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Critique of Searchinger (2008) & related papers assessing indirect effects of biofuels on land-use change

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USE OF U.S. CROPLANDS FOR BIOFUELS INCREASES GREENHOUSE GASES THROUGH EMISSIONS FROM LAND-USE CHANGE

by Timothy Searchinger, Ralph Heimlich, R. A. Houghton, Fengxia Dong, Amani Elobeid, Jacinto Fabiosa, Simla Tokgoz, Dermot Hayes &Tun-Hsiang Yu.

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Introduction

Thus far life-cycle analysis (LCA) of biofuels has acknowledged but generally excluded their indirect effects on land-use change (ILUC), because of evident difficulties in their estimation and attribution.

However, consequences for global land-use change of expanding corn-based bioethanol production in the US were highlighted in February 2008 by Searchinger *et al.* (this paper will subsequently be referenced by its initial author) and this paper has prompted much debate in subsequent publications and open correspondence. The initial Searchinger paper presented estimates of ILUC and consequent greenhouse gas (GHG) emissions due to expanding corn-based bioethanol production in the US, and concluded that pay-back periods (until net savings in GHG emissions would be achieved) were so long as to render this form of biofuel counter-productive in contributing to GHG savings.

An accompanying paper (Fargione *et al.* 2008) broadly corroborated Searchinger's conclusions. The extensive subsequent debate has included rejoinders by Searchinger *et al.* to the critiques of Wang & Hodson (refs below). This review attempts to summarise and evaluate the debate, as it relates to the Gallagher review of indirect effects of the biofuels initiative in Europe. The review is not intended to be comprehensive or to give firm conclusions, but rather to provide a summary of the contentious issues for the wider Gallagher Review. Many of the issues raised by Searchinger are tackled by separate Studies commissioned within the Gallagher Review, the final synthesis of these Studies and ultimate conclusions will be made by the Gallagher Review authors.

Principal Searchinger findings and key issues of debate

Findings:

1. There is insufficient capacity for land productivity to provide for the projected expansion of US bioethanol production, and other demands for bioethanol feedstock are inelastic.

2. Expansion of US bioethanol production will cause previously uncultivated land to be brought into crop production, both in the US and elsewhere, primarily in Brazil, China and India, and this will involve significant loss of pristine grasslands and forests, as well as lost opportunities for carbon sequestration on idle arable land.

3. The GHG emissions arising from ILUC will be sufficiently large that the period until net savings begin will be reached long after the period when GHG pay-back is required (2020-2050).

4. Biofuels made from biomass crops have similar, though smaller, disadvantages to those made from food crops. Biofuels are best made from waste products.

Key issues of debate:

5. The chain of causation is too long and complex for LUC to be attributed confidently to use of grain for biofuel.

6. The models used by Searchinger are inappropriate or inadequate for his purpose.

7. Assumptions and / or input data are unclear or inaccurate, to the extent that the conclusion is unreliable or flawed.

Key Issues for this Review

Key issues of the paper by Searchinger for a review of Indirect Effects of Biofuels in the EU are:

<u>Issue 1</u>: How well could an analysis of corn-based bioethanol production in the US, and its conclusions, relate to current intentions for biofuel production in the EU?

<u>Issue 2</u>: Is the approach taken by Searchinger sufficiently robust that it could, albeit in a modified form, be used to inform EU policy, and / or assist LCA of EU biofuels?

<u>Issue 3</u>: What elements of the Searchinger approach, or in the responses to it, that could inform policy development on EU biofuels?

The Steps in Searchinger's methodology and results are:

1. Start with existing (2004) production of US corn:

   267Mt on 30Mha, 11% for ethanol, 15% exported.

2. Calculate the increase in production of corn and bioethanol by 2016, hence the need for *extra* feedstock:

   56Blitres / year from 138Mt extra corn per annum, grown on 12.8 Mha at 10.8 t/ha.

3. Calculate consequent increases in prices of agricultural commodities:

    corn +40%, wheat +17% and soya +20%.

4. Based on short-term price elasticities, calculate consequent reductions in feed consumption:

    -0.56% dairy, -0.90% meat world-wide.

5. Assume no consequent net change in productivity of crops – price-induced increases are cancelled by extension-induced decreases.

6. Calculate LUC from un-cropped land including pristine habitats, and apportion this between idle arable land, grassland, savannah, or forest (equilibrium or growing), according to the distribution of LUC in 1990s.

    10.8 Mha net: 2.2 Mha in USA, 2.8 Mha in Brazil, 1.1 Mha in China, 0.7 Mha in Africa.

7. Calculate consequent GHG emissions due to LUC, and express these as a break-even date, when net GHG emissions due to the initiative, will equal zero.

    104 g CO_2equiv per MJ amortised over 30 years; breakeven date: 2183 (167 years).

CRITIQUE

All the evidence relating to the Searchinger paper is available to the Advisory Group, Group members have had the opportunity to question Searchinger, and a further opportunity to question the authors will arise when members attend the Sustainable Biofuels and Human Security Workshop at Illinois on 12-13 May 2008. The intention here is to distil the most telling findings and questions arising from the debate stimulated by Searchinger.

Relevance to the EU biofuels:

It is not disputed that initiation or significant extension of biofuel production will have indirect effects, including on changes in land use, and that these will have attendant effects on GHG emissions (ES15). Key issues are:

1. To what extent should ILUC be attributed to the biofuel? For example, deforestation may also be driven by meat production, timber extraction, accessibility, migration, and other changes (ES13; ES62). This question is one of philosophy, as well as practicality, and a proper response needs to recognise the interacting effects on land of policies relating to diet, energy, development, conservation, and other ecosystem services.

2. The balance of biofuels, between bioethanol and biodiesel, has consequences for rotations, hence for crop productivity. US policy favours just one fuel, which encourages mono-cropping, or may even exaggerate ILUC in order that the feedstock crop can be grown in rotation (Hodson). The US example is not fully relevant to the EU because the EU plans to balance bioethanol and biodiesel production, which will improve the balance of rotations (Hodson).

3. The motivation for the US biofuels initiative is fuel-security, whereas in the EU it is GHG mitigation. Also fiscal policy is more supportive of biofuel production in the US than envisaged so far in the EU.

4. The projected level of biofuel production in the US is high (Wang & Haq) but unlikely to compromise the relevance of GHG estimates to smaller levels of production (Searchinger).

Summary: The basic issues raised by Searchinger are relevant, but there are fundamental differences between US bioethanol and EU biofuel initiatives.

Robustness of Searchinger's approach, referring to each step in turn

Overall approach

5. Outwith the concerns below over particular assumptions, there is evident disquiet over the modelling approach taken by Searchinger. There are two main points:
   - It may not be feasible to model world economics to a level of precision that will enable quantification of secondary or tertiary effects of a relatively small perturbation in the global system. Given the limited success with modelling other complex systems – weather, biological organisms, etc. – a global model will not necessarily enable trustworthy predictions. For the predictions to be trusted, the models need to be validated, perhaps demonstrating that their predictions of past seasonal perturbations in prices match those observed satisfactorily (Wang & Haq; ES62).
   - It is not likely that the consequences of a biofuels initiative will be allowed to play out with the degree of free market economics that is modelled here. Biofuels initiatives will be accompanied by policy instruments such as certification, tax rebates and investment in research and development that will also affect GHG outcomes.

Feedstock conversion and displacement

6. There have been no criticisms of ethanol conversion rates assumed by Searchinger, however, Searchinger's 'pound for pound' substitution of feed corn for corn diverted to bioethanol appears to be an overestimate (ES15, Wang & Haq, ECCM). It should be recognised that the co-product, dried distillers grains (DDGS), has ~30% protein and ~5% fibre. If heat damage is avoided, maximum inclusion in diets can be ~400 g/kg for cattle, 200 g/kg for sheep, and 100-250 g/kg for non-ruminants (Cottrill *et al.* 2007). Thus the displacement value of DDGS is at least 23% higher than that assumed by Searchinger et al. (Klopfenstein *et al.* 2008).

Price increases

7. Searchinger assumed baseline prices equivalent to those of the last 3 years. There has been no comment on or challenge of this, or of the degree to which prices are estimated to be affected by biofuel. However, it seems likely that price assumptions will have significant effects on price results. This should be checked.

8. The important price elasticities need to be validated (Hazell), because Seale, Regmi & Bernstein (USDA), who provided the analysis of food elasticities underlying Searchinger's work, say that different specifications (such as 'AIDS' or 'Rotterdam') can generate significantly different estimates of elasticities from the same data (Wiggins).

Seachinger reports the demand for meat products to be inelastic and explains that feed price changes are only partially translated to meat prices because they are diluted by other costs. Nevertheless, it is not clear that sufficient care was taken about meat products' elasticities in the large fast-developing economies of China and India where meat consumption is particularly dynamic.

Crop productivity

9. Searchinger assumes that the net effect of biofuels on yield trends will be nil. This crude assumption has attracted extensive debate, and robust defence by Searchinger, but some points remain:

   – It is clear that a majority of yield improvement happens in response to public investment in research and infrastructure, and due to public support, as in production subsidies (Hazell). Searchinger does not acknowledge that such public intervention is likely to be associated with any biofuels initiative.

   – Searchinger accepts that private agricultural investment responds to prices. However, he appears to down-play the response (ES15). The response (ES15) needs to be quantified and documented.

   – Searchinger's contention that extension of cropping will cause a net reduction in crop productivity needs to be examined. Points are that:

     … Some LUC happens on good land, as well as on poor land e.g. soybeans in Brazil's Matto Grosso (ECCM).

     … A biofuels mix can be designed to decrease, rather than increase, mono-cropping with its associated reduced yields.

     … The productivity of grasslands is probably as responsive to prices as that of cash crops, and apparently was not included in Searchinger's calculations.

Indirect Land Use Change

10. A fundamental problem raised by several respondents arises from Searchinger's inaccurate assumption (see 6 above) of 'pound for pound' displacement of corn. Allowing for the higher protein of DDGS, and also for land to replace the oil foregone (we assumed oil palm); we calculate that Searchinger's assumption about doubles the land required to substitute for US corn-ethanol. Ensus (ES15) conclude the assumption trebles the result, but they do not account for the 'lost' oil from the displaced soya.

    It should be clarified what has been assumed in Searchinger's approach about the inter-changeability of maize, rice, wheat & barley etc. It is puzzling that there is 23 Mha of unused arable land in Eastern Europe & the former Soviet Union (Riddle 2008), yet the predicted response in these parts is for cropping to decrease!

11. LUC affects biodiversity as well as GHG emissions. Biodiversity is threatened where GHG costs are greatest (e.g. pristine forest). Governments will surely respond with stronger protective measures, albeit with incomplete effectiveness. Searchinger does not credit any tightening of statutory controls on LUC in Latin America or more environmentally conscious policies on LUC in China. Whilst it is outside his assumption of free market economics, statutory constraints (whether or not they are integral with biofuels initiatives) will mitigate ILUC (Wang & Haq).

GHG emissions

12. Searchinger sets savings of direct GHG emissions from bioethanol production relative to fossil fuels at an unrealistically small level (i.e. ~20%) compared to GHG

efficiencies of grain conversion estimated for the EU (i.e. 40-70%). A greater saving would significantly shorten his estimated payback periods (Wang & Haq; ES15).

13. Searchinger includes opportunity costs of using land to sequester carbon, instead of providing biofuel feedstock, in regions where cropping contracted in the 1990s (e.g. Europe and the former Soviet Union), but this is ignored where cropping expanded in the 1990s (e.g. Latin America & China). This is inconsistent, and gives a shortened pay-back period.

14. Searchinger admits his assumption of 25% loss of soil carbon, where land changes from un-cropped to cropped, is conservative. Wider consultation and the literature (Guo, L.B. & Gifford 2002; Lal et al. 2006; Powlson & Smith) indicate that a more appropriate value would be 30-40% (ADAS; Powlson; P Smith); revision of this assumption would increase estimates of indirect GHG emissions considerably.

Additional points relevant to policy development on EU biofuels:

15. Rosegrant *et al.* (2006) conducted a similar analysis to Searchinger, but provided much less detail. They considered smaller increases in biofuels demands, distributed globally. They suggest that, if biofuels initiatives are accompanied by extra publically instigated productivity research, then effects on prices will be acceptable.

16. It should be noted that meeting biofuels demands through productivity has associated GHG costs, mainly due to the fertiliser N needed to support genetic improvement. However, given a straight choice between biofuels causing LUC and covering biofuels demands with greater productivity, data from the UK indicate that greater productivity is better, since the use of more fertiliser (to support genetic improvement in productivity) has GHG costs similar to LUC from grassland, but much smaller than with LUC from forests, swamps etc. (ADAS). It may be that productivity has bigger advantages in developing regions.

Overall Summary and Conclusions:

The Searchinger paper has advanced EU thinking on indirect effects of biofuels initiatives. It is not reasonable for biofuel initiatives intended to save GHGs to ignore the indirect GHG effects. If nothing else, the debate prompted by Seachinger has shown the difficulties and contentious nature of attempts to estimate indirect GHG effects. Whilst the analysis of Seachinger has caused many objections and concerns, it remains eminently feasible that effects of biofuels on indirect GHG emissions could be significant in relation to intended GHG savings. The broad-ranging work being undertaken in other parts of the Gallagher Review will provide vital evidence to help clarify many of the issues raised, but until this is complete, it must be concluded that the Searchinger approach involves a high level of uncertainty, to the extent that its specific conclusion should not be regarded as safe.

In attempting to quantify indirect GHG emissions from EU biofuels initiatives, the Seachinger approach does not provide a good model. Whilst considering policy and regulatory conditions in the US, it ignores the prospects of policy and regulatory interventions arising from biofuel initiatives (and other calls on land) elsewhere. Biofuels are clearly part of a wider policy space involving all governments and concerning many land-related issues: energy, diet, development, conservation and amenity, and any initiative on biofuels needs to be devised in a way that addresses at least the main interactions. In particular, the world will need to significantly enhance food and feed production by 2050, whether or not biofuels are made. This will entail just as great a threat to GHG emissions and biodiversity as LUC due to biofuels. That we are facing the issues now, in time to prepare, is to be welcomed. Food-based biofuels may be a flawed and temporary phenomenon, but they are focussing attention on the investments and developments that may be required to ensure we can "feed the 9 billion".

Consultees

Uwe Fritsche, Oeko-Institut e.V. (Institute for applied Ecology), Darmstadt Office.

Peter Hazell (IFPRI & Imperial College, Wye) on econometric modelling, price elasticities and overall approach.

Nigel Mortimer (North Energy Associates) on the place of GREET in Searchinger's modelling approach.

Pete Smith (University of Aberdeen) & David Powlson (Rothamsted Research) on soil organic carbon losses from LUC.

Richard Tipper (The Edinburgh Centre for Carbon Management) on econometric modelling.

Steve Wiggins (ODI) on price elasticities.

Evidence used

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Evidence Submission 15 - Report by Ensus Ltd., and Ensus memo dated 2/5/08.

Evidence Submission 62: Dale.

Evidence Submission 13: ECCM.

Evidence submission 55: see Searchinger & Heimlich (2008) below.

Evidence submission 60: see Rosegrant *et al.* (2006) below.

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