Working paper
2011–9

THE INTERNATIONAL COUNCIL
ON CLEAN TRANSPORTATION

Indirect land use change in Europe – considering the policy options

Assessing the 2011 IFPRI MIRAGE iLUC modelling for the European Commission and possible policy alternatives

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Date: November 2011

Paper number: 9

Abstract

The European Commission recently released updated results of modelling by the International Food Policy Research Institute of the likely indirect effects of the EU's biofuels mandate. We critically assess this work, concluding that while there are inevitably areas that could be improved with further development it is a robust study and representative of best practice in the field of CGE modelling of iLUC. We note that in several areas criticisms made by the European Biodiesel Board do not appear to be well supported.

The European Commission is mandated by the Renewable Energy and Fuel Quality Directives to recommend a specific methodology to deal with indirect land use change, if deemed appropriate based on the best available scientific evidence. Based on a simple spreadsheet model of available biofuel feedstocks and pathways under various policy alternatives, and treating the IFPRI MIRAGE modelling results as the best available evidence, we show that without action on iLUC there are unlikely to be significant (if any) net emissions reductions from European biofuel support policies. We note that based on UK DfT cost figures for 2020, the cost of carbon abatement with biofuels in the absence of measures to address iLUC could be around €2,500 per tonne of carbon dioxide abated.

We find that the introduction of iLUC factors, or of policies that otherwise prevented the use of the highest iLUC fuels (biodiesel from unused vegetable oil), would increase the expected carbon savings of the policy by a factor of ten, but note that it might be challenging to meet the current level of aspiration for total energy use with such strong policies. We suggest that even with conservative (high) estimates of the cost of sourcing low emissions and/or low-iLUC biofuels, effective iLUC reduction policies could cut the expected carbon abatement cost of EU biofuels policy by a factor of 5.

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Introduction

Since 2008, in particular the publication of FAPRI modelling by Searchinger et al. (2008) and the UK Government's Gallagher Review (RFA, 2008), indirect land use change (iLUC) has been an important and open question for European biofuel policy. With Searchinger predicting that iLUC emissions would overwhelm any carbon savings from biofuel use, and Gallagher reinforcing the message that the issue was significant and must be addressed for biofuel policy to have clear climate benefits, pressure on the European Union to act resulted in an obligation to assess iLUC being written into the Renewable Energy and Fuel Quality Directives.

The European Commission has responded to this obligation with various studies and consultations, including proposing four different approaches to the problem that could be reflected in future European biofuel legislation. In short, these approaches are to:

- Monitor the situation but do nothing yet;
- Reduce the maximum threshold for the ***direct*** emissions caused by biofuels production (hence raising the threshold for the 'direct saving');
- Apply additional sustainability criteria to some or all biofuels;
- Account for iLUC in the GHG assessment.

In this paper, we present a short reminder of the basics of the iLUC discussion, followed by a detailed look at the quality and results of the latest iLUC modelling for the European Commission by IFPRI MIRAGE. We then take use the results of that modelling to briefly discuss the possible carbon emissions consequences of applying each if these four options in term to European biofuels policy.

The science of indirect land use change

There is no question that indirect land use change will be a consequence of European biofuel mandates. The additional supply of feedstock required to produce biofuels for Europe must come from some combination of:

- Reduced stocks of agricultural commodities;
- Reduced consumption in food and other sectors;
- Increased productivity on currently cultivated land;
- Cultivation of biofuel feedstocks on currently uncultivated land.

We tend to ignore reduced stocks in the discussion about indirect effects, because reducing stocks is unsustainable – you can do it for one year, or maybe two or three years, but it is not an option for a long term biofuel mandate. We shall therefore not discuss reduced stocks as a source of biofuel feedstock further, except to note that the reduction in stocks resulting from primarily US and EU biofuel demand has been associated with the increased volatility of agricultural commodity prices, which has significant associated welfare impacts. Reducing stocks is therefore neither sustainable nor, arguably, beneficial.

The extent to which biofuel use will lead to reduced consumption of food and other commodities is an important and controversial question. It is generally accepted that biofuel mandates will cause food prices to rise, and that this in turn will result in a reduction in food consumption. In the developing world, in particular, this is considered problematic, and several studies have suggested that the price impacts of biofuel production could result in tens of millions of people being pushed below the poverty line[1]. For other markets, we may have less concern – for instance reductions in tobacco consumption might be seen as beneficial, while food consumption reduction in developed countries like the United States would not be associated with such serious welfare impacts as in sub-Saharan Africa. Regardless of your opinion about the desirability of reductions in consumption, it is an important question for iLUC modelling – the more biofuel feedstock that comes from reduced consumption, the less need there is for land expansion.

Many biofuel stakeholders hope to see increased commodity prices due to biofuel production driving investment in agriculture, and causing an increase in the rate of yield improvement. This price induced yield change, it is argued, will reduce (or, in the most optimistic versions, prevent) the need for expansion into uncultivated areas. Economic models include this factor, but the magnitude of the effect compared to land expansion has been the subject of extensive debate.

Finally, whatever amount of the feedstock needed for biofuel production is not taken out of stocks, taken from other end users or generated through yield increase must be produced by expanding the area of agricultural cultivation. This is indirect land use change. Unless one is willing to argue that the entire resource base for the biofuel industry can be obtained through some combination of the first three elements, one must accept that indirect land use change is bound to happen to some extent. The remaining question becomes what the carbon cost of this land use change is – for instance, bringing idle land in Europe back into production will have different carbon consequences than draining and logging a peat forest in Malaysia. Because it is impossible to observe the world and identify every specific hectare of expansion that will only have occurred due to increased demand for biofuels, regulators and economists have used economic modelling to address these questions and to try to project what the likely iLUC consequences of biofuel policies will be.

Modelling the European biofuel mandate: IFPRI MIRAGE

The most important indirect land use change modelling effort for Europe has been undertaken using the IFPRI MIRAGE economic model (Al Riffai et al., 2010; Laborde, 2011). This model has been used to estimate both the overall carbon emissions from land use change due to the European Renewable Energy Directive and the emissions associated with increasing the demand for biofuel based on specific feedstocks – 'iLUC factors'.

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[1] De Hoyos and Medvedev, 2009., Cororaton, Timilsina and Mevel, 2010, Wiggins et al. 2008

IFPRI MIRAGE aims to include all of the most important factors that would affect the carbon intensity of European biofuels. This includes several factors that reduce the net land use demand from the mandate. In this section we consider several of the key elements of the MIRAGE modelling, including where appropriate considering criticisms that have been made of these model elements.

Price induced yield change

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 in the model is the process of increasing the use of labour or capital for every hectare of land. Increased capital spending represents things like adopting improved cultivation technologies and equipment. This has the effect of increasing the yield of a given crop when prices increase. This factor intensification can represent technological progress, technology adoption, the introduction of new varieties and so on. We assume that factor intensification itself (before considering its effect on land demand) would not result in significant systematic increase or decrease of carbon emissions – some technologies would no doubt increase the carbon intensity of agriculture, but equally others will no doubt reduce it. We therefore expect that factor intensification will reduce expected iLUC emissions, and that these reductions will not in general be offset by increases in other emissions.

Input intensification in the model is the process of increasing the use of fertiliser or other agricultural feedstuffs as prices increase. In contrast to factor intensification where the GHG consequences are unclear, we would expect increased fertiliser inputs to have potentially significant carbon equivalent emissions consequences, as nitrogen fertiliser manufacture and use in particular 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). We note that MIRAGE does not attempt to account for these increased fertiliser emissions (the only major modelling exercise of which we are aware that attempts to include increased fertiliser emissions is the modelling using FAPRI for the US Environmental Protection Agency[2]). It has been suggested (e.g. Edwards et al. 2010) that the increased emissions from fertiliser application could more than counteract any emissions benefit from reduced iLUC due to fertiliser intensification.

Given this, ignoring fertiliser emissions in MIRAGE is a concern, and a potentially appropriate area for additional work. Having said this, factor increase is a much larger fraction of price induced yield increase in the MIRAGE results than fertiliser intensification is. This suggests that while fertiliser emissions are important, they would be unlikely to fundamentally change the model outcomes.

The sum of the fertiliser and factor intensification effects is calibrated by varying the factor intensification elasticity in order to generate an average global yield-on-price elasticity of 0.2, with a lower value (0.15) in Europe and high value (0.3) for the developing world. This developing world value is intended to include the potential for double cropping in developing regions, and reflect the larger gap to technically achievable yields.

The magnitude and existence of price induced yield change has been the subject of much discussion in recent years, particularly in the context of biofuel production. Berry and Schlenker (2011), Berry (2011) and Roberts and Schlenker (2010) have all noted that there is a paucity of evidence for a net price induced yield change, both in the existing agro-economic literature and in the historical statistics. Berry and Schlenker (2011) in a report to the ICCT use an economically sophisticated method of instrumental variables to assess short run responses of yields to prices, finding no statistically significant evidence of a connection. For agricultural area, in contrast, they found strong statistically robust correlations to price for several regions. While this statistical evidence does not preclude the possibility of a positive but low net elasticity of yields to prices (values under about 0.1 could still be consistent with the statistical evidence, but so could small negative values), or that in the longer term the effect would be more pronounced, it certainly provides a strong counter-argument to any suggestion that yield change will be the dominant response to price increase.

Others have argued for a strong effect of biofuel related price increases on yields, such as Bruce Babcock as lead author of the California Air Resources Board iLUC Expert Workgroup subgroup report on elasticities (Babcock, Gurgel and Stowers, 2010) who has noted that increases in double cropping in the US and Brazil suggest that farmers will react to increased prices by increasing productivity. However, it is unclear how significant this effect is, or that the increases in double cropping in 2007 that are at the centre of this argument will be sustained and are really linked to price.

Overall, we believe that considering the lack of support in the historical data for a strong connection between price and yield the IFPRI MIRAGE modelling system can be considered to paint an optimistic (perhaps ‘best case’, or at least ‘good case’) picture of yield change, which would tend to contribute towards underestimating iLUC effects.

As we noted above, Berry and Schlenker (2011) find not only that there is no compelling historical evidence of net yield elasticity to price, but that there **is** in several regions significant evidence of area elasticity to price (crop areas increasing when prices increase). We note that while IFPRI MIRAGE is optimistic about yield elasticity compared to the historical data, it does apply the same *hierarchy* of elasticities identified by Berry and Schlenker; i.e. the area elasticity in MIRAGE is somewhat higher than the yield elasticity. We find the preservation of this hierarchy reassuring regarding the quality of the model results.

Co-products/by-products of biofuel production

Biofuel production does not fully utilise the crops used

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[2] For more details on this EPA rulemaking see http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm

as feedstocks. Ethanol production uses carbohydrates, for instance, so that proteins and fats are leftover. Oilseed crushing produces oil for biodiesel, but there are proteins and carbohydrate leftover. It is important in modelling iLUC that this is taken into account, as the production of these co-products reduces the net land requirement for biofuel crops by a substantial amount.

One criticism, especially from the ethanol industry, of previous modelling has been that iLUC models may have adequately accounted for the different nutritional content of different feed products. In simple form, the argument goes that both DDGS and oil meals are high in protein, but that some modelling in the past has effectively only considered the total energy content of the feed. This might mean that a model predicts that co-products would displace an energy feed that had a weak link to deforestation, when in reality it could at least partly replace a protein crop with string links to deforestation, thus failing to capture the GHG benefits. For this reason, the latest IFPRI MIRAGE modelling captures the protein content of these feeds, and allows co-products to preferentially displace other protein feed (unlike, for instance, GTAP in which distillers grains have displaced corn at the first order, and only secondarily been allowed to displace protein feed).

In a CGE model like MIRAGE there are two ways that we can look at the effect of co-products. The first is to look at the animal feed market in the model, and how it changes overall – do if DDGS use to feed animals increases, does the use of other feed products change. This gives us a 'macro' effect, but it includes not only the modelling of feed displacement but also other economic effects (changes in livestock production, changes in feed prices etc.). The second way to consider the effect is by looking directly at what displaces what. This tells us whether the model captures the dynamics described above, but may be misleading about the overall impact on the feed market. We discuss both in the following subsections on ethanol and biodiesel coproducts respectively.

Ethanol coproducts

In the case of grains for ethanol (wheat, maize) only the carbohydrate part of the nutritional value of the plant is turned into ethanol. About a third of the calorific content is left over, including a concentration of protein and fats

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). Based on Laborde (2011).

	Ethanol maize		Ethanol wheat		Biodiesel rapeseed		Biodiesel soybean	
Feedstock	**Change in feed use (tons)**	**Percentage of displacement**	**Change in feed use (tons)**	**Percentage of displacement**	**Change in feed use (tons)**	**Percentage of displacement**	**Change in feed use (tons)**	**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%**

that are largely unaffected by the fermentation process. This leftover material is referred to as Dried Distillers' Grains and Solubles[3] (DDGS).

DDGS is used as an animal feed ingredient in both Europe and the US, and we would expect increased DDGS availability to result in increased inclusion of DDGS in livestock diets. This will result in less demand for other feed ingredients. IFPRI MIRAGE models the production of DDGS based on up to date industry data, and allows them to substitute both energy feeds and protein feeds in livestock diets. This is important, because as a 'mid-protein' DDGS should in principle have more value in livestock diets than wheat feed.

In the IFPRI results, the major net outcome of increased maize and wheat ethanol production on the animal feed market is a reduction in the use of maize and wheat feeds respectively, (Table 1). There is some displacement of oil meals such as soy meal, but these changes represent feed quantities only about 5% - 10% of the increased DDGS supply. On face value, for EU wheat DDGS markets at least this result might seem to underestimate the amount of protein feed likely to be replaced – for instance, Hazzledine et al. (2011) for the ICCT suggest that in the UK soy meal would account for at least 30% of the feed displaced by wheat DDGS, with other mid proteins making up another 30% or so (in the US, a low rate of soy meal displacement may well be appropriate – a forthcoming ICCT study will suggest that a value below 10% may be reasonable).

This is not, however, the full story. IFPRI models not only the 'direct' consequence of introducing additional DDGS into the feed market (substitution according to a constant elasticity of transformation between DDGS and other feed products) but also models the knock on economic consequences of these shifts in the feed market. The results in Table 1 tell us the net outcome of this economic chain of events, and therefore we should not expect the numbers to be directly comparable to the displacement ratios suggested by Hazzledine et al. (2011) or Lywood et al. (2009).

What we find is that the combination of increased wheat/maize demand for ethanol, and increased supply of protein feed in the form of DDGS, is modelled to alter the balance of energy and protein feed use across the livestock industry.

Reduced protein feed prices drive an overall increase in protein feed demand, making up for the soy meal etc. that was displaced by distillers grains so that there is very little net change in the consumption of soy meal in these scenarios. Wheat/maize utilisation for feed reduces at the same time, because the price of these ethanol feedstocks rises, despite the low direct displacement of wheat and maize by DDGS. All of this could give the impression that DDGS have directly displaced these energy feeds – this is not so.

IFPRI provide us with the direct displacement results in Table A 12 of the IFPRI report, reproduced as Table 2 here. Looking at these results, we see that if total feed consumption is held constant wheat distillers replace 35 – 38% soy meal, which is broadly consistent with Hazzledine et al. (2011). Maize DDGS displace slightly less soy meal, about 30%. This lower value is consistent with the lower protein content of maize DDGS. For European maize ethanol production, this seems a reasonable value to us. For the US, on the other hand, we expect to see

Table 2. Displacement in tons of various animal feed commodities from the diet of given animal types when supply of each biofuel coproduct in turn increased by one ton. From Laborde (2011).

	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
DDGSWheat			-0.02	-0.02	-0.02	-0.02	-0.06	-0.07	-0.01	-0.01
DDGSMaize	-0.02	-0.03			-0.03	-0.03	-0.08	-0.09	-0.02	-0.02
MealRape	-0.14	-0.16	-0.12	-0.13			-0.49	-0.59	-0.11	-0.12
MealSoyb	-0.35	-0.38	-0.29	-0.32	-0.39	-0.43			-0.26	-0.28
MealSunf	-0.04	-0.04	-0.03	-0.04	-0.04	-0.05	-0.13	-0.16		

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[3] There are other variations on the use of this material, such as Wet Distillers' Grains and Solubles (WDGS) and corn gluten meal, but as all of these co-products are used similarly as animal feed we shall not dwell on the distinctions and assume that when we say DDGS we are referring to all of these products.

much more limited soy substitution by maize DDGS (less than 10%) due to the different market dynamics in the US, as we will outline in a forthcoming paper, so this might represent an overestimate.

While the direct replacement of soy meal and rape meal by DDGS seems broadly consistent with expectations, cereals replacement is lower than we would expect, and the overall ratio of tons of additional feed to tons of displacement for DDGS is below 1:1. This may be somewhat ameliorated by reduced requirements for pasture land as a livestock input in the model (equivalent to having DDGS replace a certain amount of forage. We would recommend that the determinants of this ratio could be further examined for future modelling, and that a ratio that is not close to 1:1 should be carefully explained. We do note, however, that across the model the net effect comes out close to an effective 1:1 displacement by mass of other feeds by DDGS.

Overall, we find that feed replacement by DDGS is adequately modelled, with a strong substitution of protein feeds by DDGS and first-order soy replacement potentially slightly over-estimated – and given the expectation that soy meal in particular has a more significant iLUC effect than cereals replacement, we would expect the overall iLUC implications of underestimating cereal displacement and a smaller overestimation of soy displacement to be relatively neutral.

Biodiesel coproducts

In the case of oilseeds, the crushing process that produces vegetable oil again results in a co-product, the oil meal. For some oilseeds, like soy, this meal is the most important part of the production with more value than the oil. For other oilseeds, like palm, a relatively small amount of meal is produced, and its value is not very significant compared to the value of the oil. The comparative importance of the oil as a product of oilseed cultivation is why we expect to see a stronger response of palm production to increased vegetable oil demand than soy production – palm production essentially responds only to oil demand, whereas soy production actually responds primarily to demand for meal. Rapeseed and sunflower meals fall somewhere between these extremes.

Looking again at Table 1, we see that for the rapeseed and soy biodiesel scenarios we get an increase in market use of not only the ‘primary’ meal, but also the other oil meals. This is because the oil markets are strongly connected, so that increasing rapeseed oil demand can also result in an increase in soy production etc.

Overall, the net outcome is more balanced than for the wheat and maize ethanol scenarios, with reductions in the use of wheat and maize feed, but also more substantial reductions in the use of oilseeds as feed, around 25-30%. This is consistent with a shift from direct use of oilseeds as animal feed to crushing an increased proportion of seeds, and using only the meals for feed.

Again, the results of looking at the ‘direct’ displacement of feed ingredients present a somewhat different picture (Table 2). We see a very strong substitution of other protein meals, with soy meal also displacing a substantial amount of cereals as well. The JRC/EUCAR/CONCAWE (JEC) Well to Wheels study (2008) suggests that rapeseed meal in Europe will replace about 50% wheat by weight and 38% soy – MIRAGE is consistent with this replacement percentage for soy, but the substitution of cereals by rapeseed is rather low, less than 10%. As in the case of DDGS, it may be that MIRAGE is to some extent allowing rapeseed meal to replace pasture rather than other feed ingredients, which could partially explain the less than 1:1 overall replacement ratio. We also note that rapeseed meal has a lower metabolisable energy per ton than some of the other feed ingredients, which also supports a lower than 1:1 replacement. Nevertheless, there is certainly a chance that the low replacement of cereals by rape meal and sunflower meal could tend to overestimate iLUC effects. Still, as discussed above the displacement of soy is likely to have the strongest effect on the end results, and this seems to be well captured, which is reassuring.

For soy meal, the overall ratio of substitution is actually above 1:1 for both cattle and other animals, presumably driven largely by the high nutritional value modelled for soy meal. The relative displacement ratios themselves seem fairly reasonable. The model may therefore have overestimated the beneficial effect of soy meal on the iLUC from soy biodiesel, but again we would not expect this to be a dominant effect in the results.

The Kiel Institute (2011)[4] review of the MIRAGE results found that “We think that by-products of bioethanol and biodiesel are well treated by the model.” (S&T)[2] (2011) also reviewed the co-product treatment, giving a more substantial critique of MIRAGE. They correctly note that the IFPRI nested substitution model is a simplification of the least cost formulations used to determine feed mix in the real world[5]. IFPRI MIRAGE does represent the protein and energy content of biofuel co-products and has a relatively sophisticated treatment that ensures a realistic replacement rate of soy meal.

While there is clearly space for additional examination and more sophisticated modelling of the dynamics of the oil seed/meal markets, we see no clear case in the available outputs that the latest MIRAGE modelling has either systematically over- or under-estimated the replacement of other protein meals by rapeseed meal or soy meal. We also note in concordance with the Kiel Institute that the treatment in MIRAGE seems to be consistent with best practice available in CGE modelling at the moment, and compares favourably with (for instance) the approach used in the GTAP model.

Vegetable oil markets

Because the modelling results suggest that biodiesel from oil crops is not a good GHG mitigation option for Europe, there has been some focus on the way that IFPRI treats vegetable oil markets. In MIRAGE vegetable oils from different oilseeds are treated as being essentially

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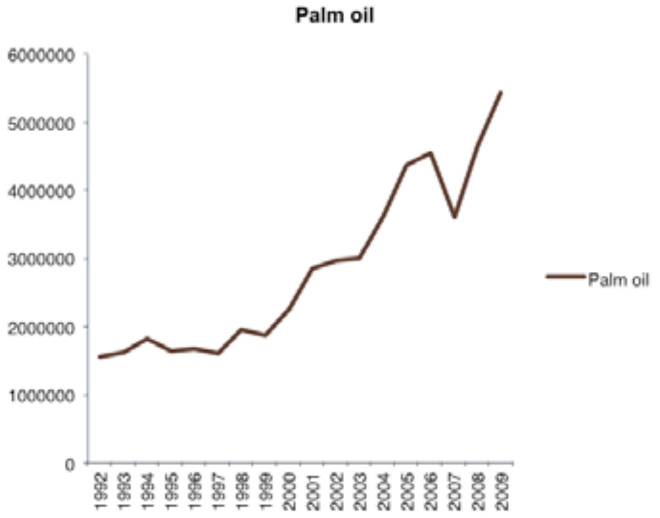
[4] http://www.ebb-eu.org/EBBpressreleases/Review_iLUC_IfW_final.pdf

[5] For more on least cost formulation see Hazzledine et al. (2011)

fungible, meaning that rapeseed oil could replace or be replaced by palm oil etc. for any given application. This is important, because palm oil expansion is associated with high emissions. 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.

This idea of 'fungibility' is consistent with our day to day experience (consider the number of processed food products that are marked as containing generic vegetable oil) and is also somewhat consistent with statistics for European biodiesel imports, with imports of soy and palm for biodiesel vs. use of domestically produced feedstocks varying as market conditions have varied (e.g. the rise and fall of splash and dash[6]). Certainly, it is not in contention that European palm oil imports have been steadily rising for the last couple of decades (Figure 1).

Figure 1. Rising palm oil imports to Europe (FAOstat)



We can highlight the place of palm oil in filling displaced demand in IFPRI 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? From Laborde 2010.

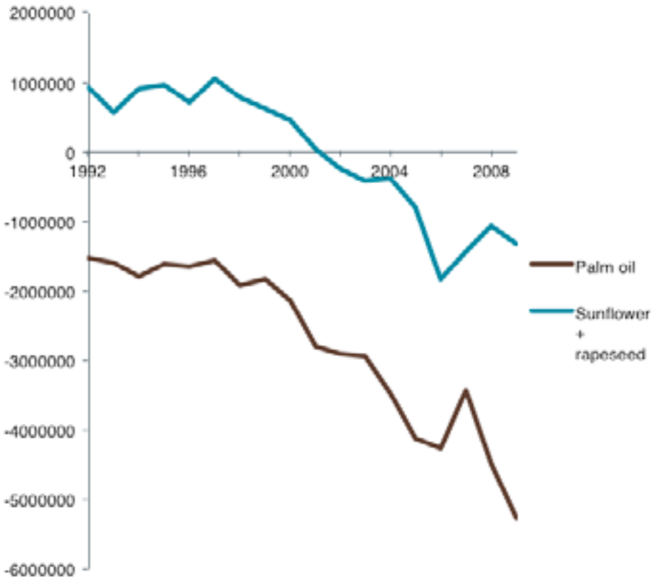
Feedstock	% of increased demand met by supply of that feedstock	% of increased demand met by palm oil/demand reduction/ other oils
Palm	96.6	3.4
Rapeseed	78.2	21.8
Sunflower	71.0	29.0
Soybeans	40.3	59.7

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.

The European Biodiesel Board has led criticism of the IFPRI treatment of vegetable oil substitution, claiming in a position paper that, "the study assumes important substitutions effects between vegetable oils, which does not to correspond to the reality of the European biodiesel market (technical limitation on palm oil use for instance)." Given the implication that MIRAGE unfairly links rapeseed and other oil demand to palm oil supply, it is worth looking in more detail at the dynamics of EU vegetable oil markets.

One place to look is at FAO data on European imports and exports of palm oil. If we compare Europe's net exports of vegetable oils over the last 20 years, a clear pattern seems to emerge (Figure 2), with demand for European vegetable oils and imported palm oil seeming to be closely linked.

Figure 2. European trade balance for palm oil and the aggregate of sunflower oil and rapeseed oil (net exports are positive, net imports negative). (FAOstat)



We can combine FAO data with European Biodiesel Board values for EU biodiesel production to further consider whether it seems reasonable to suppose that demand for European vegetable oils for biodiesel will lead to increased palm imports. In Figure 3 we see that increasing European biodiesel production has apparently coincided with a slight reduction in European vegetable oil exports, but a major increase in vegetable oil imports. If we look only at the major European produced oilseeds, we see that the increase in biodiesel production occurs at the same time as a precipitous increase in vegetable oil imports even for oilseeds produced locally (Figure 4).

We should also consider production of European oilseeds. In Figure 5 we see that rapeseed production in Europe

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[6] Splash and dash refers to a period during which biodiesel could be blended with a 'dash' of diesel in the US for a credit, and then exported to Europe to exploit biodiesel support credits, thus harnessing a double incentive. The practice has been controlled by measures in both juridictions.

Figure 3. European aggregate imports (brown) and exports (blue) of major vegetable oils, against increasing demand for oil for European biodiesel production. (FAOstat, European Biodiesel Board).

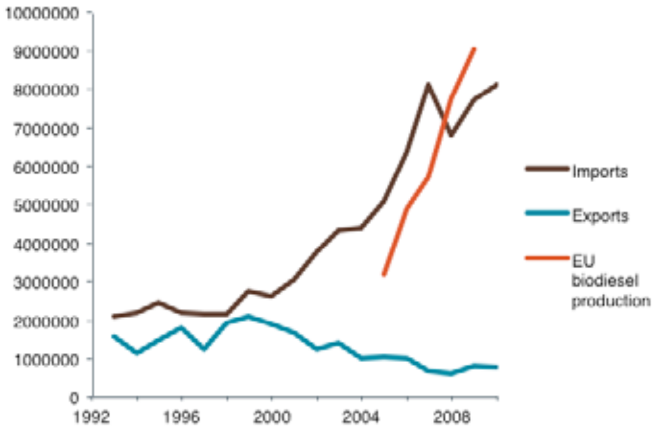


Figure 4. Sunflower and rapeseed imports to Europe increase (and exports fall) from 2000 onwards. (FAOstat).

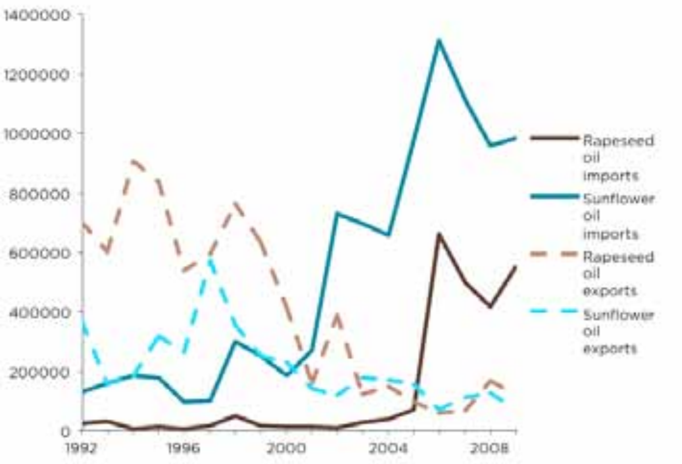
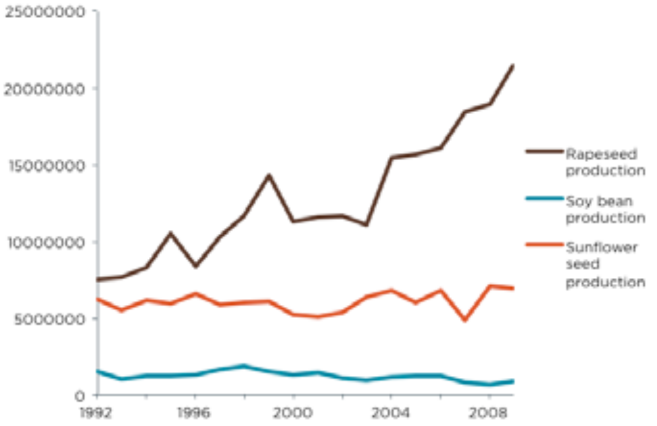


Figure 5. EU oilseed production (tonnes). (FAOstat)



has indeed also been increasing since 2003 – although sunflower and soybean production are relatively stable.

All of these trade data seem to suggest a reasonably clear narrative – increased demand for biodiesel has resulted in a combination of increased production of oilseeds in Europe, reduced exports of vegetable oil out of Europe and increased imports of vegetable oil including palm oil. This is consistent with the MIRAGE modelling.

Increased rapeseed production has not been enough to meet the full market demand for vegetable oils. It is therefore extremely reasonable for MIRAGE to expect that increased demand for rapeseed biodiesel will not result only in increased rapeseed production in Europe. Reduced exports will either mean reduced consumption in the rest of the world ('food vs. fuel') or replacement with oils from elsewhere. Increased imports (primarily palm oil – 2009 imports of palm and palm kernel oil together were three times imports of sunflower, rapeseed and soy oil together) will require either reduced consumption or increased production elsewhere.

The European Biodiesel Board implies that MIRAGE overestimates the extent to which palm oil will replace rapeseed used for biodiesel. The biodiesel industry in Europe tends to suggest that European biodiesel can and will be supplied by expanded production only in Europe and at low carbon cost. On the contrary, we believe that MIRAGE's figure of 78% of increased rapeseed oil demand being met by increased rapeseed oil production is consistent with data about global oil markets, and is at least as likely to underestimate the true long term substitutability of palm oil for rapeseed oil as overestimate it. It also seems likely that as well as rapeseed expansion in Europe and palm oil expansion in South East Asia, increased rapeseed biodiesel demand will drive expansion of rapeseed and other oilseeds in other regions of the world.

The two reviews commissioned by the European Biodiesel Board are broadly consistent with these conclusions. The Kiel Institute comments that:

> "The price competitiveness of palm oil leads to the substitution of non-energy uses of oils towards palm oil. However, since these demands cannot be met on current land areas devoted to palm oil production, there will be expansion, i.e. iLUC for palm oil plantations."

This is consistent with the trade data showing that palm oil is the dominant imported oil in Europe and that imports have grown in step with biodiesel production. Don O'Connor of (S&T)[2] makes a more subtle argument, pointing out that there are limits to the substitutability of vegetable oils. For food markets (the more important question, as the indirect effects of increased biodiesel use are transmitted largely through food markets) he notes that "in the food sector the vegetable oils do not have full substitutability. Issues such as trans fat has favoured palm oil over soybean oil in many food applications." For the biodiesel market, he further comments, "Each feedstock gives the biodiesel some unique properties, including cloud point and stability."

This concern about substitutability is reflected front and centre by the EBB, who state, "the study assumes important substitutions effects between vegetable oils, which does not correspond to the reality of the European biodiesel market." However, the case for limited substitution for food is weak, with (S&T)[2] talking only about one example limitation (which actually causes palm to be favoured over soy, potentially driving iLUC emissions up).

We believe that it is reasonable to assume that the consistently upwards trend in palm oil imports to the EU will be able to continue in the short and medium term, and that the MIRAGE results are consistent with this pattern. We believe that it is reasonable to assume that the consistently upwards trend in palm oil imports to the EU will be able to continue in the short and medium term, and that the MIRAGE results are consistent with this pattern. Furthermore, substitution does not have to be directly between rapeseed and palm oil in EU. Vegetable oil price changes are easily transmitted around the world (because of the high degree of international trade), so even if one supposes a limit on palm oil penetration in EU, that limit would have to be reached in the entire world before substitution by palm oil would cease.

Regarding biodiesel, firstly we note that as biodiesel remains a minority market for vegetable oils, technical limitations in that market are unlikely to dominate the transmission of indirect effects. That not withstanding, the Kiel Institute actually concludes that assuming high palm oil substitutability for biodiesel use may be reasonable, "A recent study by Greenpeace Germany testing for biofuel admixtures in European filling stations found high shares of palm oil in the biodiesel shares (up to 80% in Italy), showing that this result is not unrealistic." This is also consistent with the pattern of increased palm oil biodiesel imports in 2011 noted by EBB itself. If one adds to this the likelihood that hydrogenated vegetable oil processes could be significant sources of drop-in palm oil based diesel with no cold flow issues or blend limits by 2020, we see no reason to suppose that the MIRAGE modelled substitutability and overall use of palm oil biodiesel is unreasonable.

Food, feed (and other) consumption elasticity

It is a basic economic tenet that increasing the price of some good will tend to reduce the level of consumption of that good. If the price of cigarettes increases, we expect that fewer people will smoke cigarettes. If the price of televisions rises, we expect people to buy fewer new televisions.

In the same way, if the price of feedstocks rises due to increased demand for biofuel, we expect to see consumption of feedstocks in other sectors fall. The current generation of biofuels is based on crops that would otherwise be used largely for food and feed. When we say food, we mean material directly for human consumption, such as wheat to make bread. When we say feed we refer to material for animal consumption, such as wheat being fed to pigs. When increased biofuel demand raises the price of agricultural commodities, we will therefore expect to see a reduction in food and feed demand.

In IFPRI MIRAGE, the extent to which biofuel expansion causes reductions in consumption in other sectors is determined by the demand elasticity to price. If demand is highly elastic, then as prices rise consumption will strongly decrease. If, on the other hand, demand is inelastic, then even when prices rise we would not expect large reductions in consumption. In the context of the food vs. fuel discussion, we might note that either of these scenarios could have associated welfare concerns – for instance, if food consumption in the developing world is quite elastic it will make malnutrition due to price rises more likely, but if it is inelastic it would imply that consumers would need to spend an increasing fraction of income on more expensive foodstuffs, with implications for welfare in other areas. In fact, it is found that food demand elasticity to staple crop prices is highest in the developing world, primarily because in the developing world staple crop prices represent a much greater fraction of incomes. The USDA finds that developing world demand elasticities are three to ten times higher than those in the developed world, and this is reflected in the MIRAGE modelling (Laborde and Valin, 2010).

IFPRI notes that food demand elasticity has been reduced overall for the 2011 modelling work compared to the 2010 results. Food deficiency in developing countries was moderated by the assumption that as food prices increase, poor people would spend a greater portion of their income on food, and would switch to cheaper sources of calories. To help demonstrate the importance of food consumption IFPRI runs an alternative scenario in which food consumption is kept constant[7]. They find that the carbon intensity of the mandate increases by about 20% to an average of 46 gCO2e/MJ. Wheat is the individual feedstock with the largest percentage carbon intensity change (a 21% increase if food consumption is kept constant). We note that it is slightly unclear from the latest IFPRI report whether when they say food consumption is held constant this includes *all* food consumption or only that of the major modelled commodities (energy crops). There may be reductions of consumption of meat and/or fruits and vegetable etc. that are still permitted. Laborde and Valin (2011) using a similar model find an even stronger effect of holding food constant – iLUC increases by over 50% in those results to an average 61 gCO2e/MJ.

According to Table A8 of the MIRAGE report there is a very large shift of planted area away from 'other' crops and towards major commodity crops. For the maize marginal scenario, for instance, 3.69 ha/TJ is found from unspecified 'other crops', which compares to only 0.88 ha/TJ of actual cropland expansion. This gain in land must come from reduced demand for and increased productivity of other crops. IFPRI note that for wheat preventing this displacement of other crops would approximately double the iLUC factor, while for maize it nearly quadruples it. IFPRI notes that in their modelling fruit and vegetable production lose out to other crops – this may have limited impact on overall calorific production, and hence not show up as a large consumption loss in IFPRI's commodity balance sheet (Table 6 of their report), but

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[7] 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.

could have additional health implications. Therefore, apart from deriving a substantial part of the biofuel feedstock from a reduction in the quantity of food consumed, the MIRAGE model would appear to derive a potentially larger part from a reduction in food *quality*. Both sources are, of course, free of LUC.

Some models err when low-yielding but hardy crops (e.g. rye in the cereals group) are replaced with high-yielding (but sensitive) ones. As they assume single fixed yields of crops per region, the models predict that the yield will jump as a result of the crop change (in practice it could well lead to total crop failure). However, the IFPRI model, following GTAP, considers land distribution amongst crops in terms of land-rentals. IFPRI made a considerable effort to update the GTAP land-rental matrix (as a function of region, EAZ and crop-category) to make them proportional to yields in economic terms ($/ha). Therefore in principle, crops in IFPRI displace each other in terms of equal $/ha, which is economically rational. However, one can still expect problems because of the agglomeration of different crops into one category, especially one as diverse as “other crops”.

We are concerned that the ‘shuffling’ between different types of crop, leading to increases in dry mass productivity (i.e. maize achieves more tons per hectare than carrots) but not necessarily increases in all aspects of nutritional value (maize has much less vitamin A than carrots do) seems to be an important effect in the model, and may have been overestimated. If, on the other hand, it has not been overestimated, it suggests a more subtle element to the food vs. fuel debate that is worthy of discussion. While IFPRI’s treatment of food and fuel competition seems to go in the right direction, we believe that it is possible (as noted by IFPRI[8]) that for the cereal-based ethanols in particular these effects may be being overestimated, and hence iLUC underestimated – and that this underestimation could potentially be quite considerable.

Yield at the margin of production

When crops expand onto new land, it seems economically reasonable to expect that the yields are likely to be lower than on existing farmland. This is because if farmers make economically rational choices, we would expect them to be using the most productive hectares in their region.

IFPRI, following the lead of Purdue University’s GTAP model, assumes that yield on newly cultivated land is lower than on existing cropland. It sets this ratio at 0.75 for both developed and developing countries. This is a higher value for new cropland than used in GTAP for the California Air Resources Board, but in general lower than that used in a revised GTAP model in which land productivity estimates from the ‘Terrestrial Ecosystem Model (TEM)’ (Tyner et al. 2010) have been included. This TEM based analysis has been queried, however, at the CARB LCFS Expert Workgroup, notably because in several regions it predicted the economically irrational situation that new land should be *more* productive than existing land (GTAP caps the applied ratio at 1). We have yet to see convincing confirmation of the results of the TEM analysis, given that net primary productivity of corn-like crops (the modelled crop type) may not be representative of the yield of crops in general and that the inability of the model to consider economic factors may introduce unknown systematic biases. Another shortcoming of the TEM analysis is that yields were assumed homogeneous within each “pixel” of ~2500 km^2: any yield variations at finer scale were not included. That may be reasonable for the US Great Plains, but would certainly fail to capture the large range of yields in some European regions fro instance (in UK a factor of 0.65 has been reported even within individual farms).

On the other side of the marginal yield debate, some experts have contended that in reality the average yields at the margin of production could be much less than 0.75 of existing yields. Edwards et al. (2010) argues using historical data that within the EU, yields on marginal land were probably less than 1/3 of the EU average wheat yield.[9]

It is difficult given the current literature to confidently assert whether the 0.75 assigned by IFPRI is optimistic or pessimistic. Arguably, one would expect a higher ratio in countries (typically developing countries) with larger unexploited land banks, but this is not reflected in the MIRAGE modelling.

Although this is certainly an area of uncertainty, IFPRI note in their report that this parameter is rather less determinative of iLUC emissions than one might expect. While at the first order it is clear that reduced yield on new land would increase land requirements, IFPRI points out a ‘baseline issue’ that moderates the effect. In the baseline, agriculture expands in the years to 2020, even without biofuels. The lower the marginal yield, the more land is required in the baseline. However, the MIRAGE land expansion function assumes that land expansion is more likely when there is relatively plentiful land available – so if a larger fraction of the available land is used in the baseline scenario, the model is proportionately more resistant to further land expansion in the policy scenario, instead diverting pressure to demand reduction and yield improvement.

There is an insufficiently mature literature around this topic to firmly assert whether the treatment of marginal yield by IFPRI is too pessimistic or optimistic. Based on Edwards et al. (2010), we might tend to suspect that it is optimistic for the “old” world, but perhaps slightly pessimistic for the developing world. If we treat the baseline effect described above as an additional uncertainty (does the land transformation function that makes marginal yield relatively unimportant model the correct behaviour in this instance?) we might suspect that the

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[8] “It should be noted here that there is a potential risk of underestimating the LUC emissions for ethanol crops in this analysis.” Pg 71.

[9] Calculating average national yield of wheat, weighted by area of land abandonment gave a factor ~0.65, whereas the same calculation for a marginal cereal such as rye would give 0.44 of the EU average EU wheat yield. And these factors need to be multiplied by the factor of marginal/average yield inside one country (0.64 for UK) and arguably even by the ratio of yield variation between different fields on the same farm (~0.65 for UK).

uncertainty is skewed towards underestimating indirect land use change. Thus we tend to consider the treatment of marginal yield in MIRAGE to represent a conservative element of the model.

Land conversion emissions factors

MIRAGE calculates the net quantity of land expansion and the carbon emissions associated with that land expansion separately. MIRAGE endogenously determines changes in area of land under active management – managed forests and pastures – while for the remainder (the net expansion of 'exploited land') it used the Winrock MODIS land use change database developed for the US Environmental Protection Agency for the Renewable Fuel Standard 2 rulemaking to determine land types between grasslands and primary forests. IFPRI then assigns carbon emissions per hectare of land conversion in each category based on IPCC tier 1 values according to Bouët et al. (2010) – the emissions factors by AEZ for managed forest, primary forests and mineral soils are listed in Appendix II.

The use of IPCC tier 1 emissions values by MIRAGE seems to be a reasonable data source – other modellers have used Woods Hole data following the lead of Searchinger et al. (2008), and the California Air Resources Board is developing a new emissions factor model for its GTAP modelling. It would be interesting to compare the outcomes of applying these alternative emissions factors to IFPRI's land use change estimates.

While alternative carbon assessments have not yet been performed using IFPRI's MIRAGE outputs and these datasets, the land use change values have been processed by the EU Joint Research Centre using their spatial allocation methodology (Hiederer et al. 2010). They use a different land use change determination system (not relying on Winrock MODIS) and a more detailed carbon stock calculation, although it is still based on IPCC guidelines.

Reassuringly, the results of applying the JRC methodology[10] are very similar to the results of applying MODIS + IPCC tier 1.

We would sound a note of concern about the use of the Winrock MODIS dataset to allocate land use change in unmanaged categories. The Winrock MODIS values aim to historically determine the % of new cropland in a given region that has been converted from another land use type – for instance, the % of new cropland that has come from forest in a given period. MODIS is a satellite mapping utility, and Winrock have developed this dataset by comparing snapshots of land uses taken using MODIS in two different years. Unfortunately, the capacity of MODIS to accurately identify land uses is limited by resolution etc., introducing some inaccuracy into the assessment. While the level of inaccuracy is acceptable for assessing comparative land uses at a given point in time, when the data are used to attempt differencing (as in this case) the errors become compounded, with the risk that real land use changes are potentially masked by the false land use changes from classification errors. We suggest that alternative approaches to allocating between grassland and unmanaged forest would be beneficial for both the IFPRI MIRAGE modelling and for other modelling systems currently relying on the Winrock MODIS data.

While we believe that the use of the MODIS data may have limited capacity to accurately predict the proportions of grassland and forest conversion in a given region/AEZ, this may have a limited impact on the outcomes of the MIRAGE modelling. This is because the significant majority of the predicted land use change occurs from one managed category to another, e.g. pasture to cropland or managed forest to cropland. These transitions account for about 80% of the total increase in cropland, and the emissions from managed forest are the bulk of the emissions from biomass. Therefore, any uncertainty introduced by the misallocation of unmanaged land conversion is relatively small compared to other model uncertainties. Further, the broad consistency between the results of the JRC spatial allocation, a much more complex system that is not based on MODIS historical data, provides a useful indicator that the MIRAGE results are probably reasonable.

The MIRAGE land use change emissions data have also been subject to commentary in the review by (S&T)[2], however we do not see any substantial cause for concern from that review. Criticism that "The reported soil carbon losses appear to be high and could not be duplicated or reconciled with the information that is reported," seems to be misplaced, as the range of soil carbon emissions values reported by IFPRI (9-113 tCO_2 ha^{-1}) is broadly consistent with the range identifiable in the IPCC 2007 report of 14-107 tCO_2 ha^{-1}. We also believe that criticisms based on ignoring forest mortality (in general natural growth more than compensates for mortality) and on discrepancies with emissions values from Winrock ((S&T)[2] has not accounted for heterogeneity of carbon stocks across regions) are groundless.

Peat emissions

One area in which we agree with (S&T)[2] that the IFPRI MIRAGE work has not applied the best available emissions factor is on emissions from peat degradation in palm plantations. (S&T)[2] focus on estimates of carbon emissions from the peat degradation literature that are lower than IFPRI's chosen value of 55 tCO_2 $ha^{-1}yr^{-1}$. However, a recent ICCT report provides a comprehensive overview and critique of the literature on peat degradation emissions, finding that in fact the best available estimates for these emissions rates are rather higher than IFPRI uses, not lower. IFPRI have noted the availability of these new values, in particular the recommended value for average emissions over 20 years post-conversion of 106 tCO_2 $ha^{-1}yr^{-1}$, stating that applying this value would increase the reported iLUC factor for palm oil biodiesel to 85 gCO_2 MJ^{-1}. We have provided estimates of the revised emissions when this factor is applied to other feedstocks in a recent briefing paper available from our website www.theicct.org. On the % of palm expansion that occurs on peatland, we believe that the 33% value used by IFPRI is probably appropriate, but should be considered a lower bound (as suggested by Edwards et al. (2010)). A forthcoming paper in which we will present the results of satellite mapping of palm oil

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[10] http://iet.jrc.ec.europa.eu/sites/default/files/Technical_Note_EU24817.pdf

plantations on peat in Southeast Asia shows that the rate of expansion of palm onto peat has been increasing, and that there are no constraints likely to reverse this pattern in the near future.

Overall then, for biodiesel because of the strong influence of the peat emissions values on the results, we believe that the emissions factors in MIRAGE likely tend to underestimate iLUC. While there are other points of concern, notably the use of Winrock MODIS, we do not see any reason to conclude that there is a systematic bias for the non-peat emissions results.

Dealing with uncertainty

As a way of exploring the uncertainty in the iLUC emissions calculations performed with MIRAGE< IFPRI has run extensive Monte Carlo simulations to investigate the general level of certainty and the sensitivity of the model to different parameters. This is a valuable exercise that gives us signifincat insight into the results – but, as IFPRI explicitly note, it is important to bear in mind that this assessment does not include all sources of uncertainty. Notably, it does not include uncertainty in emissions factors or in the demand response.

The results of this uncertainty analysis can be seen in Figure 6. We note that while there is a substantial range on emissions values, especially for biodiesel, the results are generally supportive that biodiesel having higher iLUC than ethanol is a robust conclusion. In the words of the Kiel Institute report for the EBB, “For all biodiesel options, taking into account by-product allocation or not, the typical well-to-wheel values of the EU-RED plus land use change emission values from the Laborde’s Monte Carlo Simulation lead to higher emissions than the required 35% emission savings. These results are robust.”

Assessing the policy options

The purpose of the IFPRI MIRAGE modelling exercise is to inform the Commission’s proposal on addressing the indirect effects of biofuels production. To provide some example scenarios for the emissions and potential costs of implementing the various available options to deal with iLUC, the ICCT has constructed a simple spreadsheet model to estimate the average net emissions resulting from a European biofuels policy implementing each of five policy alternatives.

The model is based on the following assumptions:

- It is impossible to absolutely predict iLUC. Therefore, we should consider the marginal iLUC factors computed by IFPRI MIRAGE not as absolute but as indicative, and treat them as ‘central estimates’ for ‘real’ iLUC emissions.
- To account for this, we model 500 different ‘real iLUC possibilities’ at a time and compute the average emissions intensity of a given policy option

Figure 6. Uncertainty intervals, median estimates and confidence intervals from the IFPRI MIRAGE Monte Carlo simulations. Note that median values are not the same as the central estimates quoted elsewhere in this paper. From Laborde (2011).

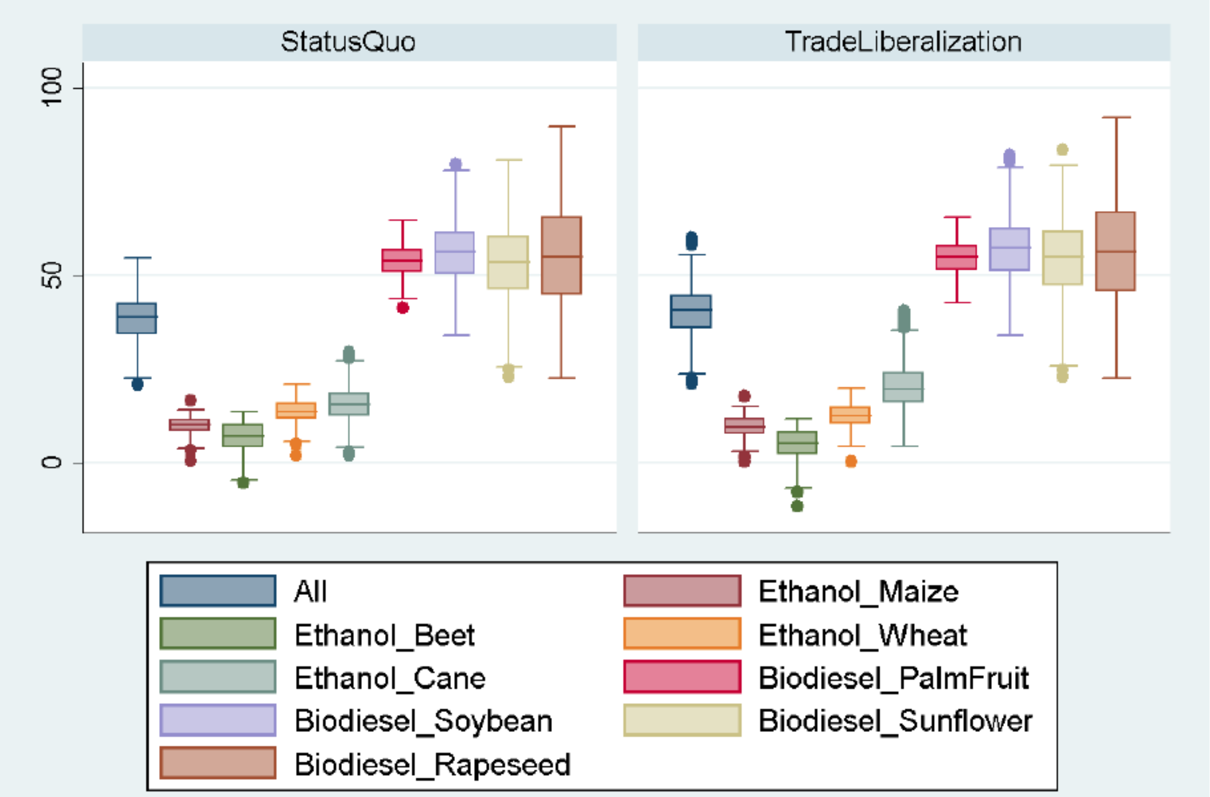


Figure 7. MIRAGE Monte Carlo analysis. From Laborde (2011).

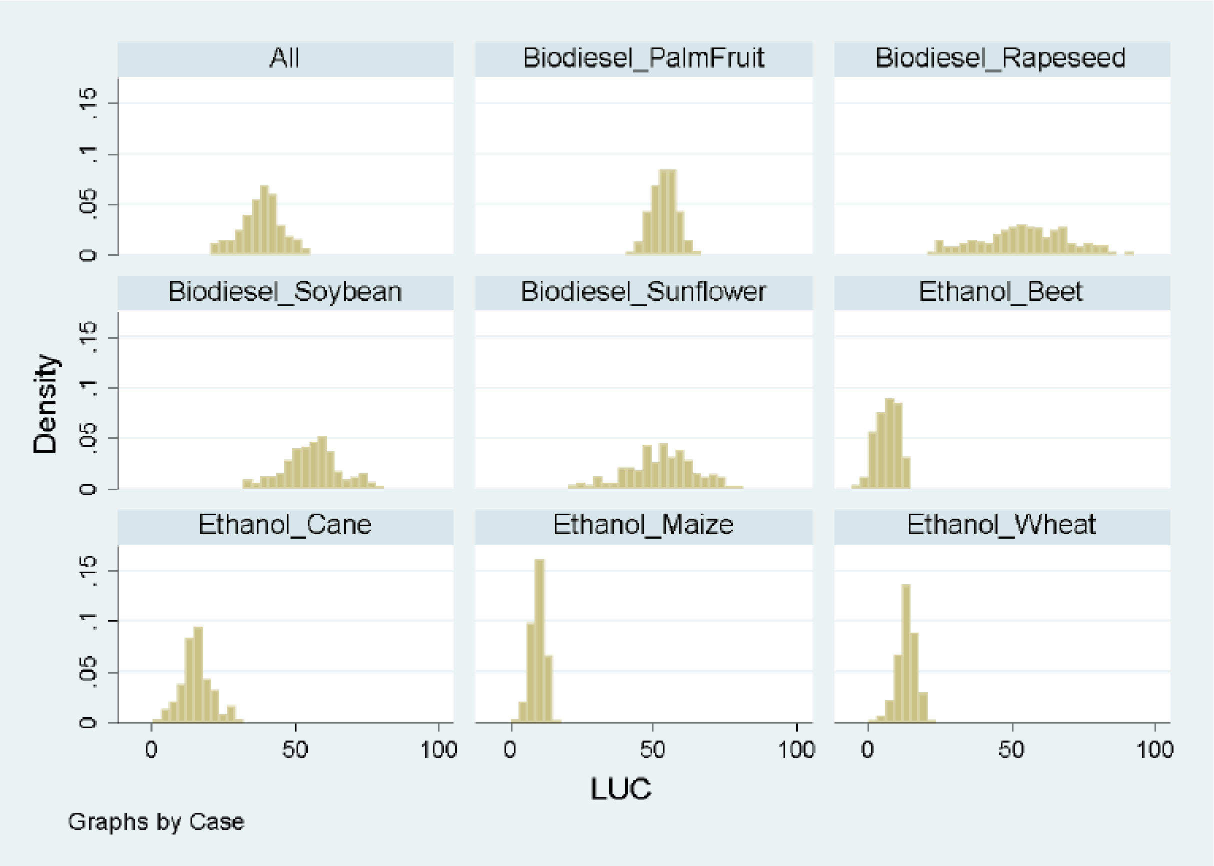
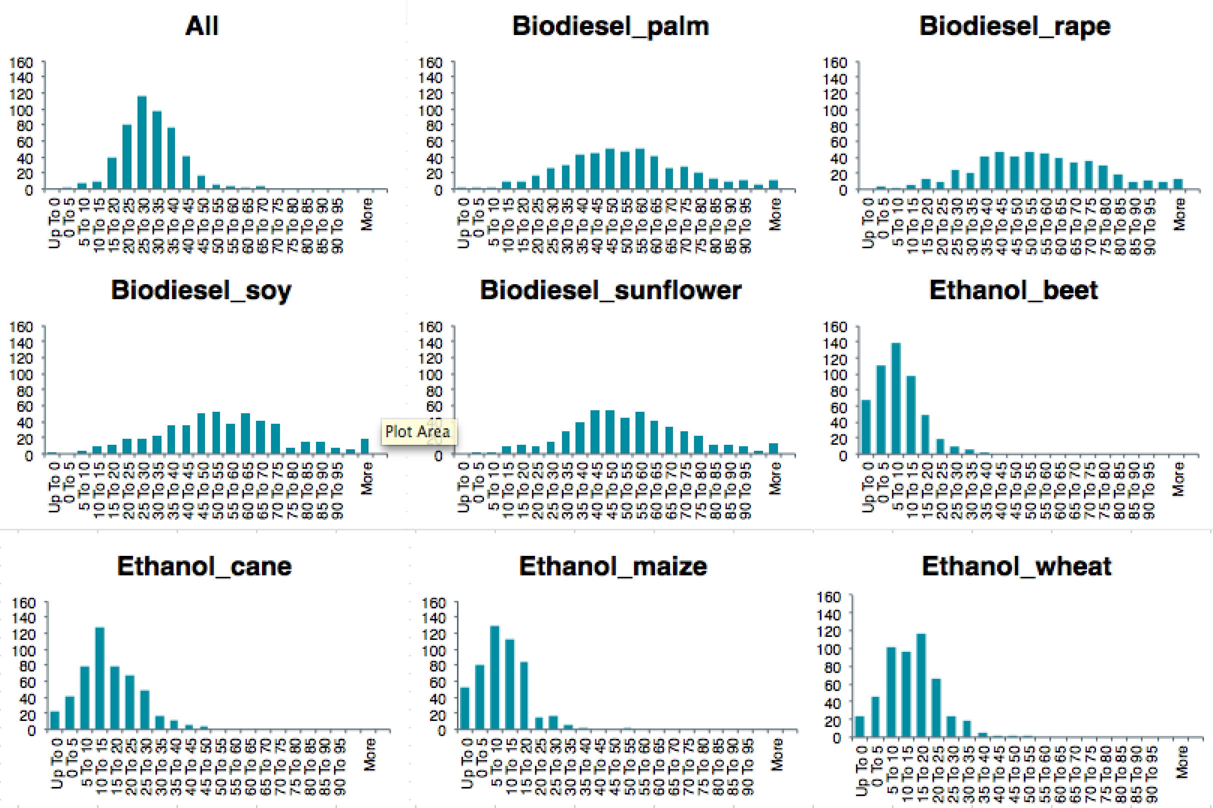


Figure 8. Frequency distributions of different feedstock specific iLUC emissions withint our 500 different ‘real iLUc scenarios



across these 500 possibilities.[11]

- If a biofuel feedstock/pathway cannot meet the minimum requirements of the policy option, we remove it from the mix and increase the use of other feedstock/pathways.
- We take the IFPRI MIRAGE projections for use of each type of biofuel as the baseline scenario, but when iLUC factors make some biodiesel pathways non-compliant we allow the % of biodiesel to shift down towards 50%. If there are no biodiesel pathways that would meet the threshold given the use of iLUC factors, then we allow biodiesel to be excluded.
- We assume that it would be possible in principle for biofuel producers to achieve low direct emissions values if necessary to qualify under the RED. We therefore allow direct emissions to be reduced by up to 80% from the typical values, and assume that producers do just enough for their biofuels to qualify. Presumably, such reductions would raise cost, which we discuss further below. While emissions reductions of 80% compared to typical would certainly be challenging, we believe that for many pathways it would be possible. As an example, the UK Renewable Fuels Agency was already reporting the supply of rapeseed biodiesel with carbon emissions 40% below the RED typical value. If this assumption of the scope for carbon reductions is too strong, it would have only a limited effect on the results presented below except where noted.
- We assume that if producers with a given feedstock need to achieve lower than default savings, the share of that feedstock in the mix will be reduced.
- We produce an emissions intensity value for the final year of the policy, 2020. We do not attempt to analyse carbon savings (or emissions increases) that might occur in the interim period due to different policy options.

We emphasise that the uncertainty distribution applied to iLUC emissions in this model is somewhat arbitrary (albeit designed to be as consistent as possible with our expectations from the literature), and therefore the results of the modelling should be treated as indicative. Our modelling is based on the assumption that the IFPRI MIRAGE modelling results represent the best available estimates of iLUC, and that they may equally over or underestimate iLUC. Some authors (e.g. Plevin et al. (2010)) have argued for a 'long right tail' on the distribution of possible iLUC. The distribution we have used has a somewhat similar form to the outcomes of the Monte Carlo modelling by IFPRI with MIRAGE (see Figure 7, Figure 8), but is broader (i.e. reflects greater uncertainty) to reflect the additional sources of uncertainty not modelled by IFPRI. In the subsequent text, when we refer to (for instance) 'a 30% chance that emissions will increase' we mean that for 30% of the iLUC scenarios on our distribution we believe that the policy would cause an increase in emissions compared to fossil fuel. Clearly, refining the probability distributions would refine the probability estimates.

Cost

The UK Department for Transport Impact Assessment on the Fuel Quality Directive[12] predicts a price spread (price difference per litre of fossil fuel equivalent) of about 30 pence per litre of ethanol vs. petrol and 35 pence per litre of biodiesel. At 32 MJ/l (petrol) and 36 MJ/l (diesel), this gives us a cost difference of about 1 pence per megajoule for both fuel types – at current exchange rates, this is close to 1 eurocent per megajoule. If a 50% carbon reduction were to be achieved by using these biofuels, this would represent a cost of the order of €250 per tonne of carbon dioxide abated. We take this carbon abatement value of €250 per tonne as our 'baseline' for the cost of supplying the additional biofuels required by the policy, so that for example if one of the policy scenarios had the same sort of feedstock mix as predicted by UK DfT but only delivered 10% instead of 50% carbon savings, we would expect the cost of carbon dioxide abatement under that policy to be 50%/10% x €250 = €1,250 per tonne. We do not attempt to include a broader consideration of either economic benefits in any given region from increased biofuel production or of economic costs from welfare losses, biodiversity losses etc.

In some cases, where we would expect sustainability criteria to raise the cost of biofuels, we have made what we believe are conservative cost suggestions (conservative in that we believe that sustainability compliance may in reality be rather cheaper). We are not suggesting these values as realistic estimates of the cost of reducing emissions or avoiding iLUC, but rather used them to demonstrate, for instance, that even if avoiding iLUC raises the price per litre of biofuel substantially (compared to fossil alternatives) it could still deliver very large reductions in carbon abatement cost. We suggest that anyone wishing to quote a plausible certification cost for iLUC-avoidance projects should not use these values, but refer to the Ecofys literature on Responsible Cultivation Areas, or other relevant reports.

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[11] These 'real iLUC possibilities' are based on taking the IFPRI iLUC values as central estimates. We then vary each iLUC factor according to a probability distribution: in which each R_i is a random value from a normal distribution with mean 0 and standard deviation 0.25, f denotes the uncertainty for a particular feedstock, c denotes the uncertainty for the category of feedstock (sugars, oils and cereals) and s denotes a systematic uncertainty for all pathways in the model together.

[12] http://www.dft.gov.uk/consultations/dft-2011-04

Overview of results

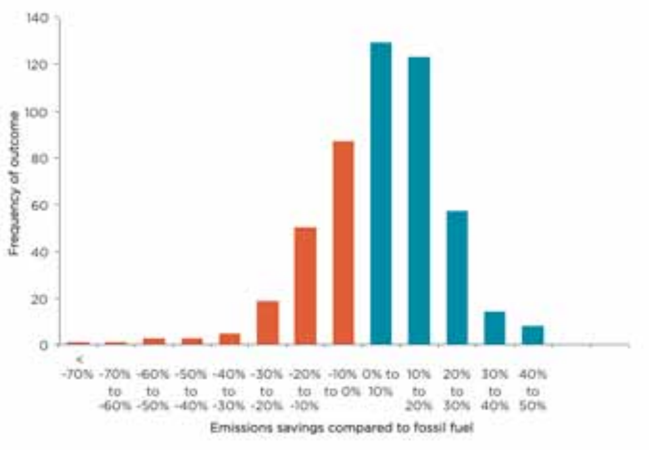
Table 4. In the sections below, we detail different policy alternatives and our assessment of the potential carbon emissions savings in each case. This table summarises those findings.

Policy alternative		Average carbon saving	Comments
1. No action/monitor the situation		5%	'Baseline' case
2. Raise the thresholds	a) to 50% immediately, but no long term increase	5%	This scenario treated as the same in 2020 as no action
	b) to 60% by 2020	14%	Unlikely to rule out any feedstocks completely
	c) to 65% by 2020	19%	Unlikely to rule out any feedstocks completely
3. Additional sustainability criteria	a) country level	n/a	We did not feel able to assess this option, but noted our concerns that it may have low certainty of being effective
	b) incentives for iLUC mitigation, but no iLUC penalties	11%	Requires relatively low volumes of low-iLUC biodiesel
	c) Biodiesel treated as high risk – all biodiesel must be low-iLUC	47%	Requires high volumes of low-iLUC biodiesel,
4. iLUC factors	a) With a 50% threshold	53%	Effectively only allow ethanol for compliance,
	b) With a 35% threshold	50%	Effectively only allow ethanol for compliance
	c) With a 25% threshold	36%	Requires direct emissions savings for biodiesel
	d) With a 50% threshold and iLUC mitigation options	53%	Requires high volumes of low-iLUC biodiesel,

Monitor the situation (take no action)

The first policy option is relatively simple it involves maintaining the direct emissions thresholds as they are and introducing no iLUC mechanism. Based on our model, we would expect on average to see a small carbon saving from the policy as a whole of about 5% - which is unsurprisingly quite consistent with IFPRI MIRAGE. We find a substantial risk (over 30%) that the policy would actually increase carbon emissions (see Figure 9). If we kept the model otherwise the same but amended the peat emissions estimate from IFPRI to match our suggested figure of 106 tCO2e/ha/yr there would be an overall emissions increase.

Figure 9. Possible carbon savings with different 'real iLUC possibilities' and no action taken (existing 50% direct carbon savings threshold)



In this policy case, the feedstock mix should be consistent with the UK DfT assumptions, so we expect the cost of carbon abatement of the Renewable Energy Directive if no action is taken to be about €2,500 per tonne (10 times the cost if the 50% carbon saving were realised).

Raise the minimum carbon saving threshold

The second option would continue not to account for iLUC, but would raise the threshold for *direct* emissions – with the intent of ruling out some poor performing biofuels and providing additional assurance that the policy was successful in achieving some level of emissions reduction.

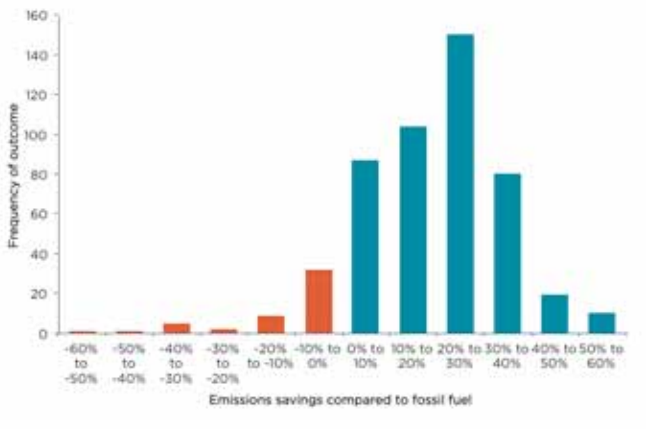
One scenario for raising the emissions threshold would be to increase it to 50% for all biofuels immediately, instead of waiting until 2017. We have looked only at the anticipated emissions in 2020, and as in 2020 we would expect this to have a limited effect on the biofuel feedstock mix, we have not attempted to analyse it – we expect the results to be similar to the 'no action' scenario (above).

We do have results for two other raised threshold scenarios, raising the savings threshold to 60% and 65% respectively. We believe that in both cases, it would be possible to achieve the requisite carbon savings with any of the major feedstocks given the appropriate investments between now and 2020 – the most challenging cases would be soy and rapeseed, needing to reduce direct emissions from typical by about 40% and 33% respectively. As noted above, for rapeseed we already know from UK reporting that emissions lower than this were being achieved in 2009/10, so rapeseed biodiesel should be perfectly possible with this threshold. Whether soy producers (for whom the oil is a relatively low percentage of value, and for whom the EU biodiesel market may not be a priority) would implement the necessary changes is more doubtful. Raising the thresholds in this way could favour palm oil biodiesel, providing methane capture can be implemented. As noted above, with revised peat emissions values we expect palm to be the most iLUC intensive fuel type, which would be unfortunate. This is a good example of the risk that raising thresholds without any reference to iLUC risk may drive unintended consequences.

For a 60% threshold the result of our modelling is a 14% carbon saving for the policy compared to fossil fuel – i.e. increasing the threshold by 15% adds 9% of carbon savings. Increasing to 65% pushes savings up by another 5% to 19% (this is because most feedstocks are assumed to be just meeting the threshold in both cases. We expect increasing the threshold to drive a movement away form biodiesel towards ethanol, as reducing direct emissions to the requisite level would be more challenging for biodiesel. .

The distribution we find of possible savings with a 65% threshold is illustrated in Figure 10. The case for a 60% threshold is very similar). For one in ten cases, we would see carbon emissions increase.

Figure 10. Possible carbon savings with different 'real iLUC possibilities' and a 65% direct carbon savings threshold



Our analysis suggests that increasing the thresholds could deliver on its objective of reducing the chance that EU biofuels policy would increase emissions, but based on our distributions the chance would still be non-negligible (we found an increase in 10% of cases).

We believe that the per tonne abatement cost in this policy would be lower than for the 'no action' policy because of the higher savings achievable. Even if achieving the requisite reduced direct carbon intensities added 0.5 Eurocent per megajoule to the cost spread of biofuel vs. fossil fuel (i.e. if it increased the marginal cost over supplying fossil fuel by 50%), we would expect to see the cost of carbon abatement fall from about €2,500 per tonne to about €1,000 per tonne – still high, but a substantial drop. While this would raise the total cost to consumers, we note that if these values are reasonable it would be possible to design a policy with lower overall targets but higher carbon savings thresholds, which would both have a lower overall cost to consumers and a higher overall carbon saving.

It is worth noting that the accounting under the increased thresholds would result in European policy delivering a headline carbon saving that would be much higher than the real global net carbon saving. For instance, under our 65% threshold scenario we would have a reported carbon saving of 67% for a policy that we expect to only deliver 19% is 'real' net global emissions reductions. We note that it would be important for the European Commission to take care in determining how biofuels policy contributes to overall climate targets, as there would be the potential for over-declaration of the benefits of biofuels policy to prevent action form being taken in other sectors.

Additional sustainability criteria 1: country level criteria

It is our understanding that the European Commission has considered two types of additional sustainability criteria. One would be 'country level' criteria, allowing imports of biofuel feedstock only from countries with defined land management practices, the other 'project level' criteria imposing a requirement to demonstrate 'additionality' on biofuel projects[13].

We believe that country level criteria would be problematic, in several cases. iLUC is, given global markets, and international phenomenon. Therefore, in several cases it is not action in the country supplying the biofuel feedstock but a third country that the problem exists. For example, increasing vegetable oil imports from the Ukraine would be anticipated to indirectly lead to palm oil expansion in Southeast Asia. Clearly, while land management in the Ukraine could deliver benefits in that region, the risks and benefits are not expected to compare to the risks and benefits of bad vs. good land management in Southeast Asia. Such a policy option would, therefore, only be expected to deliver benefits insofar as key regions for carbon loss though LUC implemented the requirements. EU biodiesel is a significant market for Indonesia and Malaysia, but still only a very small percentage of their total exports, so it is very conceivable that such a policy would lead to the implementation of good management practice in countries where there was little problem to begin with, while stopping direct but not indirect exports from countries where emissions are expected. It is difficult to make a meaningful assessment of how effective such a policy might be without a sense of what it would enforce and whether third countries would be willing to implement the requirements, so we have not attempted a numerical assessment of it. Depending on implementation, such a scheme could leave emissions and costs essentially unchanged, or have a profound effect on both as well as affecting other agricultural markets.

Additional sustainability criteria 2: project level criteria

For project level iLUC prevention schemes, the outcomes are a little clearer, although the detail of potential policy is less so. We consider three examples. In the first, 10% of all fuel is iLUC free biodiesel, but there is no specific restriction on supply of any pathway (this is similar to the policy type proposed in a recent paper by Ernst and Young[14]). In the second, we consider a policy in which the supply of all biodiesel is restricted as 'high iLUC risk' unless additionality (and hence zero iLUC emissions) can be demonstrated. In this case, we assume that because biodiesel would be more expensive it would constitute only half of the mandated fuel. Clearly this assumption is somewhat arbitrary, and could be altered, but the conclusion on CI is fairly robust.

In the third case, we consider a policy with iLUC factors and the option for iLUC mitigation. This is detailed in the next section with the other policy options that include iLUC factors. With iLUC factors based on the IFPRI results, as will be explored in more detail below, there are no biodiesel pathways from the major feedstocks that qualify, so we have essentially considered a policy that is 50% ethanol with iLUC factors, and 50% demonstrably low-iLUC biodiesel.

1) 10% of fuel comes from low-iLUC biodiesel feedstocks

The first policy option, with biodiesel from low iLUC risk feedstocks replacing normal 'high iLUC' biodiesel for 10% of the overall mandate is modelled delivering an 11% carbon saving, compared to only 5% without any incentives for iLUC free fuels. More than doubling the saving would reduce the cost per tonne of carbon abatement substantially – for instance, if we assumed that for the 'low-iLUC' biodiesel the cost spread over fossil diesel doubled (adding an extra 40 Eurocents per diesel litre equivalent for the zero iLUC fuels), the price per tonne of carbon abatement would still fall from €2,500 to €1,250. This suggests that introducing incentives of some sort for low iLUC biodiesel could deliver very good value for money in terms of the cost per tonne of carbon abatement. As in the case of increasing the savings threshold, this might raise the overall cost of the program. However, if overall cost was a concern, it would be possible to design a policy (with reduced overall usage targets combined with incentives for low iLUC fuel) that was cheaper overall, had a lower abatement cost and was expected to deliver more overall carbon savings. The distribution of expected overall carbon savings is shown in Figure 11.

We note that for this illustration we have focused on mitigating iLUC from biodiesel, as biodiesel has the

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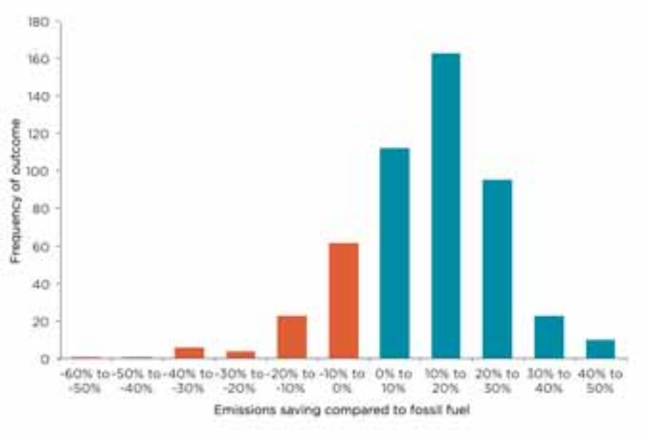
[13] Additionality means that production is added to the global supply that otherwise not have existed, and therefore feedstock need not be displaced from other uses. This concept has been explored in some detail in work on Responsible Cultivation Areas by Ecofys in partnership with organisations including IUCN, Shell, WWF, UK RFA. The aim would be to certify projects where we could reasonably expect zero iLUC emissions.

[14] http://www.ascension-publishing.com/BIZ/EY_ILUC_study_report.pdf

highest iLUC values in the IFPRI MIRAGE report. Using iLUC mitigation strategies for ethanol would also be beneficial, but the carbon benefits expected would be less.

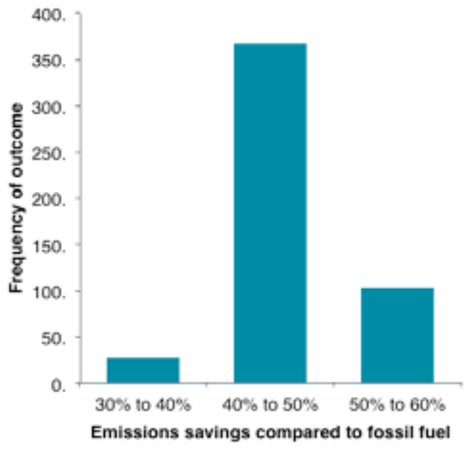
Figure 11. Possible carbon savings with different 'real iLUC possibilities' and a 50% direct carbon savings threshold and with 10% of fuel from iLUC free biodiesel



2) All biodiesel must be low ILUC, ethanol has no iLUC penalty

The second policy option, with all biodiesel needing to be certified as 'zero iLUC', is the first case we have considered in which we find that the expected emissions savings are close to the applied threshold – this is because of the availability of ethanol pathways with low direct CI and low iLUC, and no use of iLUC intensive biodiesel. The expected saving is 47%, with a narrow uncertainty profile as shown in Figure 12. The relatively narrow distribution is a result of including no uncertainty in the biodiesel iLUC, and the less broad uncertainty distributions assumed for ethanol feedstocks.

Figure 12. Possible carbon savings with different 'real iLUC possibilities' and a 50% direct carbon savings threshold and with all biodiesel (50% of total fuel use) having zero iLUC emissions



Potentially, this policy option could be relatively low cost per tonne of carbon abatement, even if we presume that low-iLUC biofuel would have a substantial cost premium compared to other fuels. If the cost spread of low iLUC biodiesel compared to diesel was three times the cost spread we assume for 'normal' biofuels, i.e. if low-iLUC biodiesel cost an additional 80 Eurocent per diesel litre equivalent, the average cost per tonne of carbon abatement would come out as about €500 per tonne of carbon dioxide[15]. This is about 1/5 of the carbon abatement cost of the policy without iLUC mitigation.

Availability of low iLUC biodiesel and the capacity of the European market to use ethanol would be important limits on the potential scale of a policy mandating the use of low-iLUC biodiesel in this way. However, as with other policy options that could raise the overall policy cost, we note that a reduced mandate combined with this use of low-iLUC biodiesel could deliver much higher overall carbon savings than the policy with no action taken, at a fraction of the abatement cost and at comparable or lower overall cost to consumers.

iLUC factors

The fourth policy option considered by the European Commission is the application of iLUC factors. We presume that these would be based on the marginal iLUC values reported by IFPRI using MIRAGE, and model on that basis.

We look at a combination of iLUC factors with three carbon savings thresholds. First, we consider the current 50% carbon savings threshold. Secondly, we consider what might happen if the threshold was frozen at 35%. Finally, we consider a carbon savings threshold of 25% (the highest threshold for which biodiesel is a viable pathway.

1) 50% carbon savings threshold

With the application of iLUC factors there are no biodiesel pathways that would qualify for use in the RED with a 50% carbon saving threshold, as the iLUC values computed with MIRAGE are already more than 50% of fossil fuel emissions. You would therefore need to be able to produce biodiesel with negative direct emissions for it to qualify. This means that in the absence of any sustainability criteria for awarding fuels that avoid indirect land use change, only ethanol would qualify to be supplied to the European market.

For the 50% threshold, with iLUC factors applied, we find an average carbon saving for the mandate of 53%. Maize ethanol would need to be able to demonstrate better than typical performance, and wheat plants would need to be straw fired or achieve savings in some other way,

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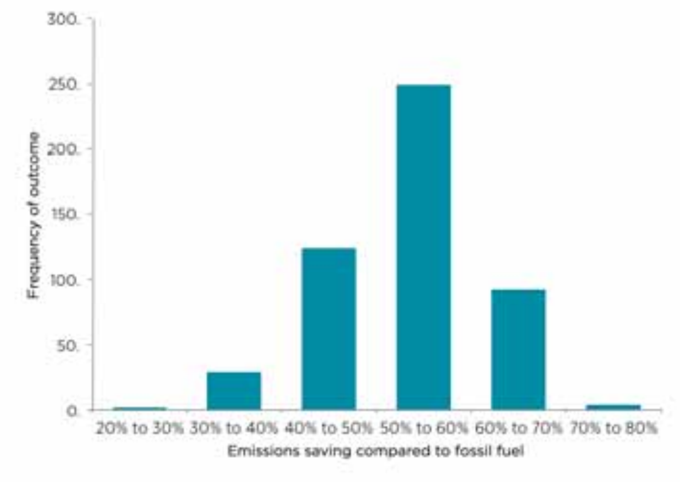
[15] Ecofys (2010) note that the barriers to development of low iLUC biofuel projects are typically not cost based. Therefore, if clear incentives were put in place to allow investment, and opportunities for 'additionality' were available, we see no reason not to believe that a substantial supply of low-iLUC biodiesel could be generated well within this cost limit. C.f. http://webarchive.nationalarchives.gov.uk/20110407094507/renewablefuelsagency.gov.uk/reportsandpublications/iluc/indirectimpactsofbiofuelproduction

but we anticipate that these additional savings would be available if necessary. This policy version would be expected to deliver 10 times the carbon savings of the option in which iLUC is not addressed, with a distribution as shown in Figure 13.

Figure 13. Possible carbon savings with different 'real iLUC possibilities', iLUC factors and a 50% direct carbon savings threshold



2) 35% carbon savings threshold

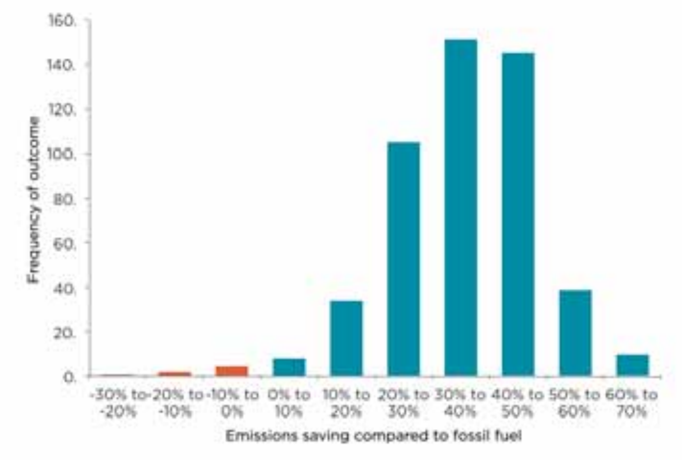
Given the high iLUC predicted by IFPRI MIRAGE for biodiesel, with a 35% threshold and iLUC factors there would again be no biodiesel pathways that met the sustainability criteria. The average carbon saving in our scenarios is 48%, with a distribution similar to that with a 50% threshold.

3) 25% carbon savings threshold

We have included the case of a 25% carbon savings threshold as an example of a policy in which iLUC factors would be applied, but the supply of 'high iLUC' biodiesel would still be possible if very high direct emissions reductions could be achieved. In this case, we expect an average carbon saving of 36%. With our assumption that an 80% reduction in direct emissions would be achievable with adequate market incentive, all biodiesel feedstocks except soy would be potentially eligible, though this would presumably require both agricultural and industrial practices to be altered to target minimum emissions. With biodiesel in the fuel mix, we have a wider distribution of outcomes than in the policy cases where the only eligible fuel is ethanol, as shown in Figure 14.

While this type of policy option (iLUC factors combined with setting the threshold to a level that was very challenging but achievable by biodiesel with very low direct emissions) would potentially increase the number of options for biofuel supply, it would be likely to put a significant premium on the price of ultra-low carbon RED compliant biodiesel (a similar outcome to imposing an extremely high savings threshold).

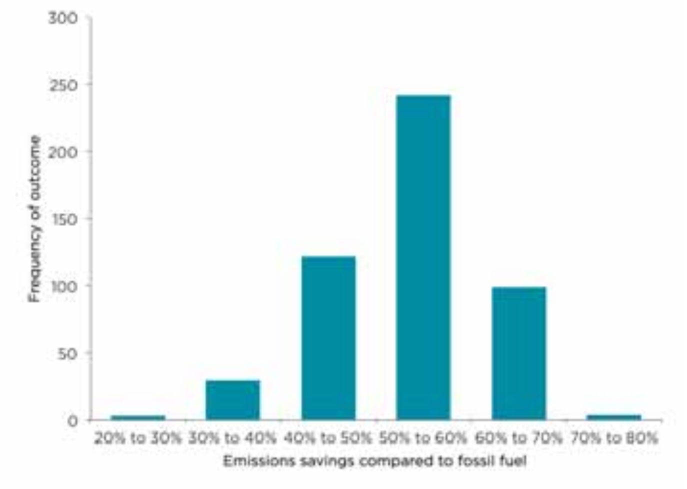
Figure 14. Possible carbon savings with different 'real iLUC possibilities', iLUC factors and a 25% direct carbon savings threshold



4) ILUC factors plus a 50% threshold ensure that all biodiesel is low-iLUC

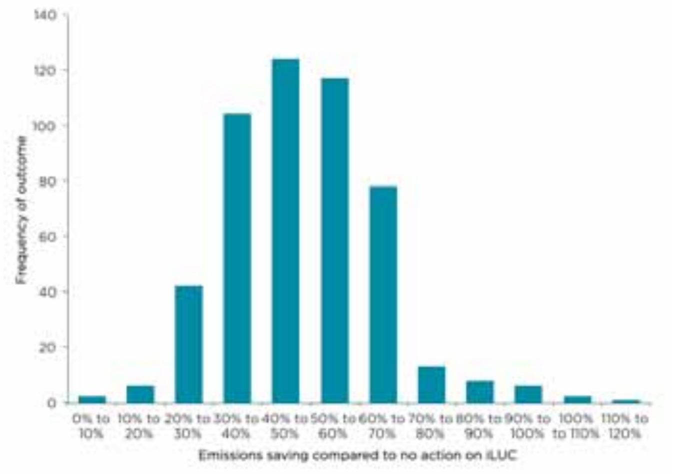
We can also consider a policy in which you have iLUC factors and an iLUC mitigation option. In this case, rather than marking biodiesel as high risk, iLUC factors based on the IFPRI MIRAGE marginal iLUC results would be applied to each feedstock. Combined with the 50% threshold, this would make the supply of biodiesel without iLUC mitigation impossible.

Figure 15. Possible carbon savings with different 'real iLUC possibilities', iLUC factors, iLUC mitigation options and a 50% direct carbon savings threshold



In this option, the savings are slightly increased, primarily because the direct emissions of some ethanol pathways must be reduced to meet the threshold. We find an average saving of 53%, with the distribution shown in Figure 15. This is the same average carbon saving we find without iLUC mitigation options but using only ethanol. Presumably the limits on potential ethanol supply and desire to allow the biodiesel industry to continue would provide reasons to include iLUC mitigation options for biodiesel if available instead of forcing a sole reliance on ethanol pathways. The cost of this option would presumably be similar to the option in which all biodiesel must be iLUC free, but there is no iLUC factor applied to ethanol, or a little higher (as the cost of lower CI ethanol may be marginally higher). If the additional reductions necessary in ethanol CI cost 10 Eurocents per petrol equivalent litre, and (as suggested above) low-iLUC biodiesel was as much as three times the cost spread of normal biodiesel, the implied carbon abatement cost would be about €550 – as with all the other policy options that reduce iLUC, a much lower expected carbon abatement cost than if iLUC is ignored.

Figure 16. Difference between expected carbon savings with iLUc factors and mitigation vs. scenario where no action is taken to deal with iLUC



We can also look at the distribution of the *difference* in emissions savings between a policy with no action to address iLUC, and this scenario in which substantial volumes of low-iLUC biodiesel are available and iLUC factors are applied. The average increase in saving from applying iLUC factors compared to the existing policy is 48%, and the distribution of the benefit is shown in Figure 16. We notice that we are quite confident in achieving a significant benefit by adding iLUC factors and mitigation to the policy, and that in some cases adding iLUC factors would improve carbon performance by over 100%. There is no scenario in which applying iLUC factors and mitigation reduce carbon savings.

This assessment of the carbon benefit of implementing iLUC factors vs. not implementing iLUC factors (or other robust policy) is shared more or less by all of the policy cases in which iLUC factors are included. If we consider the results of IFPRI MIRAGE to be the best available estimates of the extent of iLUC emissions, then we should expect that without iLUC factors the Renewable Energy Directive is likely to offer low or negative carbon savings.

To put it another way, insofar as the Renewable Energy Directive is intended as a climate change mitigation strategy, based on our model the application of a combination of iLUC factors and iLUC mitigation options would make it likely to be effective, while without addressing iLUC it is unlikely to be effective. It is a question for policy makers whether the additional cost to consumers (which could be managed by reducing the mandate size) and potential reduced opportunities to some stakeholders outweigh this magnitude of potential benefit.

Conclusions

In this paper, we have discussed extensively the modelling of indirect land use change by IFPRI using its MIRAGE computable general equilibrium model. We have noted that in general MIRAGE compares favourably to other iLUC models, and in particular that the modelling has dealt with various issues that have been criticised by the European Biodiesel Board in what we consider to be a reasonable and appropriate fashion. Notwithstanding this, it is clear that iLUC modelling remains a challenging area and that there is substantial room for uncertainty, both in the parameters that have been included in Monte Carlo analysis by IFPRI, in other parameters and in more fundamental aspects of the modelling for instance whether the structure of the model equations is inappropriate or inadequate in some specific market situations.

Despite the acknowledgement of uncertainty, this modelling represents the most sophisticated, complete and well structured modelling of the iLUC consequences of the European biofuel mandates that we have seen to date. Given that, we believe that it would be consistent with the language of the Renewable Energy and Fuel Quality Directives for the European Commission to put significant weight on the results of the IFPRI study when making a proposal for measures to address indirect land use change.

We have used a model of European biofuel policy outcomes, that is limited in several ways (notably in that it lacks a full consideration of costs) but that we believe provides useful insights into possible outcomes of policy measures, to make a quantification of the possible carbon emissions benefits of different biofuel policies for Europe. Using this tool, we have demonstrated that based on the IFPRI results, inaction on the iLUC emissions from biofuels would be likely to result in a Renewable Energy Directive that failed to deliver carbon savings, while allowing a misleading level of policy efficacy to be reported.

We have compared alternatives in which iLUC mitigation is allowed and encouraged, in which iLUC factors are applied and in which the direct emissions savings are increased by increased savings thresholds. We have found that the most carbon effective options are those in which biodiesel supply is either extremely limited (by iLUC factors), or in which any biodiesel supplied is required to demonstrate that it has not caused indirect land use change. Even with what we consider to be high estimates of the cost of sourcing low-iLUC fuels, these policies deliver a much lower cost per tonne of carbon abatement than either policy without change, or policy with increased direct saving thresholds across the board. We find that increasing the general emissions threshold may have more limited carbon benefits, because it would not give such a strong signal to move away from high-iLUC feedstocks.

We have noted that for any of the policies we have described, if cost is a key concern it is likely that a reduced mandate coupled with strong sustainability measures (some combination of iLUC factors and iLUC mitigation) is likely to deliver substantially more and cheaper carbon savings per tonne than the current policy framework. We note that a policy as recommended by Ernst and Young[16] in there recent report, where incentives were provided for low-iLUC fuels but biodiesel was not penalised, would deliver some improvement but in our assessment would deliver an overall carbon saving only about 20% of what could be achieved with iLUC factors as well as mitigation options, providing the necessary volumes were achievable in this regime.

We have also noted, but only cursorily explored, the likelihood that strong sustainability criteria would make sourcing large quantities of biofuels more expensive and could make quantities large enough to meet the current targets challenging. Clearly, this is an important consideration in determining what might be the most appropriate combination of energy use targets and iLUC criteria moving forwards.

Finally, we recommend that whatever proposal is adopted following the current decision making process, that a clear review date should be set. If grandfathering is implemented as presumed in the Directives, such a review could allow existing industries an opportunity to demonstrate that they are lower iLUC than IFPRI estimates, to implement low-iLUC supply chains or to move towards exiting the market. There are events external to EU biofuels policy that could effect the conclusions of iLUC modelling, an obvious example being peat protection in Indonesia and Malaysia. If these types of policies are effectively enacted at some point in the future, it would be appropriate to review our expectations of emissions from iLUC at that point.

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