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GOLDMAN SCHOOL OF PUBLIC POLICY

Memorandum on Land Use Change and the Global Food System

Michael O'Hare
Daniel Kammen

May 9, 2008

Summary

The LUC (Land Use Change) term in an LCA assessment of a biofuel's global warming effect (GW), while superposable for small excursions, is not independent of other events in the global food system. In particular, the GW effect of biofuel use resulting from remote land use change mediated by global grain markets is probably larger to the extent that food supplies are under pressure from whatever other causes.

Fuel use of any inputs to food production, especially land, unambiguously causes an increase in food prices relative to what they would otherwise be as long as the demand curve for food slopes upward to the left.

Limited opportunities do exist for what are termed 'pro-poor' land use strategies; namely positve, synergestic, interactions of biofuel production and food availability. An example from Africa is included in this memo. Past experience with the 'Green Revolution' of agricultural intensification suggests, however, that the chance to improve the sitation of the global poor can be exceedingly difficult to implement.

Discussion

Current analysis of the global warming (GW) effect resulting from the substitution of biofuels for petroleum recognizes that land use change (LUC) remote in space (and possibly time) induced by competition with food consumption for biofeedstocks may be large, and that the carbon releases from these changes may not only reduce the GW advantage of [some] biofuels over petroleum but actually reverse it. The discussion has been especially influenced by two recent journal articles (Fargione, Hill, Tilman, Polasky, & Hawthorne, 2008; Searchinger et al., 2007).

Because LUC is 'caused' directly by price changes for food crops, discussion of policy implications, including especially discussion in the popular press (for example, (Garber, 2008)), has noted the rapid worldwide increase in food prices, especially grains, over the past two or three years. A good part of that discussion comprises contradictory assertions about whether the increase in US corn ethanol production is responsible for the increases, part of them, or very little. Other

MICHAEL O'HARE
PROFESSOR OF PUBLIC POLICY
TEL: 1-510-642-7576
FAX: 1-510-643-9657
OHARE@BERKELEY.EDU

factors increasing food prices recently certainly include (at least): increasing demand from growing population, from increasing consumption of meat in India and China resulting from economic growth there, from climate events like the Australian drought that have reduced production, and from export restrictions in countries fearing food shortages.

Parties to this discussion, and policymakers, have drawn or offered a variety of not entirely consistent or logical inferences, such as 'food prices would have gone up anyway so any effect of ethanol is unimportant' and 'with food prices so high, it's inappropriate to use any food grain for fuel.'

This memo briefly discusses the relationship between biofuel LUC effects and contemporaneous events in world grain markets. First, a short review of the LUC issue: the LUC effects of biofuels are understood as proportional to land area converted to agricultural from natural conditions, per unit of food crop land diverted from food to feedstock use. This relationship is considered causal, and the arrow of influence goes from biofuel use of feedstock on farmland that would otherwise grow a food crop, through a complex web of elasticities to land conversion. Note that the land conversion associated with a unit of biofuel production at location A (for example, the US Midwest) not only occurs where the fuel is produced (for example, conversion of conservation land to cultivation) but also far away in location B, for example in Brazil or Indonesia where some rainforest is cut down and burned to provide farmland. Note also that the crop on the converted land is not necessarily, or even probably, a biofuel crop.

At any moment, we assume that if F t of a biofeedstock is grown, or used for fuel instead of food, C_1, C_2, ... ha will be converted from each of various natural conditions 1,2,... to agriculture, each with a characteristic release of GHG to the atmosphere from burning or decay of vegetation. The functional relationship of the $\boldsymbol{C}$ vector to F (Searchinger et al.) is central to attributing the correct amount of LUC GHG to the fuel produced from the F t of feedstock. For simplicity in this discussion, we define L as the generalized ratio of land use change GW of all kinds to feedstock fuel use. If crop yields are higher, either on the newly cultivated land or for biofuel production; or if the converted lands have less standing vegetation in their natural state; or if the price elasticity of demand for food is greater; L will be smaller and conversely.

Constant slope demand

Figure 1 presents generalized supply and demand functions for food. Diversion of food grain to fuel use moves the supply curve to the left, with a corresponding increase in price and decrease in food consumption. The result that use of food crops, or food-capable land, to fuel production will increase food prices is extremely robust, depending only on the assumption that the demand curve for food slopes downward to the right (any other assumption is implausible and not consistent with any known data). Furthermore, some increase in food prices will occur no matter whether food is relatively abundant or relatively scarce when the shift to fuel occurs.

The curves in this figure implies that a given quantity movement in supply will cause the *same* change in price no matter what the current price is. *Assuming a similarly linear relationship between land conversion and crop prices, L* (the GHG effect of a given quantity of biofuel use), will be the same no matter what amount of food is being consumed when the supply curve is shifted by diversion to fuel. This linear model is appropriate for small changes in the variables, but note that linear demand functions do not have constant elasticity (elasticity is the ratio of a percentage change in quantity to a percentage change in price). The curve in this figure requires that demand elasticity is larger for smaller *Q*—that people will give up a larger and larger percentage of the food they eat for a dollar change in price as they have less and less food.

Constant elasticity demand

A more realistic picture is in Figure 2A and 2B, where food demand is characterized by a so-called "constant-elasticity" function (solid line). Note that in this model, the price change induced by a given *volume* of crop diverted from food to fuel is higher when there is less food in the market than when there is more.

In 2B, the price changes are translated to a notional land supply curve; the additional land brought into cultivation will depend on the slopes of this curve at the two regions of price change. A variety of land supply curves can be constructed according to which the land conversion from a unit volume of biofeedstock use is greater, the same, or less when food is scarce than when it is abundant, though the last case requires it to be convex downward, which is intuitively implausible.

Decreasing elasticity demand

In general, the demand for cereals is inelastic (a 1% change in price induces less than a 1% decrease in demand) (Regmi, Deepak, Seale, & Bernstein). It remains to consider whether this elasticity is constant: as grain consumption falls, does demand become more or less elastic? Recent history has only begun to provide data in the relevant range, but as food consumption declines, especially for the poor whose diet includes more cereals and less of everything else proportionally, consequences like malnutrition and starvation begin to appear, consequences much more compelling than the hedonic costs of consuming a less-preferred diet or wasting less food. It seems reasonable to think that the demand for cereals becomes less and less elastic as reserve stocks are consumed—that the price response to supply reduction becomes more than proportional as portrayed by the broken line construction in Figure 2.

If this is true, and we assume constant elasticity of land supply, a given quantity of biofuel will induce a larger change in land use when biofuel use and/or other forces have reduced food supplies, and therefore current estimates of LUC GHG effects *have to be regarded as a lower bound insofar as increased biofuel production on crop land moves the food supply curve to the left, and more so to the extent that anything else does so at the same time.* This effect can only be counterbalanced by increased yields sufficient to stabilize the food supply curve against fuel feedstock diversion, a degree of cost reduction that exceeds predictions even from optimistic analysts for significant quantities of fuel.

In general, the demand for cereals is inelastic (a 1% change in price induces less than a 1% decrease in demand) (Regmi et al.). It remains for further examination to consider whether this elasticity is constant: as grain consumption falls, does demand become more or less elastic? Recent history has only begun to provide data in the relevant range, but as food consumption declines, especially for the poor whose diet includes more cereals and less of everything else proportionally, consequences like malnutrition and starvation begin to appear, consequences much more compelling than the hedonic costs of consuming a less-preferred diet or wasting less food. It seems reasonable to think that the demand for cereals becomes less and less elastic as reserve stocks are consumed—that the price response to supply reduction becomes more than proportional as portrayed by the broken line in Figure 2A. If this is true, and we continue to assume constant elasticity of land supply, a given quantity of biofuel will induce a larger change in land use when other forces have reduced food supplies, and therefore current estimates of LUC GHG effects *have to be regarded as a lower bound (i) insofar as increased biofuel production on crop land moves the food supply curve to the left, and (ii) more so to the extent that anything else does so at the same time.* This effect can only be counterbalanced by increased yields sufficient to stabilize the supply curve, a degree of cost reduction that exceeds predictions even from optimistic analysts.

Quantifying these effects awaits the economic modeling studies the UCB/CARB project and others currently have underway, but their sign is strongly indicated by the foregoing discussion.

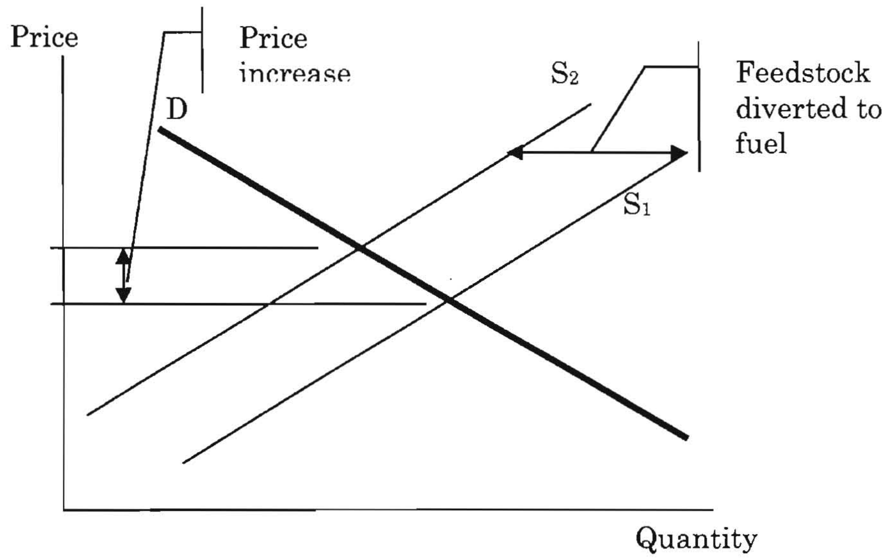

Figure 1: Constant-slope demand. A given quantity of fuel diverted from food to fuel will cause the same price increase no matter where the market is when the diversion occurs.

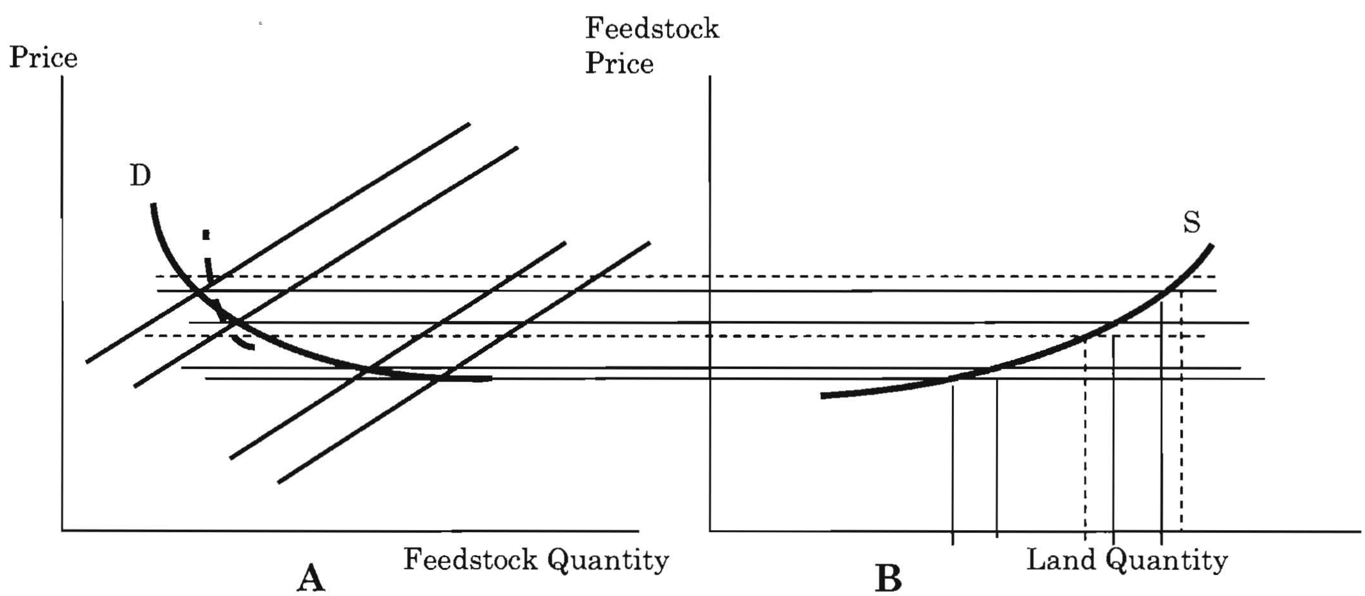

Figure 2. Constant- (A) and variable- elasticity (B) demand. A given decrease in food feedstock availability will induce larger price changes as total quantity is lower. If the supply of natural land for conversion also has constant elasticity, the amount of land converted will be about the same for a given diversion amount. However, if the elasticity of demand for food decreases as food availability falls, (broken lines) land conversion will be greater.

Positive Food-Fuel Interaction

The foregoing conclusions assume that food and fuel use of land are substitutes, which is typical on productive land with high yields. In some cases, however, they may be complements, and fuel production may actually shift the food supply curve to the right.

Africa, southeast Asia, and part of Central American each have significant areas of land that have been greatly degraded, although these lands remain in use and are, in fact, vital to the survival of local populations (Bailis, Ezzati, and Kammen, 2005). An example scenario is to utilize drought resistant and salinity tolerant 'dual use' cultivars such as sweet sorghum on these lands to increase yields. A number of candidate crops exist, but most have properties similar to that of sorghum, namely good water-use and resilience features, but often at low yields, similar to the native prairie grass cultivation examined in (Fargione et al., 2008), *e.g.* 5 – 7 t/ha. In a preliminary analysis, taking the indirect land use effect into account, we find limited, but positive opportunities to increase both food production and biofuel yields while improving soil quality and decreasing erosion. We outline one such ase in Figures 3 and 4. An extensive analysis of this issue is forthcoming (Dargouth and Kammen, 2008).

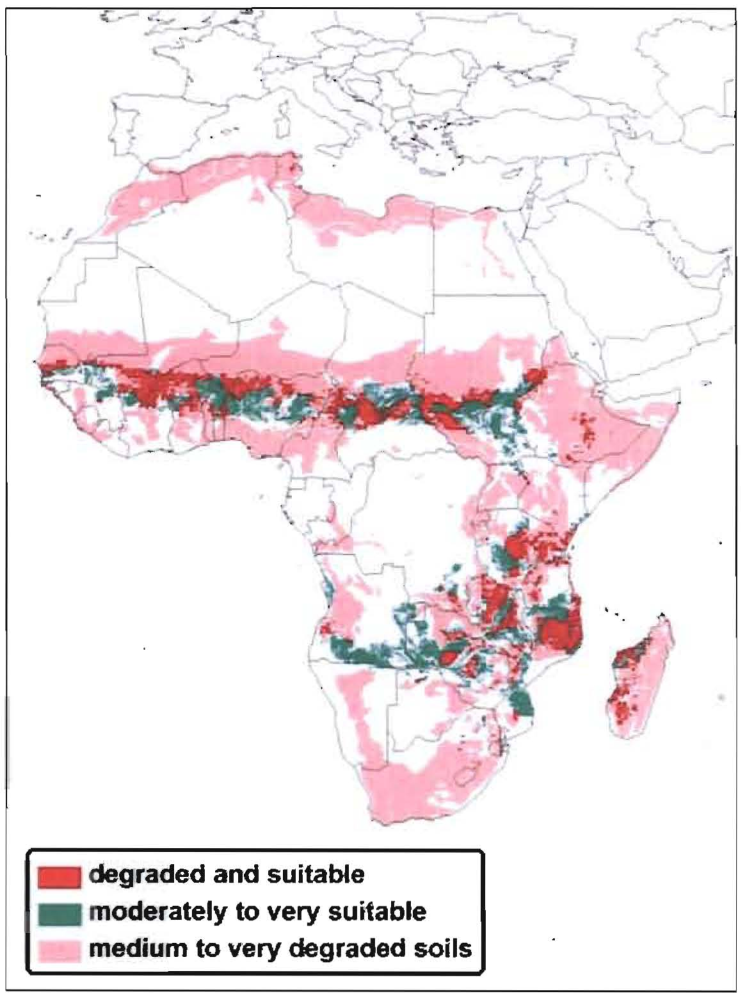

Figure 3: The extent of degraded lands in Africa that are suitable for the production of 'pro-poor' biofuels such as sweet sorghum. Source: Bailis, Ezzati and Kammen (2005); Dargouth and Kammen (2008).

At this point we conclude that while the potential exists, particulary good management practices – although not necessarily exceptional yields – would be required to take advantage of this effect. Important opportunities do exist as part of international assistance efforts, or in programs to reinvest in ecosystems through policies that could tie land-use to LCFS compliance.

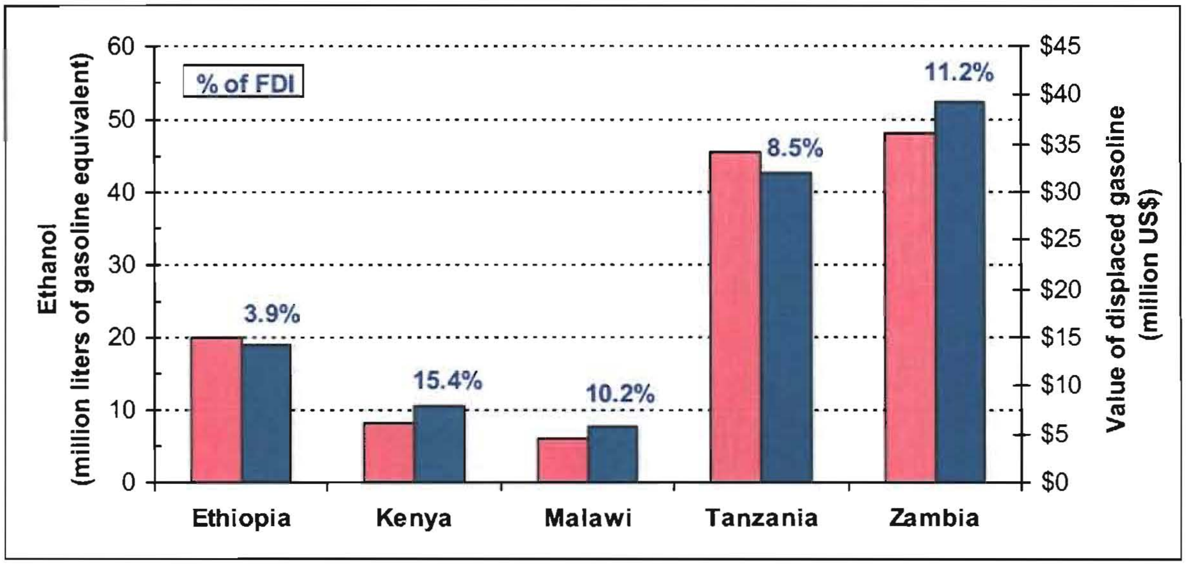

Figure 4: Percent of domestic petroleum consumption that could be met with local biofuel production with no new pressue on food production, namely using severely degraded land and currently wasted crop residues. FDI: foreign direct investment. IN both Tanzania and Zambia the biofuel yields would meet 10 – 12% o total current petroleum demand. Reductions in petroleum use of this level are not trivial, but could likely be met with readily available efficiency measures. The fuel source for this analysis is improved sweet sorghum, with food and biofuel production per hectare both increased over the baseline 'business as ususl' scenario. Source: Dargouth and Kammen (2008).

References:

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