WHY UNCERTAINTY IN MODELING INDIRECT LAND USE CHANGE FROM BIOFUELS CANNOT JUSTIFY IGNORING IT

Timothy D. Searchinger (tsearchi@princeton.edu) (July 14, 2009)

Princeton University & German Marshall Fund of the U.S.

Critics have argued that estimates of the greenhouse gas benefits of biofuels should not incorporate emissions from indirect land use change (ILUC) because the estimates of those emissions are too uncertain. ILUC emissions result from the expansion of agricultural or managed timber lands into forests and grasslands to replace food or timber diverted to biofuels. Modeling analyses by the major world land use and agricultural modelers have estimated that large-scale use of biofuels will trigger large-scale land use change and carbon emissions. (Results have come from separate teams in the United States at Iowa State University, Purdue University, the Massachusetts Institute of Technology, and the Pacific Northwest National Laboratory, a lab of the U.S. Department of Energy, and Europe-based teams at the OECD, the International Institute for Applied Systems Analysis, and Wageningen University.[1]) But critics are correct that estimating ILUC is sufficiently uncertain that the details of any one estimate are not reliable. The uncertainties reflect the limitations of economic methods, the uncertainty whether past economic relationships will remain the same in the future, and the somewhat uncertain responses of governments, which may facilitate or discourage conversion of some of the world's most carbon-rich habitats in response to increased demand for food.

[1] Dumortier, J. et al. (2009). *Sensitivity of Carbon Emission Estimates from Indirect Land-Use Change* (09-WP 493, Center for Agriculture and Rural Development, Iowa State University); Keeney, R., and Hertel, T. (2008). The Indirect Land Use Impacts of U.S. Biofuel Policies: The Importance of Acreage, Yield, and Bilateral Trade Responses (GTAP Working Paper No. 52, Purdue University, West Lafayette, IN); Melillo, J. et al.. (2009). *Unintended Environmental Consequences of a Global Biofuels Program* (MIT Joint Program on the Science and Policy of Global Change); Department of Agricultural Economics, Purdue University. Wise et al. (2009). " Implications of Limiting CO2 Concentrations for Land Use and Energy," *Science* 324:1183;1186; Gischer G. et al. (2009). *Biofuels and Food Security* (IASSA, Laxenberg, Austria): M., H. van Meijl, G. Woltjer (2008b). *The Impact of First Generation Biofuels on Global Agricultural Production, Trade and Land Use*. Paper presented at the 12th EAAE Conference.26, 29 August 2008, Gent, Belgium; Organization for Economic Co-operation and Development (OECD).(2008). *Economic Assessment of Biofuel Support Policies* (Directorate on Trade and Agriculture, OECD, Paris)

For several reasons, this uncertainty cannot logically or practically justify ignoring this source of emissions.

- Standard lifecycle analyses credit biofuels with all the carbon absorbed by plants used to make them, and this credit is the source of biofuel's potential greenhouse gas benefits. But land will grow plants whether used for biofuels or not – plants that may either store carbon directly as in trees or may supply food or timber to people. Diverting this plant-producing capacity of land to biofuels does not inherently create any net gains, as people must in some form use the plant-producing capacity of other lands to replace any diverted food. Calculating direct or indirect land use change is necessary to calculate the extent of any net gains by subtracting the carbon costs of devoting land to fuel when also calculating the carbon benefits.

- When biofuels use existing crops – contrary to simple understanding – that use alone produces no direct greenhouse gas benefits. The direct emissions of burning biofuels in a car or truck are the same as burning fossil fuels,[2] and diverting existing crops that would grow and absorb carbon anyway by itself generates no additional crops that absorb additional carbon. The potential benefits of biofuels therefore depend on indirect effects as consumers and farmers respond around the world to the diversion of crops by eating less (and thereby emitting less carbon) or producing more food (and absorbing more carbon). These responses can only be estimated as part of the same analysis that also estimates indirect land use change, which is the other possible response to diverting crops into fuel.

- Ignoring indirect land use change makes any effort to limit direct land use change futile. Biofuel producers can avoid direct land use change just by supplying biofuels from existing croplands used for food at the same time they convert new forests to replace food supplies.

---

[2] IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme*, Egleston H.S., Buendia L. Miwa K. Ngara T. and Tanabe K. (eds.), IGES, Japan; Farrell A. E. et al. (2007). "Ethanol Can Contribute to Energy and Environmental Goals," *Science*, 311: 506 – 508 (2006).

- A simple opportunity cost analysis explains why indirect land use effects from the use of cropland, although uncertain in precise amount, are likely to be large.

Some biofuels, such as those from crop residues, present little risk of land use change because they do not explicitly divert the productive capacity of land. But for those biofuels that do, the reasonable approach to uncertainty is to use a variety of different methods of estimating indirect land use change and use an estimate based on a precautionary approach to provide reasonable assurance that biofuels will truly reduce greenhouse gas emissions by the required amounts when accounting for ILUC.

1. Indirect Land Use Change is Necessary to Determine if Diverting Managed Lands into Fuel Production Provides a Net Carbon Gain or Just Moves Carbon Around.

Whether cars burn biofuels or fossil fuels, their tailpipes emit the same amount of carbon. Under the conventional view, biofuels reduce greenhouse gases by replacing fossil fuels. But while emissions from fossil fuels are reduced, they are replaced by emissions from burning biofuels. Replacing fossil fuels with biofuels therefore only saves greenhouse gases to the extent the production of biofuels reduces greenhouse gases in some other way.

That potential exists because the growth of plants turned into biofuels absorbs carbon from the atmosphere, and while overall emissions do not change, this plant growth has the potential to provide a form of offset to the emissions. But if not used to produce plants for fuels, land will still grow plants that absorb carbon from the atmosphere. Growing plants for biofuels requires that biofuels divert the productive capacity of land – its capacity to support plants that absorb carbon – from some alternative use. The key question presented by biofuels is whether diverting this productive capacity into fuel overall absorbs or withholds more carbon from the atmosphere.

That is inherently a net calculation that credits the carbon gained in the fuel but subtracts what diverting this productive capacity gives up. When biofuel crops are produced directly on forests, the loss of storage and ongoing sequestration in the forest provides the measure of what is given up from a greenhouse gas perspective. When biofuels divert crops or cropland, carbon storage is not sacrificed directly because the carbon produced is consumed by people and livestock and put back into the atmosphere through their metabolism. But in some form or other, to the extent people still wish to consume the same amount of food, they must use the productive capacity of other lands to replace the food. The greenhouse gas implications are therefore measured by the losses in storage and sequestration that occur when the productive capacity of additional lands are altered to replace the food, i.e., ILUC.

Typical greenhouse calculations for biofuels simply assume that they should receive a credit equal to all the carbon absorbed by the plants turned into fuel. In other words, they count the benefits of using land and its productive capacity but not the costs. Diverting the productive capacity of land to fuel does not come carbon free. If calculations choose to credit biofuels with the plant carbon incorporated into them, those calculations must also take account of the plant carbon not grown on that land for other purposes, reflected by the indirect land use change that occurs to replace it. Only in that way, can the calculations reflect whether there is a net gain in carbon or whether biofuels simply shift carbon from providing greenhouse gas benefits in one way rather than another.

2. Potential Greenhouse Gas Benefits of Diverting Crops to Biofuels Actually Result from Indirect Effects

The discussion above also shows that when biofuels use existing crops, there are no direct greenhouse gas benefits. The emissions from car tailpipes remain the same. The emissions from the process of producing biofuel feedstocks and refining them into fuel also typically match or exceed those used when producing gasoline and diesel, so different production processes do not result in lower greenhouse gas emissions (see Farrell et al., n. 2, Online Supporting Information). Finally, when existing corn, rapeseed oil or other crops are diverted to biofuels, by definition, no additional crops are grown and therefore no additional carbon is removed from the atmosphere. In short, there are no direct changes that reduce greenhouse gases in the atmosphere.

Conventional lifecycle accounting obscures the lack of direct benefits because it automatically credits biofuels with all the carbon incorporated into the crops turned into the biofuel. This carbon then offsets the carbon emitted by burning the biofuel. But because diverting existing crops absorbs no more atmospheric carbon, that credit can at best represent an accounting shortcut for some other, indirect source of benefits.

Following the actual flow of carbon reveals the potential indirect sources of these benefits, as well as the potential indirect carbon costs.

First, higher prices spurred by diversion of crops may reduce total crop consumption, so some of the diverted crops may not be replaced. Some of these reductions may have relatively benign causes: For example, livestock farmers faced with higher crop prices may feed their animals more efficiently. Some reduced consumption may be extremely harmful, as the world's poorest and hungriest people are forced to eat less. Either way, this reduction in food consumption results in greenhouse gas benefits, and the true source of the reduction (perhaps surprisingly) lies in reduced livestock and human metabolism. When crops are consumed by livestock or people, the carbon in the form of carbohydrates, proteins and fats are burned off and returned to the atmosphere through respiration. To the extent crops diverted to biofuels are not replaced, the carbon dioxide exhaled by livestock and people will decline, and that provides actual source of greenhouse gas benefits.

Second, farmers may replace diverted crops by boosting their crop yields even more than they otherwise would in a world without biofuels. Such efforts may also increase some emissions, particularly if achieved through increased fertilizer application, which leads to more nitrous oxide, a powerful greenhouse gas. But ignoring these input effects, the increase in crop yields means more plant growth, which absorbs more carbon from the atmosphere and therefore reduces greenhouse gas emissions. Again, the potential greenhouse gas benefit is an indirect one, as this additional plant growth results from efforts by all the world's farmers to boost yields in response to higher crop prices.

Finally, the world's farmers may replace crops diverted to biofuels by plowing up new land from forest or grassland. That releases carbon dioxide from vegetation and soils, and gives up the ongoing carbon sequestration that would occur on these lands if they remained in their present use. This release of carbon, which increases greenhouse gases, is ILUC.

Figures 1 illustrates the direct and the three possible indirect effects.

Although these effects can in theory either reduce or increase greenhouse gases, they all represent the responses of consumers and farmers other than those generating the biofuels or their feedstocks and are therefore indirect. It is also not possible to calculate one effect without at least implicitly estimating the others. The balance of these three economic effects – reduced consumption, increased yields, and agricultural land expansion -- lies at the core of the economic modeling used to calculate indirect land use change and also represents the principal sources of uncertainty in its calculations. Ignoring indirect land use change implies an assumption that the only indirect effects are those that reduce greenhouse gases, an approach that does not ignore indirect effects but treats them simply and counter-factually.

Conventional lifecycle analyses have obscured the indirect nature of potential through their assumption that the carbon in biofuels somehow should not count despite its very real emissions when burned. Having assumed this large benefit, critics attack the uncertainty of indirect calculations and therefore call for no deduction. But the real question is whether the predominant indirect effects reduce greenhouse gases or increase them, and indirect land use changes are a necessary part of that calculation.

3. Incorporating Direct but not Indirect Land Use Change would be Futile.

When forests, grasslands and savannahs provide the direct land for biofuels, their conversion releases large quantities of carbon that can completely cancel out greenhouse gas benefits from biofuels for decades,[3] and few disagree that lifecycle analyses should count these direct releases. Recognizing these emissions, the European Union directive on renewable fuels counts these direct emissions. But regulating only these direct emissions is futile because producers can freely convert new land while avoiding direct emissions for biofuels simply by managing their supply chains.

For example, palm oil expansion in Southeast Asia primarily to meet the world's voracious demand for vegetable cooking oil is causing large-scale deforestation and releases of carbon from drained peat soils. Palm oil can also supply biodiesel. Under the rule that counts direct but not indirect effects, a palm oil producer would be able to meet greenhouse gas criteria by storing in one tank all the palm oil now produced from already-cleared forests and selling that for biodiesel. The producer would then clear more forest to replace the vegetable oil for food. So long as it stored that oil in a second

[3] Fargione J., J. Hill, D. Tilman S. Polasky, P. Hawthorne. (2008). *"Land Clearing and the Biofuel Carbon Debt," Science* 319, 1235-1238 (2008); Gibbs, H.K., et al. (2008). "Carbon Payback Times for Tropical Biofuel Expansion: The Effects of Changing Yield and Technology," *EnvironmentalResearch Lett*ers, 3, 034001.

tank, the producer would comply with greenhouse gas reduction requirements. Such an easily avoided standard is worth little.

4. Opportunity Cost Analysis Explains why Direct or Indirect Land Use Change Emissions of Diverting Crops to Biofuels are Substantial.

Because the potential greenhouse gas benefits from biofuels result from growing plants to offset the emissions from burning, land use provides the key to biofuels. Biofuels in essence channel the productive capacity of land into fuel, but doing so sacrifices alternative uses of that productive capacity. Calculating emissions from direct or indirect land use change simply means calculating the greenhouse gas benefits of land in its most likely alternative use if not used for biofuels. In one sense, that means calculating the opportunity cost.

One simple way of estimating the cost of that diversion in productive capacity is simply to assume that the land is surplus – in one sense, an inherent assumption of biofuel policies -- and therefore at a minimum could be simply left alone. In the United States, for example, most such land would regenerate as trees, which would sequester carbon in branches, roots and soils for decades at a probable rate of 7.5 to 12 tons of carbon dioxide per hectare per year.[4] Land in the wet tropics would generally reforest and gain carbon at even higher rates, at rates up to 14 tons of carbon dioxide per hectare.[5] By contrast, a hectare of corn ethanol in the U.S., according to the GREET model, would save roughly 3 tons of carbon dioxide per hectare per year after accounting for the food value of by-products. And even extremely optimistic estimates for cellulosic ethanol – at extraordinarily high yields and conversion ratios – tend to hope for 17 tons of CO2 gain per hectare per year. That implies a greenhouse gas gain if fallow surplus land were used in that way, but even then the land use costs are substantial, and generate only around a 35% greenhouse gas reduction in switching from gasoline to ethanol using the GREET model.

---

[4] Searchinger, T., et al. (2008). Use of U.S. Croplands for Biofuels Increase Greenhouse Gas Emissions Through Land Use Change [Online Supporting Materials]. *Science* 319:1238-1240; Watson, R.T., et al. (Eds.). (2001). *Land Use, Land Use Change and Forestry*. Intergovernmental Panel for Climate Change. Geneva; Jackson, R., W.H. Schlesinger. (2004). "Curbing the U.S. Carbon Deficit," *Proceedings of the National Academy of Sciences* 45:15827-15829.

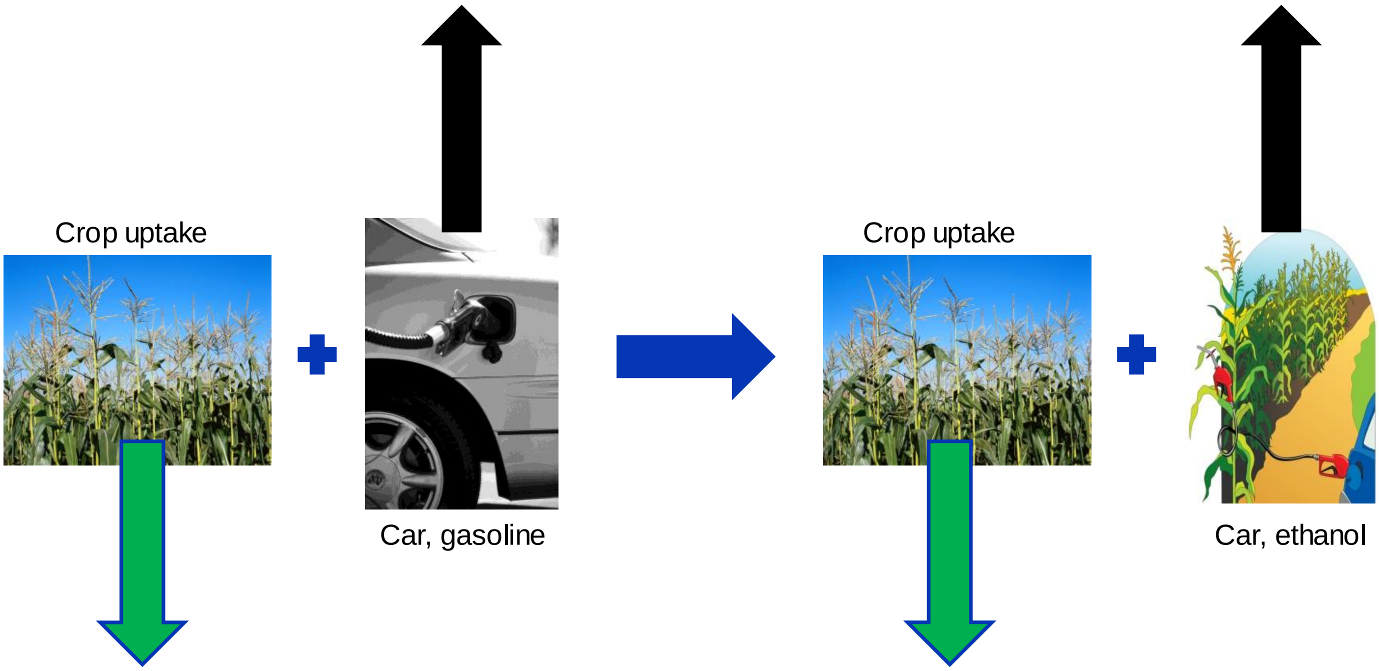
[5] Righelato, R. & Spracklen, D.V. (2007). "Carbon Mitigation by Biofuels or by Saving and Restoring Forests." *Science*, 317, 902.

This opportunity cost approach is not the same as predicting what would happen when existing crops or cropland are diverted to bioenergy. For example, it does not credit biofuels with the greenhouse gas benefits that result from reduced food consumption. On the other hand, it also does not calculate the high levels of stored carbon that will be released quickly when relatively mature natural habitats are converted to replace crops. What it does do is provide a good way of valuing the productive capacity of land in carbon terms and show why diverting that capacity into biofuel production inherently has large, real costs.

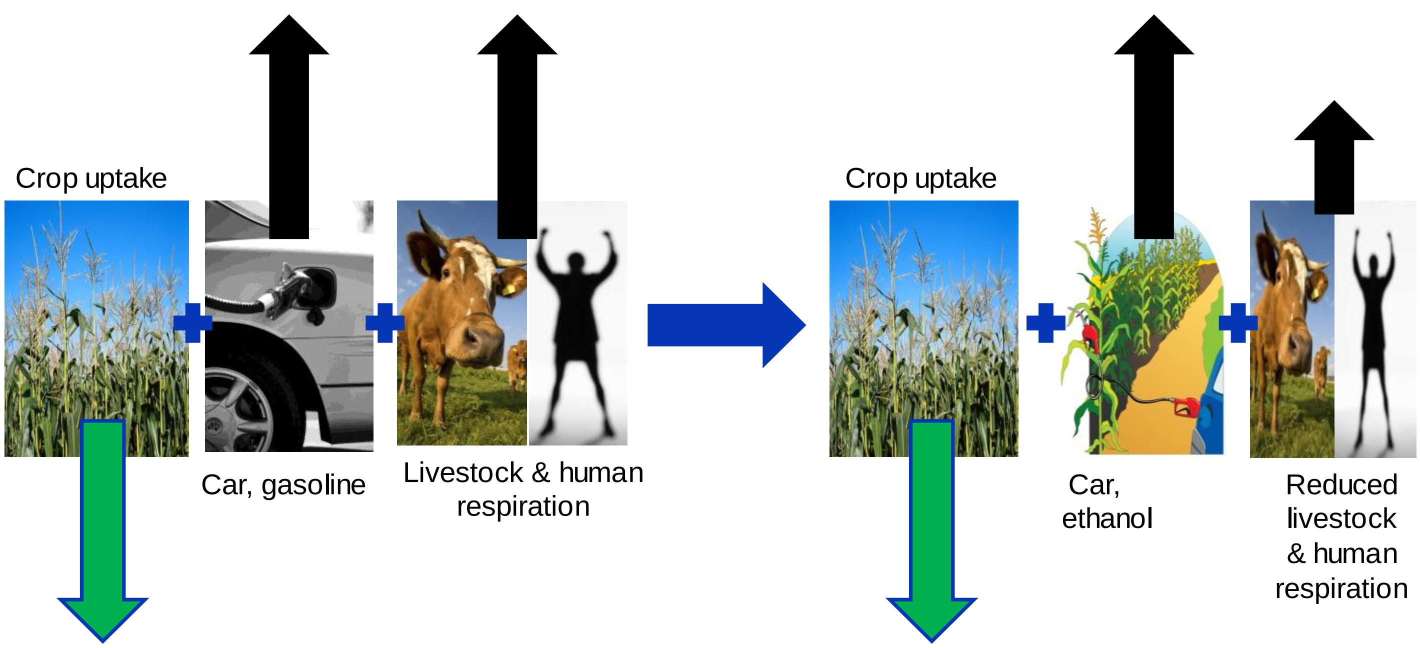
Conclusion

Despite some inherent uncertainties in estimating ILUC, the failure to include its emissions results in a one-sided and fundamentally flawed accounting of greenhouse gases when biofuels use existing crops or cropland. This accounting assumes, in effect, direct benefits that do not exist. Viewed another way, this accounting calculates the gross benefit of using land to make biofuels instead of the net benefit. Such a limited approach also provides no defense against even the most harmful direct clearing of carbon-rich habitats, so long as suppliers use multiple tanks to store their feedstocks. And this approach ignores the high likelihood that emissions from ILUC are substantial for the simple reason that the productive capacity of land, if not diverted for biofuels, typically results in levels of carbon sequestration and storage that provide benefits comparable to those from the use of biofuels.

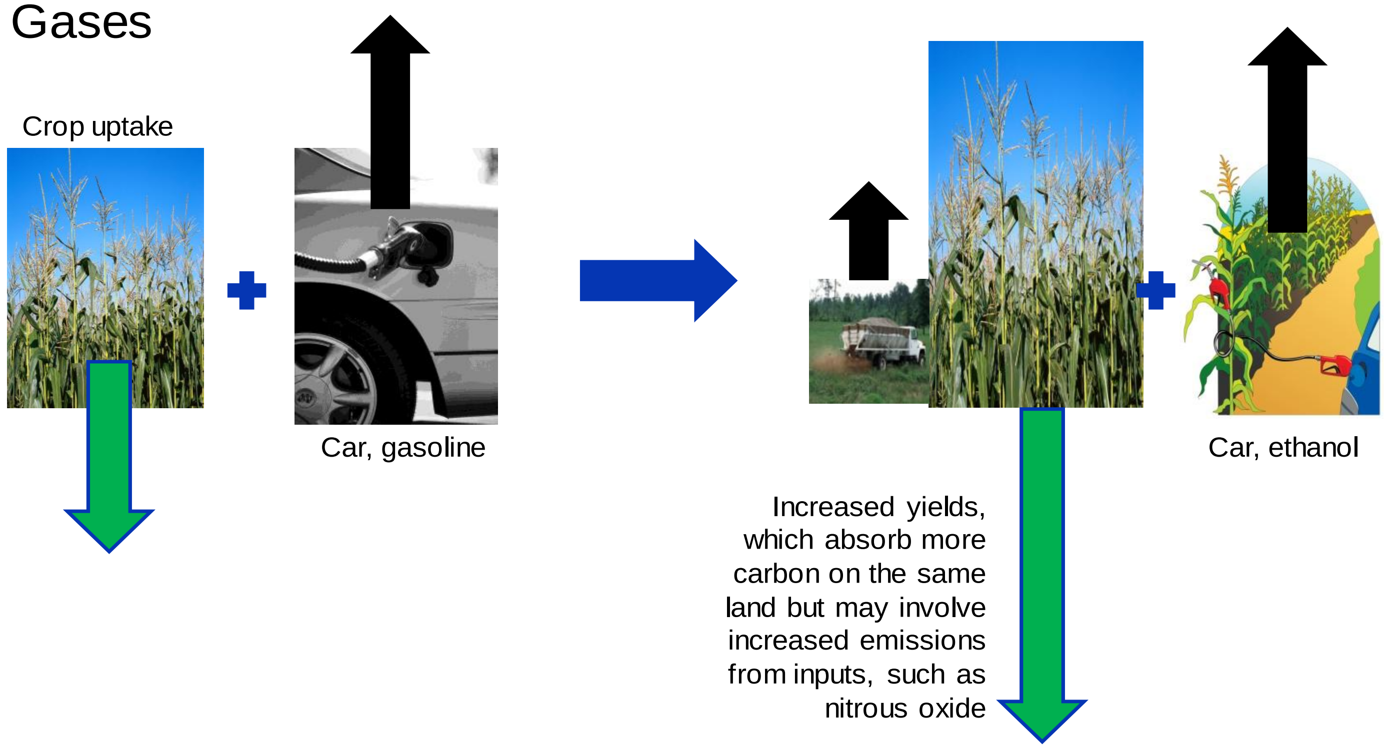
Direct Effects of Diverting Crops to Biofuels – No Change in Emissions



Indirect Scenario 1 – Ethanol Leads to Less Crop Consumption for Food, which Creates Greenhouse Gas Benefits



Indirect Scenario 2 – Ethanol Leads to Yield Growth to Replace Diverted Crops, which Absorb More Atmospheric Carbon and Reduce Greenhouse Gases



Indirect Scenario 3 – Diverted Crops Replaced by Agricultural Land Expansion