Briefing

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

IFPRI-MIRAGE 2011 modelling of indirect land use change

Briefing on report for the European Commission Directorate General for Trade

Author: Dr. Chris Malins

Date: November 2011

Keywords: iLUC, IFPRI, MIRAGE, RED, FQD, biofuels, CGE

Contents

Washington
+1 202 534 1600

Brussels

San Francisco
+1 415 399 9172

communications@theicct.org | www.theicct.org

Summary

The European Renewable Energy and Fuel Quality Directives require the European Commission to propose, based on the best available data, a methodology to control indirect land use change emissions due to biofuels expansion. To support its Impact Assessment of iLUC policy options, the Commission asked the International Food Policy Research Institute (IFPRI) to update its modelling of iLUC emissions from European biofuel mandates. The new IFPRI-MIRAGE study is an important and detailed contribution to the EU biofuels debate. The key points relevant to the ongoing biofuel policy discussion are:

- European biofuels mandates are likely to cause significant indirect land use change emissions. IFPRI calculates an average for the policy of about 38 g CO2e/MJ. Using improved estimates for the 20-year impact of peat degradation, we suggest that this figure should rise to about 50 g CO2/MJ.
- With iLUC emissions on that scale, without action to reduce iLUC the EU biofuels mandate will in all likelihood deliver no net climate change mitigation benefit.
- Biodiesel has much higher iLUC than ethanol in the modelling. Based on IFPRI's results, biodiesel from rapeseed, soy, sunflower or palm is more emissions intensive than fossil diesel. Sugar and cereal based ethanol production, however, could potentially deliver 50% net carbon reductions.
- A large fraction of carbon emissions, especially for biodiesel, come from peat degradation in Indonesia and Malaysia. Effective peat protection in these countries would substantially improve the emissions profile of biodiesel (though it would still seem unlikely that biodiesel would meet a 50% net carbon reduction target).
- The 2010 IFPRI model used an unrealistic split between ethanol and diesel. The new modelling uses the split specified in the national Renewable Energy Action Plans.
- The model includes effects from price led yield increase, displacement of animal feed with co-products (DDGS and oil meals) and reduction in food demand.
- If food demand is held constant, the emissions increase by about 20%.
- IFPRI notes that there are limitations to the ability of CGE models to reflect some of the detailed dynamics of agricultural systems. They also note that the results are inevitably subject to substantial uncertainty.
- In the report, IFPRI does not recommend the application of iLUC factors. They do, however, recommend measures to shift demand from biodiesel to ethanol.
- Within the context of measures to shift demand from biodiesel to ethanol, IFPRI is supportive of raising the *direct* GHG savings threshold, and potentially reducing the mandate.

Feedstock	Modelled iLUC (gCO2e/MJ)
Wheat	14
Maize	10
Sugar beet	7
Sugar cane	15
Soy	56
Sunflower	54
Rapeseed	55
Palm	54

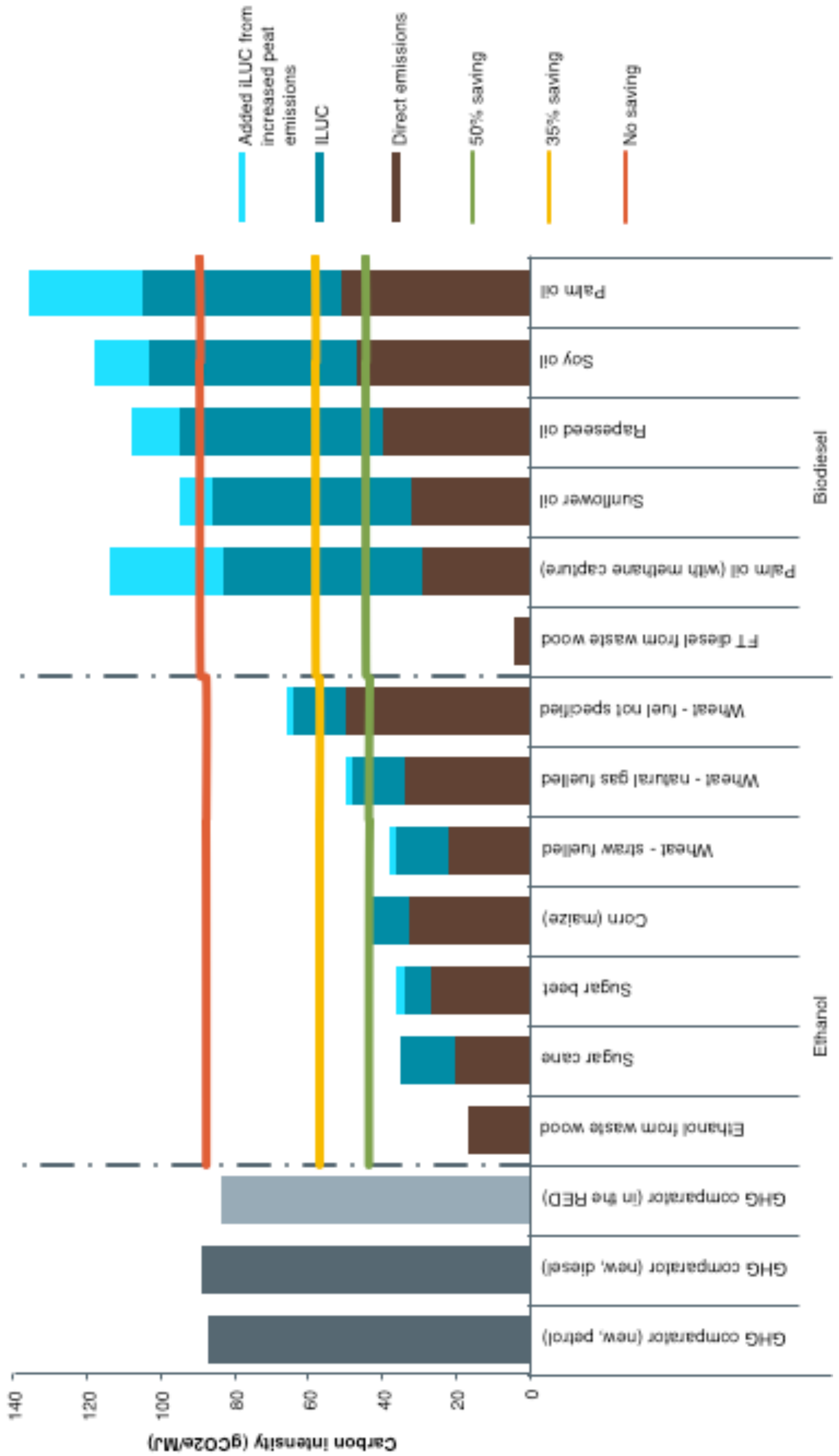


Figure 1. Emissions from different biofuel pathways based on the 'typical' direct emissions specified in the Renewable Energy and Fuel Quality Directives and the new IFPRI MIRAGE iLUC factors

Background

In 2010 the European Commission released four studies as evidence for consideration in the consultation on dealing with indirect land use change. One of these studies (Al-Riffai et al., 2010[1]) was a General Equilibrium economic modelling study commissioned by the Directorate General for Trade from the International Food Policy Research Institute, IFPRI, using its MIRAGE model. The study made projections about the overall carbon footprint of European biofuels policy, and also was used to provide projections for the carbon intensity of specific biofuel feedstocks, by marginally increasing supply of each in turn. It was run for two trade policy scenarios, one based on current (relatively restrictive) trade policies and one based on open trade.

The results of this study were mixed, but in general could be characterised as follows:

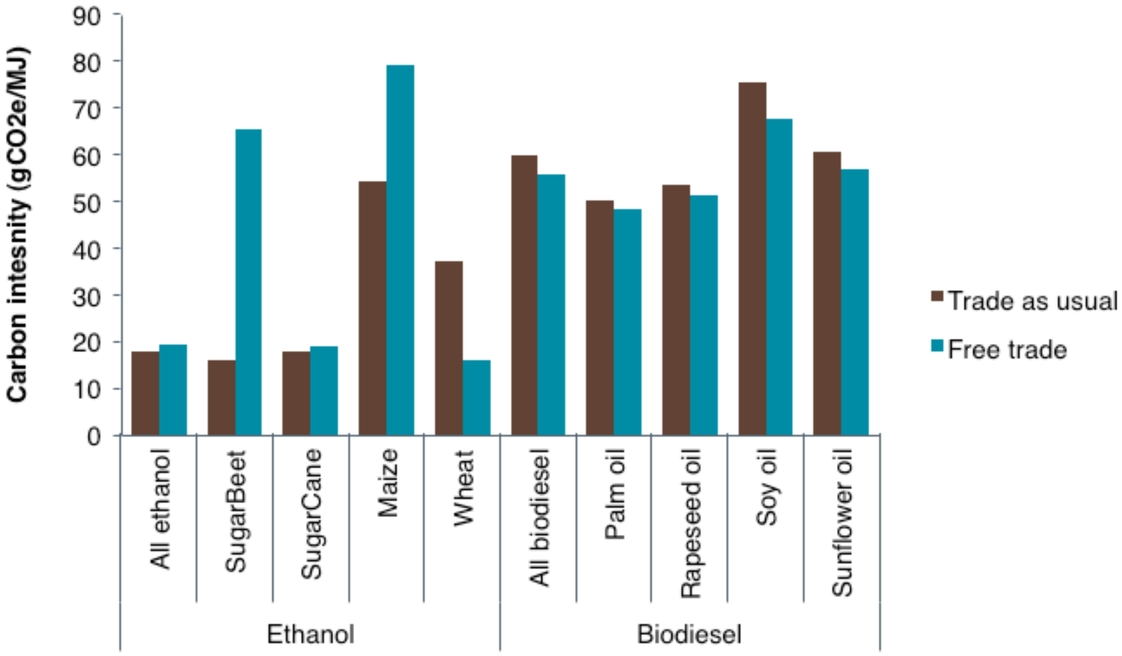
- iLUC emissions are significant.
- iLUC emissions from biodiesel are likely to be higher than from bioethanol.
- iLUC emissions from sugarcane are likely to be particularly low, so that a mandate driving a large increase in sugarcane ethanol imports would have a lower impact than a biodiesel heavy response.
- The Renewable Energy Directive (RED) would lead to overall carbon reductions *assuming that a high use of sugarcane ethanol was correctly forecast* (there is some degree of consensus that the feedstock predictions were unduly skewed towards ethanol and sugarcane in particular).
- Few fuels would meet the minimum carbon savings in the Renewable Energy Directive if iLUC emissions derived from the IFPRI MIRAGE marginal calculations for specific fuels were added to the carbon intensities.

The marginal emissions projected by Al Riffai et al. (2010) are shown in Figure 2 below.

The 2010 modelling received a number of comments, including as a result of the 2010 European Commission consultation on addressing iLUC. In response to these comments, and in light of the continuing development of the capabilities of the general equilibrium modelling, The European Commission's DG Trade asked IFPRI to undertake revisions to the model to better represent the biofuel sector, and to rerun the modelling. This new report represents one of the key inputs to the European Commission's impact assessment on options to deal with iLUC, which is expected to be published at some point in the next few months.

1 http://www.ifpri.org/publication/global-trade-and-environmental-impact-study-eu-biofuels-mandate

Figure 2.iLUC emissions as projected by MIRAGE 2010, gCO2e/MJ



Introduction

The new 2011 MIRAGE study is a successor to the 2010 Al-Riffai et al. paper, with several changes made in response to comments on the 2010 paper. Again, IFPRI has projected the response to the Renewable Energy Directive, with a set ratio of ethanol to biodiesel use, but no exogenous assumptions on which feedstocks are used. IFPRI has run three scenarios to 2020, a baseline without increased biofuel support, a 'business as usual' scenario with existing trade policies and a trade liberalisation scenario. IFPRI also runs each of these three scenarios with an incremental increase in the use of specific biofuel feedstocks – this allows them to suggest 'iLUC factors' for individual crops.

Unlike the 2010 study, the assumptions about trade liberalisation make little difference to the carbon intensity prediction for either the whole mandate or for individual feedstocks, so we have used only the business as usual results for the discussion here.

Changes to the model for 2011 include using fuel split predictions from the National Renewable Energy Action Plans (NREAPS), recalibrating the elasticities of substitution for land supply and demand, revising the co-product treatment by allowing increased substitutability between energy and protein feeds, an increased emissions value for peat degradation and a dynamically re-calibrated food demand elasticity (to prevent food demand elasticity from increasing over time).

Key modelling issues:

The size of the mandate – NREAPS

One criticism of the 2010 results was that they assumed the biofuel market to be inconsistent with most expectations for biofuels in Europe – in particular, that the modelled demand used in 2010 was smaller and more ethanol focused than suggested by the 27 Member States National Renewable Energy Action Plans. In the new study, the ratio of ethanol to biodiesel consumption is modelled at 28:72, while the total demand is modelled as 8.6% of EU transport energy demand, an additional consumption compared to the baseline of 15.5 Mtoe.

Co-products

The 2010 IFPRI MIRAGE study followed the example of modelling for CARB and the EPA by including co-products into the model. DDGS from ethanol production are modelled as a specific fraction of ethanol production. These then compete with other animal feeds. On the biodiesel side, oilseeds are an input to the oilseed crushing industry, which produces oils and meals. Vegetable oils can be used as a feedstock for biodiesel production, while the meals compete with DDGS and other animal feeds in the animal feed market. MIRAGE recognises the different protein content of the various feed ingredients.

Table 1. Change in animal feed for scenarios with significant co-product production. Note that in biodiesel scenarios, fungibility of oils means that production of several meals increases at once (e.g. rape meal and soy meal production both rise in rapeseed biodiesel scenario).

	Ethanol maize		Ethanol wheat		Biodiesel rapeseed		Biodiesel soybean	
Feedstock	Change in feed use (tonnes)	Percentage of displacement	Change in feed use (tonnes)	Percentage of displacement	Change in feed use (tonnes)	Percentage of displacement	Change in feed use (tonnes)	Percentage of displacement
Maize	-2693	-77%	-213	-9%	-2000	-31%	-4431	-44%
Wheat	-333	-10%	-2799	-116%	-2228	-34%	-1740	-17%
Palm Fruit	-1	0%	-2	0%	-81	-1%	-110	-1%
Rapeseed	-4	0%	-5	0%	-465	-7%	-126	-1%
Soybeans	11	0%	12	0%	-810	-12%	-2747	-27%
Sunflower	-6	0%	-6	0%	-126	-2%	-131	-1%
DDGS	3485	100%	2419	100%	1	0%	-32	0%
Meal-Palm	1	0%	1	0%	23	0%	29	0%
Meal-Rape	-37	-1%	-78	-3%	3841	59%	813	8%
Meal-Soyb	-187	-5%	-105	-4%	2431	37%	8954	89%
Meal-Sunf	-1	0%	-5	0%	253	4%	272	3%
Other Crops	174	5%	411	17%	-154	-2%	-834	-8%
Total change in feed use	**409**	**12%**	**-370**	**-15%**	**685**	**11%**	**-83**	**-1%**

For grain-ethanol, co-products play an important role. Demand from the livestock sector for grains is replaced by the use of co-products – this accounts for 90% of the total reduction in grain demand in the model (i.e. only 10% of the reduced grain demand is a real reduction in consumption).

In the model, distillers grains from production of maize and wheat have the net effect of displacing maize and wheat as animal feed (see Table 1). There is some net displacement of oil meals such as soy meal, but this is only about 5% - 10% of total displacement.

Similarly for increased availability of rapeseed and soy oil meals the largest part of the net displacement is away from wheat and maize - for instance, in the rapeseed biodiesel scenario we see a net displacement of about 20% from protein feeds and 65% from energy feeds.

Table 2. Displacement in tonnes of feed ingredients when one tonne of each co-product is added to the feed mix, with total feed use held constant.

	DDGS Wheat		DDGS Maize		Meal Rape		Meal Soyb		Meal Sunf	
Displaced products:	**Cattle**	**OthAnim**	**Cattle**	**OthAnim**	**Cattle**	**OthAnim**	**Cattle**	**OthAnim**	**Cattle**	**OthAnim**
Wheat	-0.07	-0.03	-0.06	-0.02	-0.07	-0.03	-0.23	-0.11	-0.05	-0.02
Maize	-0.03	-0.01	-0.02	-0.01	-0.03	-0.01	-0.1	-0.05	-0.02	-0.01
Soybeans	0	0	0	0	0	0	-0.01	-0.01	0	0
Sunflower	0	0	0	0	0	0	0	0	0	0
Rapeseed	0	0	0	0	0	0	0	0	0	0
Other Crops	-0.05	-0.02	-0.04	-0.02	-0.05	-0.03	-0.17	-0.09	-0.04	-0.02
DDGS Wheat			-0.02	-0.02	-0.02	-0.02	-0.06	-0.07	-0.01	-0.01
DDGS Maize	-0.02	-0.03			-0.03	-0.03	-0.08	-0.09	-0.02	-0.02
Meal Rape	-0.14	-0.16	-0.12	-0.13			-0.49	-0.59	-0.11	-0.12
Meal Soyb	-0.35	-0.38	-0.29	-0.32	-0.39	-0.43			-0.26	-0.28
Meal Sunf	-0.04	-0.04	-0.03	-0.04	-0.04	-0.05	-0.13	-0.16		

It is important to understand that the net displacement results include the full range of economic interactions included in the model, including shifts in livestock feeding patterns due to overall price shifts (protein feed becoming cheaper overall compared to energy feed). Table 2 (Table A 12 in the MIRAGE report) gives replacement values from MIRAGE for a marginal increase of one ton in co-product availability, if the total level of feed is held constant. This table shows that in terms of the 'direct' displacement effect, MIRAGE strongly assumes that both DDGS and oil meals will substitute high protein feeds (oil meals etc.) more than energy feeds (cereals). This reflects the inclusion in IFPRI MIRAGE of information about the relative protein and energy content of different feed types. Based on this table, it seems in fact that MIRAGE may be overstating the direct replacement of protein feeds by distillers' grains and rapeseed meal. A forthcoming ICCT report on the use of DDGS in Great Britain suggests that cereal replacement is likely to be a much larger element of feed displacement by DDGS than shown in Table 2, and JRC well-to-wheels study values for rapeseed meal displacement give a similar message. It is normally presumed that displacing protein meals tends to reduce iLUC more than displacing cereals - hence based on these values MIRAGE may tend to overstate the positive effect for wheat and maize ethanol of co-products in reducing iLUC.

The net displacement results in the model show an overall displacement of energy feeds despite the strong 'direct' displacement of protein feeds. We believe that this is because when a full scenario is run, protein feeds become comparatively cheaper, allowing their use to expand. This emphasises that it could be misleading to consider the effects of biofuel mandates on feed markets only in terms of nutritional content, when other market mediated impacts could be important.

Overall, while there is potential to explore livestock feed displacement in increased detail, we concur with the Kiel Institute (2011)[2] review of the MIRAGE results, which said, "We think that by-products of bioethanol and biodiesel are well treated by the model."

Yield effects

IFPRI MIRAGE assumes that if the price of biofuel feedstocks increases, then farmers will take action to improve the yield per hectare of these commodities. This price induced yield increase takes two forms in IFPRI MIRAGE: factor intensification and input intensification. Factor intensification is the process of increasing the use of labour (more workers) or capital (more investment) for every hectare of land. Input intensification in the model is the process of increasing the use of fertiliser or other agricultural feedstuffs as prices increase. These both have the effect of increasing the yield of a given crop when prices increase.

We would expect increased fertiliser inputs to have potentially significant carbon equivalent emissions consequences, as fertiliser manufacture and use results in the emissions of substantial amounts of nitrous oxide, a greenhouse gas with a global warming potential equivalent to about 300 times that of carbon dioxide. MIRAGE does not however attempt to account for these increased fertiliser emissions.

The dominant of these effects in MIRAGE is factor intensification, which represents the full range of possible technical innovation, improved practice etc. This factor increase plays an important role in reducing the overall iLUC effects from the biofuel mandate.

Vegetable oil markets

In the IFPRI MIRAGE model, as in real life, palm oil is the cheapest available vegetable oil, and thus when demand for any other vegetable oil increases MIRAGE predicts that some of this increase in supply will come from palm oil. We

2 http://www.ebb-eu.org/EBBpressreleases/Review_iLUC_IfW_final.pdf

can highlight this by considering the percentage of demand for a given oil that is met by that specific oil, where the rest is primarily palm oil (but also potentially some element of demand displacement).

Table 3. How is additional vegetable oil demand met?

Feedstock	% of increased demand met by supply of that feedstock	% of increased demand met by palm oil/ demand reduction/ other oils
Palm	96.6	3.4
Rapeseed	78.2	21.8
Sunflower	71.0	29.0
Soybeans	40.3	59.7

Notice that while the vegetal oil market is modelled as strongly connected, the dominant response in all cases except soy biodiesel is still increased production of the oil in question – so e.g. rapeseed biodiesel demand is met largely with increased rapeseed supply, but also by about 20% palm oil.

Peat emissions

In this work, IFPRI has assumed that 30% of palm expansion occurs on peatland (Edwards et al. (2010)[3] suggest a minimum of 33%, which we consider an appropriate lower bound given current trends), and that this results in emissions of 55 t CO2e/ha/yr. This is an improvement on the 2010 work, and they find that peat degradation accounts for 1/3 of total emissions. We recently reported (Page et al. 2011) that 55 t CO2/ha/yr is still an underestimate for the carbon emissions from degrading peatland under palm cultivation[4]. If one applies the Renewable Energy Directive 20 year land use change accounting, based on our review a better estimate would be 106 t CO2/ha/yr. This would raise the carbon intensity of the overall mandate by about 12 gCO2e/MJ, and raise the CI of biodiesels by between 9 (sunflower) and 31 (palm) g CO2e/MJ. It makes palm oil the worst biodiesel feedstock for iLUC emissions.

3 http://publications.jrc.ec.europa.eu/repository/handle/111111111/15324

4 http://www.theicct.org/2011/10/ghg-emissions-from-oil-palm-plantations/

Key results:

Overall impact of mandate

The European mandate is projected to cause about 1.8 million hectares of agricultural expansion to 2020, an area slightly smaller than Slovenia.

Land use emissions are projected to be of the order of 500 Mt CO2.

The absolute values are less important than the magnitude of emissions compared to the potential carbon savings from displacing fossil fuels:

- The overall mandate would not achieve the intended saving of over 50% compared to fossil fuels.
- With IFPRI's values for peat emissions, there would be a carbon saving of only 10% compared to the fossil fuel comparator in the Renewable Energy Directive (83.8 g CO2e/MJ). IFPRI compare biofuels to a higher fossil fuel default of 90.3 g CO2e/MJ to give a 17% saving.
- With our improved peat emissions value of 106 tC/ha/yr, biofuels to meet the mandate would have an average carbon intensity of about 87.5 gCO2e/MJ, higher than the current fossil fuel comparator from the RED.
- Biodiesel is modelled to be more carbon intensive than fossil diesel for all feedstocks. With our improved estimate of peat emissions, all biodiesels are at least 10% worse than fossil diesel.
- Ethanol is modelled to have the potential to deliver savings of over 50%.
- Palm oil and rapeseed will be the main suppliers of additional biodiesel demand.
- Sugarcane will be the main source of ethanol in the scenario with trade liberalisation (i.e. without trade barriers, ethanol expansion will happen in Brazil), while the use of sugarbeet, wheat and maize also grows in the scenario with trade barriers.

Marginal iLUC factors

IFPRI have modelled marginal increases in each of 8 major biofuel feedstocks and reported 'iLUC factors' associated with each one. The ethanol feedstocks are all much lower land use impacts than the oils. None of the biodiesel feedstocks deliver carbon savings, even assuming direct emissions half or less of fossil diesel.

For some crops, additional demand is met almost entirely by increased supply – for others, additional demand is met by reduced demand in other sectors and/or displacement to other crops. Demand for sugar ethanol or palm oil biodiesel, for instance, is met largely by increasing supply of these commodities. Rapeseed and sunflower are met by 70-80% increased supply of those commodities, but also by increased palm oil supply. Increased maize and wheat demand is met about 50% by increasing supply, and substantially by co-products and reducing consumption in other sectors. Soy demand is met 40% with additional soy, but largely by increasing palm oil production.

Figure 3. Emissions by feedstock for: iLUC only, from IFPRI report; iLUC only, with revised peat emissions; total emissions. Percentage contribution of each feedstock to the mandate (right axis) marked in tan.

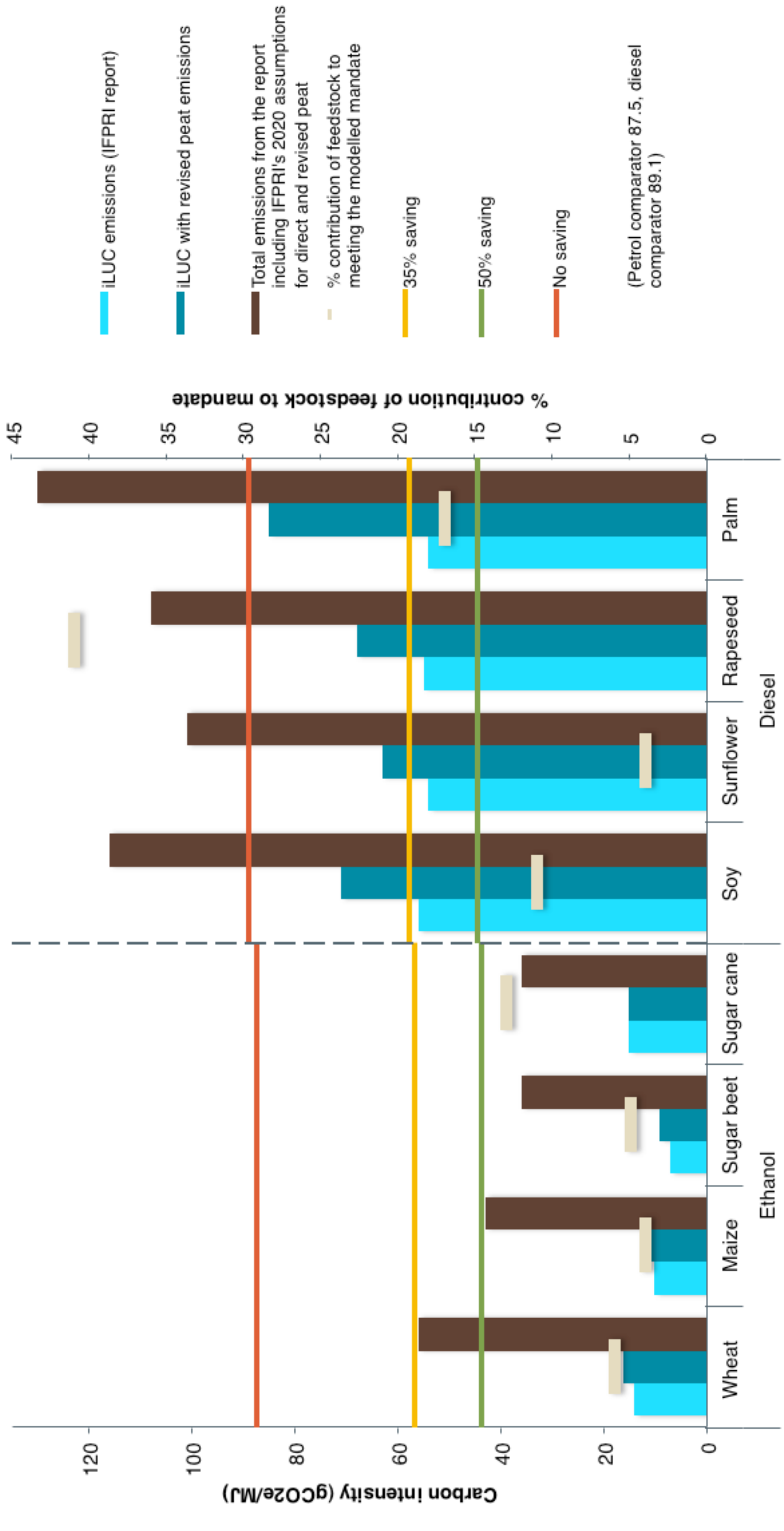


Table 4. IFPRI MIRAGE 2011 model results for use of feedstocks and iLUC emissions (incl. with revised peat emissions from Page et al. (2011))

Feedstock	Percentage contribution to the modelled mandate	iLUC emissions	iLUC with revised peat emissions	Total emissions including typical direct (with revised peat)
Wheat	6%	14	16	56
Maize	4%	10	11	43
Sugar beet	5%	7	9	36
Sugar cane	13%	15	15	36
Soy	11%	56	71	116
Sunflower	4%	54	63	101
Rapeseed	41%	55	68	108
Palm	17%	54	85	130

The IFPRI explanation for the low land use change emissions of the cereals (wheat and maize) is that because the global markets for these crops are very large compared to biofuel demand, there is more space for overall demand to be reduced instead of requiring additional supply. For wheat, holding food and feed consumption steady would increase iLUC by 40%. They also note that the displacement of livestock feed by co-products plays an important role.

Competition between food and fuel

One source of biofuel feedstock in economic models is reduced consumption in the food sector. IFPRI runs an alternative scenario in which food consumption is kept constant[5]. They find that the carbon intensity of the mandate increases by about 20% to an average 46 gCO2e/MJ. Wheat is the individual feedstock with the largest percentage carbon intensity change (a 21% increase if food consumption is kept constant).

IFPRI notes that in their modelling fruit and vegetable production lose out – this may have limited impact on overall calorific production, but could have additional health implications.

Biodiversity

As well as carbon emissions, there is a concern that iLUC could lead to biodiversity loss. MIRAGE models the substantial majority of land use change happening on managed land (cropland or managed forestry) with only 3 or 4% of expansion occurring in primary forest, and about 16% coming from savannahs. If we assume that cropland expansion on managed areas is likely to be relatively biodiversity neutral (although this is worthy of further consideration) that means that there

5 The use of products as inputs for food processing is still allowed to vary – e.g. the use of oils in processed foods could change, or the quantity of flour in processed food could be reduced.

would be up to 300 – 400 kha of land converted with a significant biodiversity effect.

Uncertainty

The report notes that several factors that could affect net emissions are unaccounted for:

- Any possible reductions in iLUC due to the RED sustainability criteria. IFPRI note (and we concur) that there is little or no evidence that this would be a significant factor;
- Emissions from extra fertiliser use that is modelled to increase yields;
- Emissions from the 'fossil rebound', where biofuel availability slightly reduces **crude oil** prices, which in turn causes crude oil consumption to push back slightly (i.e. total consumption of energy rises due to the availability of biofuels);
- Emissions savings from reductions in European transport fuel consumption because biofuel blending pushes up the price **in Europe** of petrol and diesel at the pump.

IFPRI have also explicitly undertaken sensitivity analysis on several supply side parameters: share of expansion in primary forest; elasticity of demand for food commodities from processing sectors; yield on new land; 'factor intensification' (capacity to use capital and labour to increase land yield); 'input intensification' (capacity to use feedstuff and fertiliser to increase land yield); ease with which one crop (e.g. wheat) displaces other types of crop (e.g. cotton); elasticity of land extension.

They find that the ranking amongst crops is quite robust to varying parameters. This is important, as it supports the viability of using iLUC factors to drive feedstock choices. They do note, however, that this sensitivity work still does not capture the full range of potential uncertainty. For instance, Laborde and Valin (2011)[6] found much higher iLUC values by constraining demand side parameters (inelastic food and feed demand).

Effect of trade liberalisation

IFPRI, as in 2010, has modelled two sets of scenarios – one with liberalised trade and one with current trade rules. Liberalising trade rules is projected to slightly increase the carbon intensity of the mandate by 2 gCO2e/MJ. Unlike in the 2010 modelling, changing the trade regime is not projected to make a substantial difference to the carbon intensity of any given feedstock. We therefore do not consider the trade regime to be a significant source of uncertainty in the marginal iLUC factors.

6 We blieve this paper is forthcoming, an early version can be downloaded from lnkd.info/sites/default/files/Laborde&Valin.pdf

Why does ethanol perform better than biodiesel?

- Demand shifting – IFPRI models vegetable oil markets as being relatively inelastic compared to cereals markets – i.e. demand for vegetable oil for food, cosmetics, etc. doesn't fall much even if prices rise.
- Sugarcane and palm oil are both high yielding, but palm is heavily associated with carbon loss (notably peatlands) while sugarcane is much less so.
- The vegetable oil market is well connected, so any vegetable oil demand results in some palm oil expansion (which is linked to high emissions) and some sunflower expansion (which has low yield and thus requires a large area).
- There is more 'flex' in cereals markets than vegetable oils markets. Wheat and maize are expected to displace other crops in the first instance, which can displace other crops again, with this crop shifting reducing the net land demand. According to IFPRI, preventing this displacement from happening would approximately double the iLUC emissions.

Conclusions

IFPRI conclude that 'in terms of environmental benefits, [biofuels] may not be the best tool to achieve initial targets.' The report suggests that without further action European biofuel support policies may not deliver any net GHG benefits, but also gives a clear steer that ethanol pathways are likely to be significantly less carbon intensive than biodiesel pathways (unless iLUC could be avoided for some vegetable oil crops). It identifies measures to increase relative ethanol supply as environmentally positive.

The report provides potential iLUC factors, but we should note that IFPRI is cautious of iLUC factors as a policy solution. On the other hand, IFPRI is positive about the possibility of revising the energy mandate downward and allowing only the 'best' biofuels to contribute. They also clearly identify that it would be appropriate to shift demand away from biodiesel and towards ethanol based on these results.

IFPRI argue that biofuel policy should be flexible to overall redirection in the light of new information (such as this report). Also, because biofuel demand is quite inelastic it will increase agricultural market volatility, with potential adverse welfare consequences. IFPRI therefore argue that more short-term flexibility should be built into the biofuel mandate, e.g. to reduce biofuel demand in periods of high prices.