased demands for other biofuels that also use cropland. Even so, the basic outcome will not significantly vary.

2. The Land Use Change Emissions for Fossil Fuels Are Very Small By Comparison with Biofuels

The NFA also criticizes the studies on the grounds that they do not calculate the emissions from land-use change for fossil fuels and therefore are unfair. However, the amount of land used to produce a gallon of gasoline is extremely small — according to some energy experts we have quickly consulted, it is less than 1% off the amount of land used to produce a gallon-equivalent of ethanol. And many oil-drilling lands, such as desert, support little carbon. Much of the world's oil is either produced in deserts or offshore or on land that still remains in productive agricultural use. Because the effect of oil production on emissions from land use change is small, it is reasonable to omit it. Research into the land use implications of fossil fuel are worthwhile but not everything can be included in a single research article.

3. The Study is Far From a Worst Case Scenario. Actual Emissions Could be Lower But Are More Likely Higher.

The NFA claims for a variety of reasons that the study sets out a worst-case scenario. In addition to other reasons for this claim discussed above, each of the other reasons offered fails to accurately present the basic workings of the study.

First, the NFA claims that the study simply assumes that each acre diverted to ethanol results in one acre planted abroad. In fact, the study *calculates*, based on a sophisticated agricultural model, that worldwide only around 84% of an acre is planted to replace each acre diverted to grow corn for ethanol. Moreover, far less than 84% of the diverted grain is replaced. The number of newly planted acres remains that high only because foreign agricultural yields generally cannot match those in the United States

The NFA implies that actual demand elasticities for grains should be higher than calculated by the model. In simple language, that means people would reduce their food consumption as crop prices rise even more than our study projects. Bigger reductions in food consumption would reduce the magnitude of adverse greenhouse gas effects, but at the expense of poorer nutrition for the world's poor. For a good discussion of this issue, see the May/June 2007 article in *Foreign Affairs* by C. Ford Runge and Ben Senauer, "How Biofuels Could Starve the Poor."

The NFA also claims that the study assumes all newly planted land converts pristine ecosystems. To the contrary, the study calculates that many of the "new" cropland acres are actually acres of existing cropland in Europe and the former Soviet Union that would otherwise leave crop production. The study accordingly assumes that keeping these lands in crop production causes no immediate release of carbon at all. But by keeping these lands in crop production, biofuel demand keeps those lands from reverting to grassland and forest, which would sequester carbon over 30 years. For this reason, there is a large opportunity cost to biofuel production, even if the lands they cause to be in crop production are far from pristine. The study similarly concludes that many of the forests converted to crop production because of biofuels are non-pristine young forests. Their carbon losses are also lower, but converting them also foregoes the carbon benefits of their continued growth. And overall, the study calculates a broad mix of different kinds of habitats converted to cropland, with very different carbon effects, reflecting the real experience in the 1990s. In short, the NFA misunderstands the study's findings and also fails to realize that converting non-pristine lands can also have high carbon costs.

The NFA also criticizes the study for assuming that biofuels will not be produced on marginal lands, and it is true that the study's analysis of corn ethanol assumes that it will be produced on land of average productivity. If corn for ethanol were produced on lands of lower productivity, each acre diverted would generate less land use change. But each acre would also produce less ethanol, and the emissions per gallon would remain comparable. As a whole, because rational farmers tend to put the most productive land into use first, new lands are likely to be less productive than today' average, which played a role in our study. (As a separate matter, our paper points out that if biomass can be generated productively on marginal lands, there could be opportunities for greenhouse gas benefits.)

Although these criticisms are invalid, any estimates of the kind in our study cannot be precise, and could be either high or low. In our view, our estimate could be too high because farmers could be more successful in boosting yields in specific response to higher ethanol-related prices than we assume. These effects are extremely hard to study. However, the study also made many assumptions that probably make its result too low.

i) The study assumed no conversion of wetlands outside of Southeast Asia. Many of the world's best croplands are former wetlands, and they often release large amounts of carbon when drained for agriculture.

ii) Agricultural production releases nitrous oxide, a potent greenhouse gas. There are significant reasons to believe that the traditional estimates of nitrous oxide production incorporated into our results are too low. P.J. Crutzen et al., *Atmos. Chem. Phys. Discuss.* 7:11191-11205 (2007).

iii) Around half of the new croplands according to our estimate are converted from grasslands, nearly all of which are probably grazed today. Converting those grasslands to cropland sacrifices the livestock forage produced on them. Our study assumed that there would be no further land-use change – such as forest clearing – to replace this forage. (This assumption causes our estimates to be too low, but we disregarded this impact because there is no accepted model for calculating these effects.)

iv) Finally, there is substantial evidence that converting some rainforest has a drying effect on adjacent rainforests, making them more prone to fire. Our analysis left out this effect as well. These and other effects, such as changes in albedo (surface reflectivity) of converted lands, deserve further study, but generally suggest a very cautious approach to any contemplated expansion of land use for biofuel production.

4. <u>The study's basic causal chain is straightforward, even though the details reflect sophisticated modeling.</u>

The NFA claims that the basic logic of the study is in fact highly speculative and attenuated. There is nothing speculative about global commodities markets – more demand means higher prices, which leads to greater production. This is exactly what we've seen in the corn market for the last several years. The study authors view the basic causal chain to be straightforward.

5. <u>Land Use Effects Are Intrinsic to the Calculations for Biofuels But Have Been Previously Left Out</u>

The NFA finally claims that the studies arbitrarily decide to calculate greenhouse gas emissions from land-use change, which are only some of the many possible indirect effects of biofuels and fossil fuels. While any life-cycle analysis of a fuel has to place some limits on what it calculates, any proper life-cycle analysis has to focus at least on the major sources of greenhouse gas emissions. According to our analysis, land-use change is the single largest source of emissions for corn-based ethanol and probably any other biofuels grown on cropland. It is a large, and real effect and must be considered in any accurate accounting.

More precisely, our analysis only provides a more complete view of land use effects that are otherwise incorporated into greenhouse gas studies in a one-sided way. Previous analyses attribute greenhouse gas reductions to biofuels because they attribute to the biofuel the carbon out taken out of the atmosphere by growing crops (or other feedstocks). For most biofuels, that requires land, and is in reality a land-use effect, but it is a one-sided accounting of the land-use effect. Any calculation that assigns biofuels the carbon benefits of using land to grow them must also deduct the carbon costs of that land-use decision. If not used for biofuels, land would already take carbon out of the atmosphere and continuing to store carbon previously removed, and much of this benefit is lost by using the land to produce biofuels. If you want to calculate the carbon benefit of using land for biofuels, you have to count the carbon cost.

Put another way, previous analyses have looked at land used for biofuels as a carbon free asset. It is not. These analyses were equivalent to calculating the profit from farming, which requires cropland, without factoring in the rental cost of the land.

SIGNIFICANCE OF YIELD IMPROVEMENTS

Our study assumes that yields in each country would continue to increase according to present growth trends. Beyond the NFA press release, other critics claim that yield increases could grow even more, either in the U.S. or worldwide, which could free up additional lands from food production for biofuels, avoiding the need to convert pristine ecosystems. Higher yield increases would have enormous environmental benefits, but this argument mostly confuses changes to baseline conditions – the way the world looks without more biofuels – and the incremental effect of more biofuels.

If the world can dramatically improves agricultural yields beyond existing trends, less additional forest and grassland will be converted to cropland. That would obviously be good for global warming because it would decrease the total amount of land conversion. But reducing the amount of deforestation overall does not by itself affect the amount of additional deforestation for each gallon of ethanol. Even in the unlikely event that the world's farmers could boost increases so high that the need for world cropland declines even with a higher population, each additional gallon of ethanol would still preclude some amount of cropland from reverting to forest or grassland.

Future yield increases above recent trends could alter the incremental affects of biofuels but only in more modest ways. If U.S. corn yields grow faster than current trends predict and reach 189 bushels/acre instead of 172 bushels per acre in 2015, emissions from land-use change would decline by 10% because less land would be diverted to produce each acre of corn ethanol. That would not significantly alter our conclusion.

In addition, ethanol itself will spur price increases that could spur additional yield increases beyond those that would occur without ethanol as farmers invest in more irrigation, drainage and fertilizer. Unlike general yield effects, large yield increases spurred by ethanol itself to replace diverted grain could significantly reduce land conversion. In effect, in response to higher prices, farmers will increase production both by plowing up more land and by trying harder to boost yields on existing land, and the relative cost and ease of doing each will determine how much of which occurs. As discussed in our study, there are also countervailing forces (like the fact that expansion of corn production outside of the corn belt will involve lower yields), and it is extremely hard to estimate these effects. For this reason, we looked at alternative scenarios in our sensitivity analysis. Even if higher prices due to ethanol boosted yields enough to replace one half of diverted grain, the pay-back period for corn ethanol would still last 84 years.

RESPONSE TO WANG AND HAQ

The public letter from Wang and Haq repeats some of the errors of the NFA press release and makes additional factual and logical errors.

Scale of Ethanol: Wang and Haq repeat the claim that the study is flawed because it analyzes the wrong scale of corn ethanol. As discussed above, the study focuses on the amount of land use change per gallon, or per mile driven, with ethanol, and that rate will remain comparable at different analyzed levels of ethanol, and probably increases at lower ethanol levels.

Corn Yield: Wang and Haq complain that our study "used a constant corn yield," and did not factor in rising yields. As our study states: "Our analysis assumes that present growth trends in yields continue."[1] Using the predictions of the Food and Agricultural Policy Research Institute, the most authoritative source of information on this subject, the study incorporated rising yields not just for corn but for all world crops, even varying those rises in yields by country and by region of the United States. In fact, our projected yields of 172 bushels per acre in 2015 exceed those of 166 bu/acre used by Wang in his GREET model. In any event, even higher corn yields would only modestly affect our results, as discussed above.

Our Study's Export Predictions: Wang and Haq claim that our study has already proven false because it "maintain[s] that the United States has already experienced a 62% reduction in corn exports," and that does not occur. The study makes no such claim. It actually finds that an increase in corn ethanol from 15 to 30 billion gallons by 2016 would reduce corn exports by 62% compared to otherwise existing export levels in 2016 if the U.S. then produced only 15 billion gallons of ethanol. Obviously, the absolute effect on corn and other exports would be much lower at today's lower production levels, and any such large prediction at today's production levels would be absurd.

Recent Export Behavior: As alleged proof that U.S. corn ethanol is not impacting the U.S. exports at all, Wang and Haq point out that U.S. corn exports have remained basically constant for many years and modestly rose in 2007. But to maintain this level of exports, the U.S. planted almost 20 million more acres to corn in 2007 than it did in 2004 – mainly by shifting acres out of soybeans, but also some acres out of cotton and wheat. Given that 25% increase in corn acres, flat corn exports are proof of the impact of ethanol, which absorbs nearly all the increase. Even so, corn exports could attain these levels only through reduction in feed use and by reducing stocks. And as predicted by our study, the shift of soybean acres to corn in the U.S. has reduced exports of soybeans, while also depleting its year-end stocks. In short, as USDA has also

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[1] Wang and Haq were apparently confused by the explanation that our study assumes constant growth in yields according to existing trends but not additional growth in yields due to the higher prices that result from ethanol, i.e., the growth in yields "from biofuels." Our study assumed that the *additional* efforts by farmers to boost yields, would be balanced out by the need to rely on more marginal land, but we analyzed a different scenario as part of the sensitivity analysis that assumed additional yield increases.

concluded, rising ethanol production will reduce U.S. corn exports and trigger increased production abroad. P.C. Westcott, *Ethanol Expansion in the United States: How Will the Agricultural Sector Adjust* (Economic Research Service, USDA 2007).

Wang's claim also logically confuses the relevant comparison needed to determine the incremental effect of biofuels on land use. Because of rising yields, in the absence of biofuels, the U.S. would increase its overall agricultural exports, either in the form of grain or meat (which can be viewed as a grain product.) Constant exports indicate biofuel impacts, not their absence. The proper analysis is not the absolute levels by which exports change over time, but the way in which biofuels alter what exports would otherwise be at a particular time, such as 2015.

Finally, focusing on any single year is always misleading. In any year, many circumstances influence what happens to imports and exports, including currency swings and weather patterns around the world. U.S. wheat exports this year remained high because of a combination of good growing weather in the U.S. and terrible weather abroad. Any use of a single year, particularly one which ignores stocks, is misleading. The basic proof that biofuels in the U.S. are influencing world agricultural production is the sharp rise in crop prices, significantly but not exclusively attributable to biofuels, which by its nature triggers agricultural expansion.

<u>Ethanol By-Product</u>: The Wang letter criticizes the study for giving insufficient credit to the nutritional value of distiller's grains, a corn ethanol by-product, by failing to recognize its higher protein content. Although at most a moderate factor in the analysis, the study did not assume that distillers' grains would only replace corn on a pound-for-pound basis as claimed. The letter greatly oversimplifies the nutritional issues involved in using this by-product. The actual use of distiller's grains varies by the type of livestock. The model attributes its use for energy and protein in the feed ration based on least-cost formulations considering all the nutritional requirements by type of animal, including lysine, which is a critical nutrient in the poultry diet that is deficient in DDGs. The parameters in our model used to calculate DDG use in feed ration are based on current research information from actual animal feeding experiments. Rather than based on a simple assumption of displacement value, the use of DDGs is calculated by the model based on technical maximum inclusion limit, displacement rates for both corn and soymeal, and adoption rates of DDG. All these vary by type of animal feed ration formulated. (Assuming one kind of simple displacement value of a by-product, rather than modeling how by-products are actually used and affect demands of other products, is a much simpler form of analysis, and the kind that prevails in nearly all greenhouse gas studies.) USDA has come to similar general conclusions about the use of distillers grains.[2]

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[2] See P.C. Westcott, Ethanol Expansion in the United States: How Will the Agricultural Sector Adjust (Economic Research Service, USDA, May 2007): "[D]istillers grains from each bushel of corn used to produce ethanol substitutes for about a fifth of a bushel of direct corn feeding in livestock rations. Since beef cattle are large users of distillers grains, only a small reduction is expected in soybean meal use due to the substitution of distillers grains in rations."

Recent Patterns of Land Use Change Abroad: Wang and Haq claim that our study wrongly predicts forest and grassland will provide new cropland because "deforestation rates have already declined through legislation in Brazil" and because of efforts elsewhere "to convert marginal crop land" into grassland and forest. There is no logical connection between the conclusion and the premise. World deforestation and other land use changes are continuing. The amount depends on a range of factors, including the total demand for agricultural land for food, and biofuels are only one factor. The world could reduce conversion and global warming in a variety of ways, including laws and efforts to boost agricultural yields around the world. Efforts that reduce the amount of land use change would alter the baseline condition but would not necessarily alter the amount or type of land that would be converted to replace any particular acre of grain diverted to biofuels. So long as people are able to maintain their food consumption, the world will expand its agricultural land to meet demands.

The influences on world deforestation rates are also far more complex than can be captured by a few random facts. There is no evidence that deforestation rates are declining worldwide or even in Brazil overall. Rates of deforestation in Brazil declined in recent years with lower crop prices, but they have spiked in recent months in apparent response to higher crop prices, precisely as shown by previous studies. Reuters, "Amazon Rain Forest Destruction Quickens" (January 21, 2008). More broadly, there is no reason to assume that the release of carbon in Brazil for each new acre of cropland will be lower in the future than it was in the 1990's. In the 1990's, the great bulk of conversion occurred in a lower forest/savannah area known as the Cerrado, but most of the Cerrado is now already converted. The Amazon, whose forests are higher and more carbon-rich, has therefore increasingly become the prime area of new conversion for cropland. Meanwhile, new roads, such as the Trans-Pacific highway, are potentially opening up portions of the Amazon to agricultural development in other countries, such as Peru. On a worldwide basis, the best estimates find that greenhouse gas emissions from land use change in 2000-2005 closely tracked those from the previous two decades. J.G. Canadell et al., "Contributions to Accelerating Atmosphere CO2 Growth From Economic Activity, Carbon Intensity and Efficiency of Natural Sinks," *Pro. Nat. Ac. Sci.* 104:18866-18870 (2007). Today's record high crop prices, in significant part a reflection of biofuels, increases the likelihood of the kind of government and private investments that lead to agricultural conversion in more remote, carbon-rich lands.

Which lands provide the cropland for the future are in part unknowable because, among other factors, it will turn on shifting government policies and infrastructure. If one country tightens its controls on land use, agricultural expansion may shift to another. Precisely because of this complexity, our study used actual data from the 1990's and assumed that future conversion would follow the 1990's. By some amount or other, that will obviously be untrue because the future never perfectly reflects the past. The most important lesson of the 1990's is that conversion occurs in a wide variety of habitat types, some richer in carbon than others, but all with high carbon losses. Our study by no means predicts that land conversion will typically come from the most carbon-rich lands, and while future results could be better than the 1990's, they could also be worse.

Possible Improvements in Ethanol Efficiency: Wang and Haq correctly observe that new technologies could improve the efficiency of the ethanol conversion process. Our study analyzed the impact of vast improvements in ethanol refining efficiency and found that they had a meaningful effect but still left corn ethanol triggering large net increases in greenhouse gases.

Possible Use of Different Feedstocks or Lands: The letter also correctly points out that other feedstocks could be used, but as the Wang letter fails to recognize, the effects of a shift to cellulosic ethanol depend on the form of cellulose. Waste products would cause no land use change emissions. Biomass produced abundantly on otherwise unproductive land would cause small land use change emissions. And feedstocks produced on productive land (whether productive of food, forest or grassland) would cause high land use change emissions. Searchinger et al. and Fargione et al. are consistent.

A DOE release that largely mimics Wang and Haq also argues that using corn land to produce biofuels is unlikely because of higher corn prices and therefore not proposed. We agree that higher corn prices decrease the likelihood of using corn lands, but DOE has previously incorporated the conversion of tens of millions of acres of croplands into its biomass projections, and whole workshops and study teams focus on the potential to convert some of the best parts of the corn belt to biomass. The poor economics of doing so provide another reason to produce biofuels if possible in productive ways on otherwise unproductive lands.

Confusion of Effects on Baseline with Effects of Ethanol: Apart from specific errors, the Wang letter appears to repeat the common error that has guided previous greenhouse gas accountings, which is to attribute to biofuels any factor that could improve or hold down the baseline level of land use change. It is not proper to attribute benefits to biofuels for changes that would occur with or without biofuels. And factors that influence the baseline – even factors that could theoretically cause overall crop prices to drop – do not necessarily affect the incremental effect on land use by diverting an acre of cropland to produce biofuels.

GENERAL DISCUSSION OF UNCERTAINTIES

Although we consider these recent criticisms off the mark, we fully acknowledge many inherent uncertainties in this kind of study. Studies of particular countries could provide more detailed information about source of agricultural conversion or soil carbon content. Difficult studies might provide more information about how higher prices themselves triggered by biofuels might spur greater yields. But many uncertainties will remain. For example, higher crop prices could encourage more countries to build the infrastructure to expand agriculture in carbon-rich habitats, including countries that share the Amazon with Brazil or the rain forests of Africa, which would increase the emissions from land use change. The power of our study lies in the robustness of the result even with very different assumptions. That suggests a cautionary approach, and yet more reason to focus on biofuels that do not create high risks of substantial land use change.