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PROGRESS IN ESTIMATES OF ILUC WITH MIRAGE MODEL

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Abstract

JRC started in 2012 a collaboration with the International Food Policy Research Institute (IFPRI) to carry out further work with the economic model MIRAGE used to calculate the ILUC emissions included in the Commission policy proposal COM(2012)595. Results are expected to further reduce uncertainties in ILUC estimates.
This work presents and discusses the results of new runs of MIRAGE model delivered to the JRC-IET.
In particular, IFPRI was asked to:
- Evaluate GHG emissions by crop groups (sugar, cereals and oil crops), maintaining the same model assumptions/parameters as in the previous analysis.
- Make new runs of the MIRAGE economic model, with improved assumptions/parameters as suggested by the JRC.
The changes brought by IFPRI to their model raise the ILUC emissions compared to 2011 values, especially for EU ethanol.

Disclaimer:

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Abstract

This report presents the results of work carried out in 2012-2013 by the JRC in collaboration with the International Food Policy Research Institute (IFPRI) using the economic model MIRAGE.

This model was previously used to calculate ILUC greenhouse gas (GHG) emissions[1] which were included in the Commission policy proposal COM(2012)595. IFPRI-MIRAGE is a Computable General Equilibrium (CGE) model particularly suitable to assess the impact of EU biofuels policy, as it has been optimized in this direction over several years. The results of MIRAGE used in the Commission Impact Assessment and policy proposal (COM(2012) 595)[2] could be considered as the best available at that time.

But as science continuously evolves, further analysis (including additional work with the same model as well as the use of alternative models and approaches to estimate ILUC) can help to improve the understanding of ILUC[3]. The new analysis presented here focused on:

- Evaluation of GHG emissions by crop groups (sugar, cereals and oil crops), maintaining the same model assumptions/parameters as in the previous analysis. The ILUC values for the crop groups reported in the Impact Assessment were estimated as a weighted average of the “crop-specific” ILUC values calculated by IFPRI in 2011[4] (maize and wheat for cereals; beet and cane for sugars; palm fruit, soybean, sunflower, and rapeseed for oilseeds). In this new run of MIRAGE, the JRC requested IFPRI to aggregate the crops in the above-mentioned groups, and then run the model. This leads to a set of new central, mean, median and percentile values consistent with each other.
- New runs of the MIRAGE economic model, changing some assumptions/parameters that the JRC deemed incorrect in the IFPRI 2011 study, and reporting on the effects of reduction in food consumption:

  1) yield increase projections in IFPRI 2011 work[5] are higher than all values reported in other agricultural outlooks. In particular for EU wheat, the yield in 2020 assumed by IFPRI was 8 t per physical ha, compared to a value of 5.5 t per harvested ha in OECD-FAO projections. For some other crops, like rapeseed, the gap is much smaller: 3.9 t per physical ha for rapeseed in IFPRI model vs 2.9 t per harvested ha for

[1] Laborde D., 2011. Assessing the Land Use Change Consequences of European Biofuel Policies. Final Report October 2011. International Food Policy Research Institute (IFPRI).

[2] SWD(2012) 343 final and COM(2012)595

[3] The JRC has already started examining the need to run further sensitivity analyses on other parameters and assumptions, which may shift ILUC emissions in either direction. The results shown here are those available at the time of preparation of this report; additional runs should be part of future work and collaboration with IFPRI.

[4] Ibid.

[5] Ibid.

oilseeds in OECD-FAO[6];

2) IFPRI 2011 work assumed that cereals could expand at the expense of “other oilseeds” as easily as any other arable crop. However, the crop category “other oilseeds” consists of a large mix of crops (annual and perennial) and, in the EU in particular, of olives, which are less easily displaced by cereals;

3) agro-economic models, like IFPRI-MIRAGE, assume that biofuels will cause an increase in crop demand. This results in increased prices for crops, which cause both supply to increase (through an increase in yields) and competing demand in other sectors (mainly food and animal feed) to decrease. In order to give a quantitative estimate of the magnitude of this effect, IFPRI was asked to make a new run of the MIRAGE model fixing food consumption.

The JRC asked IFPRI to quantify the effect of the three issues listed above one by one and simultaneously to have the “cumulative” results.

The results of these new runs show that, aggregating the crops into the proposed groups and running the MIRAGE model with the same assumptions as in the 2011 analysis, ILUC emissions values reported in the Commission Impact Assessment and policy proposal are confirmed.

However, changing some of the assumptions as proposed by the JRC, the new results show that:

- ILUC emissions of wheat-ethanol increase by 15% with assumptions on yield increase for EU wheat in line with OECD-FAO projections for 2020, assuming no multiplier related to cropping intensity for wheat production in the EU;[7]
- ILUC emissions increase from 0% to 29%, depending on the crop type, if the definition of the crop category “other oilseeds” becomes more restrictive (excluding olive area for instance) in the EU;
- ILUC emissions change from -20% (sugar beet) to +30% (soybean), depending on the crop type, if food consumption is maintained constant by excluding switches between food categories and thus changes in overall food quality;
- ILUC emissions increase from 0% to 34% when the EU wheat yield is corrected and the assumption on the expansion of major crops onto other oilseeds (like olive) is changed; the increases are even higher (from 3% to 62%) if food consumption is also fixed (and the three changes are applied simultaneously in the model run).

[6] OECD-FAO yield projections are aggregated for different oils.

[7] Only the EU wheat yield value has been changed here. However, yield for other crops may be also overestimated on average, but the values for the other crops was not changed, which would have resulted in higher emissions.

The set of sensitivity analyses presented in this report is limited to some assumptions and parameters that were identified by the JRC as important to investigate. All of them are likely to push ILUC results, mainly for cereals, upwards. This selection of sensitivities reflects in particular the need to check the robustness of the cereals values in the IFPRI report, as they show, compared to other modelling exercises, low ILUC values for cereals. However, a range of parameters, assumptions and structural modelling challenges remain, such as determining the ease of new cropland expansion onto forests, yield elasticities, the extent to which land governance policies reacts to changes in biofuel demand, etc, which may have the opposite effect on ILUC estimates. Nevertheless, the work presented in Laborde (2011) already provides a systematic sensitivity analysis on several key parameters (including yield elasticity) and covers a wide range of possibilities.

1. Background

The EU Renewable Energy Directive (2009/28/EC) calls for a 10% renewable energy use in transport by 2020, of which biofuels are expected to be a significant part. The Renewable Energy Directive (RED) defines the sustainability criteria that biofuels must adhere to in order to be counted as contributing towards the 10% target, including the land the raw materials come from. The Directive includes a requirement for the Commission to report by 2010 on indirect land use change (ILUC) and, where appropriate, to make proposals on how to address this issue. The Fuel Quality Directive (FQD), adopted at the same time as the RED, includes identical sustainability criteria and targets a reduction in lifecycle greenhouse gas emissions from road transport fuels consumed in the EU by 6% by 2020.

The European Commission has responded to this obligation with various studies and consultations. In particular, during 2010 and 2011 the Commission mandated the International Food Policy Research Institute (IFPRI) to analyze the impact of the EU biofuels mandate, and possible changes in EU biofuels trade policies, on global agricultural production and the environmental performance of the EU biofuel policy. For this purpose, IFPRI developed an extended version of the general equilibrium model MIRAGE, which is widely used for trade policy analysis[8].

A first report was published in March 2010[9], and its results were presented to stakeholders in October 2010 as part of a public consultation on this matter[10]. Subsequently, an updated report, with an improved version of the MIRAGE model, capturing relevant data submitted by the Member States in their 2010 National Action Plans as well as key assumptions reflecting stakeholder and expert comments, was published in October 2011[11]. This was presented to stakeholders in November 2011[12] and included in the Impact Assessment released in 2012. The model and the study results have been widely featured in scientific literature[13].

IFPRI-MIRAGE is particularly suitable to assess the impact of EU biofuel policy, and since 2010 it has been optimized in this direction. The model has been expanded in the areas which are important to cover in the analysis of EU biofuel policy, in

[8] Available at: http://www.ifpri.org/book-5076/ourwork/program/mirage-model.

[9] Available at: http://www.ifpri.org/sites/default/files/publications/biofuelsreportec.pdf.

[10] Available at: http://ec.europa.eu/energy/renewables/consultations/doc/public_consultation_iluc/global_trade_environmental_impact_study_eu_biofuels_mandate.pdf.

[11] Available at: http://trade.ec.europa.eu/doclib/docs/2011/october/tradoc_148289.pdf

[12] Available at: http://ec.europa.eu/energy/renewables/studies/doc/land_use_change/presentation_iluc_ifpri_nov_2011.pdf.

[13] Results and models have been extensively presented and reviewed in many international conferences and workshops. The 2011 study has not been submitted in a journal but a very similar version has been published (and peer reviewed) in a key journal for the field: Laborde D. and Valin H. (2012). Modeling Land-use Changes in a global CGE: assessing the EU Biofuel Mandates with the Mirage-Biof model. Climate Change Economics, Vol. 3, No. 3 (2012). Moreover, peer-reviewed papers using the 2011 results have also been peer reviewed and published, e.g. http://onlinelibrary.wiley.com/doi/10.1111/j.1757-1707.2012.01207.x/pdf.

particular by considering vegetable oils individually and by improving the modeling of by-products in the animal feed sector. Furthermore, the baseline and the scenarios were adjusted to the requirements of policy analysis by the Commission, for example taking into account Member States' projections of biofuel consumption in the National Renewable Action Plans.

On 17 October 2012, the EC issued a policy proposal (COM (2012) 595) on how to minimise Indirect Land Use Change (ILUC) risks through legislation by amending relevant directives. The proposal currently under discussion within the European Parliament and the Council introduces "ILUC values" for reporting purposes. These are indirect land use change emission values per crop groups like cereals and other starch-rich crops, sugars and oil crops, based on the results of the IFPRI-MIRAGE modelling of 2011. However, in the RED and in the FQD, this is only a reporting requirement (i.e. the emission factors are not included in the sustainability criteria of the Directives and do not have to be added to direct GHG emissions).

Particularly for regulatory purposes, the robustness of ILUC estimates and assumptions is crucial. It must be recognized that ILUC estimates will always come with uncertainties, but the understanding of ILUC emissions and the modelling thereof have improved over the past years, helping to reduce uncertainties in the results.

As part of its scientific and technical support to the Commission's activities for the definition and implementation of EU biofuel policies, the JRC has performed various analyses of ILUC emissions from biofuels and of biofuel market developments, to further improve the understanding of ILUC and the quantification of the related effects. The work has focused notably on uncertainties and limitations, and on extending results to solid biomass feedstocks.

2. Introduction

JRC analysis of IFPRI work carried out in 2011 suggested that some assumptions and methodological choices required further analysis.

Therefore, the JRC launched in 2012 a collaboration with IFPRI, on request from DG ENER and DG CLIMA, to carry out further work with the economic model MIRAGE used to calculate the ILUC factors included in the Commission proposal COM(2012) 595.

In particular, IFPRI was asked to:

1. Evaluate GHG emissions by crop groups (sugar, cereals and oil crops), maintaining the same model assumptions/parameters as in the previous analysis. The Commission had estimated the ILUC values for the crop groups reported in the Impact Assessment by taking weighted averages of the "crop-specific" ILUC results calculated by IFPRI in 2011 (maize and wheat for cereals; beet and cane for sugars; palm fruit, soybean, sunflower, and rapeseed for oilseeds). The JRC requested IFPRI to check these figures by making new runs of the same 2011 version of MIRAGE, in which the crops are aggregated into groups already in the definition of the biofuel scenarios. Each run then produces an aggregate ILUC result for the whole crop group.

2. Make new runs of the MIRAGE economic model in which the following assumptions in the original 2011 runs are addressed one by one and simultaneously:

- Reduction in food consumption: agro-economic models, like IFPRI's MIRAGE, assume that biofuels will cause an increase in crop demand. This results in increased prices for crops which cause both the supply to increase (through an increase in yields) and competing demand in other sectors (mainly food and animal feed[14]) to decrease. This biofuel-induced reduction in food consumption translates into a significant GHG emission reduction for biofuels. It is debatable whether GHG savings due to a reduction in food consumption should be considered as lowering estimated ILUC values, In view of this, it is important that the magnitude of this effect in the MIRAGE model is clearly explained and reported, in particular to measure the GHG balances of biofuels without requiring food consumers to modify their behavior.
- Yield increase: IFPRI 2011 projections of EU wheat yield were much higher than the values reported by other agricultural outlooks.
- Cereals replacing "Other oilseeds": in the IFPRI 2011 work it was assumed that cereal production could expand onto "other oilseeds" crop category as easily as any other arable crop. To see the magnitude of this effect, the category "Other Oilseeds" is maintained constant in Europe in the simulation (no crop reallocation in this category). This may slightly overestimate the effect, as it is reasonable to assume that increased demand from biofuels indeed increases pressure to convert other oilseeds to some extent. On the other hand, the effect is anyway moderated by more expansion onto "other oilseeds" in the rest of the world, and onto crops like vegetables and fruit, which is also questionable. For a rigorous assessment, a deeper land reclassification would be needed, which is part of future work.

This study does not consider possible competitive uses of biomass, for example for green chemistry, bio-based products (bio-based polymers, lubricants, surfactants) etc. However, a significant use of 1st generation feedstocks at commercial scale for these purposes cannot be expected before 2020 (which is the timeframe of this study).

Some other further research issues are also listed at the end of this report. Further work on these issues could be expected to push estimates in both directions (i.e. higher or lower ILUC).

This report contains the analysis of the new runs of the IFPRI-MIRAGE model.

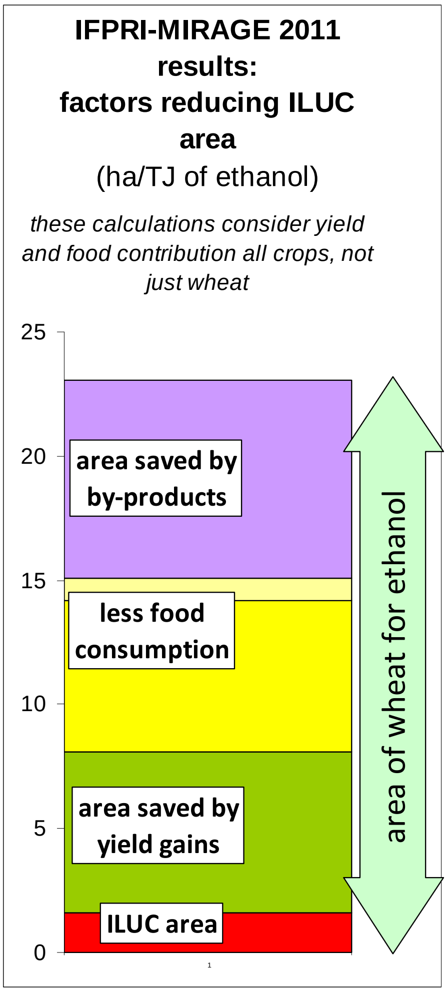
The ILUC emissions by crop group ("group coefficient") are discussed in Section 3. Results of the new runs of the MIRAGE model with sensitivity analyses on some of the suggested parameters are discussed in Section 4. A discussion of the results and conclusions are provided in Section 5.

The Appendix includes a description of the full package of sensitivity analyses run by IFPRI and a detailed description of the results for some marginal scenarios.

[14] In fact MIRAGE and other models indicate that most of the effect is on direct consumption of crops by people, as the use of by-products for animal feed almost cancels the animal feed crops which are diverted to biofuel production.

How economic models estimate ILUC area

To understand the discussion in this report, an explanation on how economic models estimate ILUC area is necessary. In fact, for economic models like MIRAGE, the ILUC area only makes up a small part of the total area needed to grow more crops for biofuels. This is a common feature of the family of Computable General Equilibrium models, which typically include a high number of feedback loops. In the MIRAGE model (as in many other models), the areas saved by by-products, by a reduction in food consumption, and by yield increases, are each considerably greater than the residual crop area increase which causes ILUC.



The JRC's decomposition of the results for IFPRI-MIRAGE 2011 scenario of ethanol from EU wheat is shown in the figure on the left (the principles apply to all scenarios). The total height of the column represents the increased area of wheat devoted to ethanol production reported in the model results, compared to the baseline scenario.

Apart from the expansion of cropland the model derives land for wheat-ethanol production from 3 other sources:

- substitution of animal-feed crops by by-products of biofuel.
- reduction in crop consumption for competing uses (mostly food – see footnote 7).
- land freed up by additional yield gains induced by higher crop prices caused by biofuel demand.

The area saved by yield gains in the biofuel scenario (compared to the baseline scenario) was calculated by multiplying the total area of each crop by its fractional yield increase, and then summing up for all crops.

The remaining area savings come from by-products and reduced food consumption. The JRC calculated the areas saved by by-products and food consumption (in calories), independently of each other, on the basis of IFPRI's output tables. There remains a small area which is ascribed to a change in the *quality* of human food consumption (replacement of vegetables and fruit by cereals and of meat by diets with less meat, for example), an effect which is also reported qualitatively by IFPRI. This happens because the IFPRI model, like other general equilibrium models, considers two market-driven effects. Firstly, increased oilseeds demand results in farmers switching from other crops (including vegetables) to oilseeds. Secondly, when oil and grain prices increase, families redistribute spending to cheaper sources of calories (cereals) and away from more expensive foods such as oils, vegetables and meat. IFPRI reports very little net effect of biofuels on animal feed use, indicating that the use of by-products practically compensates the reduction in crops fed to animals.

Models can run sensitivity analyses in which these sources of area savings are eliminated in turn. These give different results from what one might expect from the areas on the bar chart. That is because the other area savings do not stay constant if one of them is eliminated. For example, when eliminating a reduction in food calories in the model, yields are likely to increase, and food quality to decrease, resulting in an increase of ILUC area.

3. IFPRI ILUC results by crop group ("group coefficients")

The Commission policy proposal COM (2012) 595 reported annualised ILUC GHG emissions (gCO_{2eq}/MJ) calculated by IFPRI for biofuels from 3 crop groups: oilseeds, cereals, and sugar crops. These emissions were estimated as a weighted average of the results for individual crops in each crop group, reported in Laborde, 2011 report. IFPRI re-calculated these crop group values by simultaneously increasing biofuel demand for the individual crops within a crop group in new model runs, using the same version of the MIRAGE model and the same assumptions as the ones used in the study carried out for the Commission in 2011.

This analysis confirms the validity of the estimated ILUC emission values included in the Commission proposal. The results are slightly lower for sugar and biodiesel oil crops compared to those reported in the policy proposal (Table 1): the small reduction is due to optimization of the agricultural response when all the crops in a group are shocked simultaneously.

It should be noted that these estimates do not include changes and improved parameters as listed in Section 4.

Table 1. Estimated annualised ILUC emissions associated with main crop groups used for the production of biofuels (gCO_{2eq}/MJ of EU Consumption, 20 years)

	Mean values in ILUC policy proposal (weighted average)	**Mean values 2013 (modelled)**
Ethanol Sugar	13	11
Ethanol Cereals	12	12
Biodiesel	55	52

IFPRI considers marginal shocks in biofuel demand.
IFPRI creates a baseline with the overall policy and lets the "last mile" to be provided by one crop group to get the marginal effect.
In the baseline scenario, EU27 biofuel consumption amounts to 25.5 Mtoe in 2020 (73% biodiesel and 27% ethanol), which represents an increase of 15.2 Mtoe compared to 2008. The incorporation rate in the baseline is 7.9%, which corresponds to the final blending target minus the marginal shock.
In the two marginal scenarios Ethanol Sugar and Ethanol Cereals, the shocks correspond to an increase of 1.4 Mtoe in EU27ethanol consumption compared to the baseline; whilst in the Biodiesel scenario, the shock is an increase of 1.5 Mtoe in EU27biodiesel consumption.
As far as we can tell, the size of the shock, and the level of demand in the baseline to which it is applied, make little difference to the results as long as they are reported *per MJ of biofuel in the shock* (which is done here).

3.1 Monte Carlo analysis for crop group results

A sensitivity analysis on ILUC emissions for crop groups has been provided by IFPRI adopting the same methodology as the one used in the 2011 report for individual crops.
The estimates are subject to uncertainties related to the model parameters; therefore, a sensitivity analysis on the parameters affecting the land use consequences of biofuel policies either directly (e.g. elasticity of transformation between land activities) or indirectly (yield elasticity) has been included. IFPRI uses a Monte Carlo approach, in which alternative sets of values from assumed parameter distributions are used to run alternative simulations.
The ranges of uncertainty on ILUC emissions are shown in Table 2 and Figure 1:

- for ethanol-cereals, values range from 7.6 gCO_{2eq}/MJ (5^{th} percentile) to 16.5 gCO_{2eq}/MJ (95^{th} percentile) with a mean of 12.3 gCO_{2eq}/MJ. The mean and the median are close and the median is equal to the central scenario value (12.5 gCO_{2eq}/MJ).

- for ethanol-sugar, the central scenario value (11.2 gCO_{2eq}/MJ) is equal to the median and it is very close to the mean. The values range from 4.4 gCO_{2eq}/MJ (5^{th} percentile) to 17.4 gCO_{2eq}/MJ (95^{th} percentile) with a coefficient of variation of 34%.

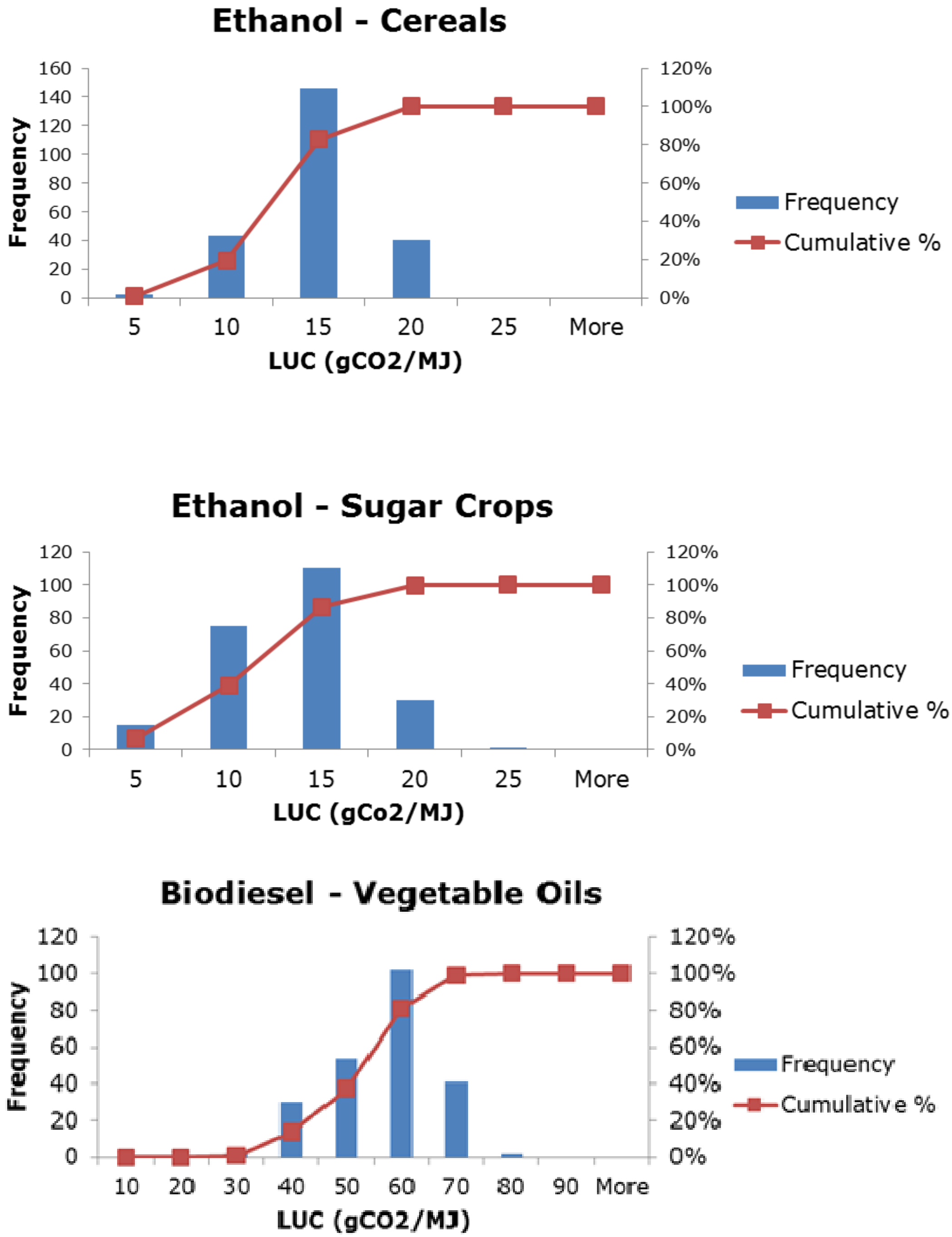
- for biodiesel, values range from 33.1 gCO_{2eq}/MJ (5th percentile) to 66.5 gCO_{2eq}/MJ (95th percentile). The mean and the median are quite different (52.1 gCO_{2eq}/MJ and 53.6 gCO_{2eq}/MJ respectively) and the central scenario value (53.1 6 gCO_{2eq}/MJ) is quite close to the median. However, the coefficient of variation is lower than in the two other crop groups.

Table 2. Summary of sensitivity analysis on LUC emissions (gCO_{2eq}/MJ) for crop group results (modelled)

	Ethanol Cereals	Ethanol Sugar	Biodiesel
Mean	12.3	11.1	52.1
Median	12.5	11.2	53.6
Standard Deviation	*2.9*	*3.8*	*9.6*
5 percentile	*7.6*	*4.4*	*33.1*
95 percentile	*16.5*	*17.4*	*66.5*
Coefficient of Variation	23%	34%	18%

It has to be noted that the sensitivity ranges in table 2 are consistent with the crop group approach chosen by the Commission in its proposal COM (2012) 595. The average values for crop group percentiles calculated in the Impact Assessment (SWD(2012) 343 final, p. 125, table 22) were based on approximation (exogenous weighting system for crops belonging to one category).

Figure 1. Sensitivity analysis on LUC emissions for crop groups



4. What is new in IFPRI-MIRAGE ILUC model results

The careful and complex analysis carried out by the JRC of IFPRI 2011 results highlighted 3 issues which needed to be addressed if the MIRAGE model is to be used for estimating ILUC. IFPRI ran the model addressing each issue separately and simultaneously. The results are shown and discussed in sections 4.1, 4.2 and 4.3, separately, while section 5 presents the "cumulative" results.

In addition, the JRC requested IFPRI to run various sensitivity analyses on the 2011 MIRAGE model applied to crop-specific scenarios, with the objective of clarifying the importance of various factors in the model. Details of these sensitivity analyses are presented in Appendix 1, along with details of the runs to address the issues described in section 4.

The biofuel demand shocks are unchanged.
The 'shocks' in biofuel demand used by IFPRI in these results are the same as in their 2011 report.
IFPRI increases the blending rate in the EU by 0.5 percentage points, maintaining the consumption of all other feedstocks by all other biofuel industries in the world constant. Therefore, any increase in biofuel supply that should match the new EU demand could be generated only with one feedstock.
The marginal shocks in the sensitivity runs are four shocks for ethanol (ethanol beet, ethanol cane, ethanol maize, and ethanol wheat) and four for biodiesel (oil palm, oil rapeseed, oil soybean, and oil sunflower).
In the biodiesel marginal shocks, each shock corresponds to an increase in EU biodiesel consumption of 1.5 Mtoe compared to the baseline.
In the ethanol marginal shock, the increase in biofuel demand is completely achieved by an increase in ethanol consumption of 1.4 Mtoe in all scenarios. The difference in shock size is unimportant, as the results are all quoted per MJ of biofuel demand shock.

4.1 Changing IFPRI's projection of EU wheat yield

The evolution of future crop yields is a source of uncertainty in ILUC estimates. If crop yields are high in the baseline, less crop area is required to produce the same amount of feedstocks for biofuels, and ILUC is lower. The projected increases in EU crop yields in the IFPRI model baseline appear as exceptionally optimistic. In particular, in its 2011 study, IFPRI assumed that EU wheat yield – by physical hectare - are 45% higher in 2020[15] than the DG-AGRI[16] and OECD-FAO projections[17]., A yield of 5.5t/ha in line with OECD-FAO projections is now considered.

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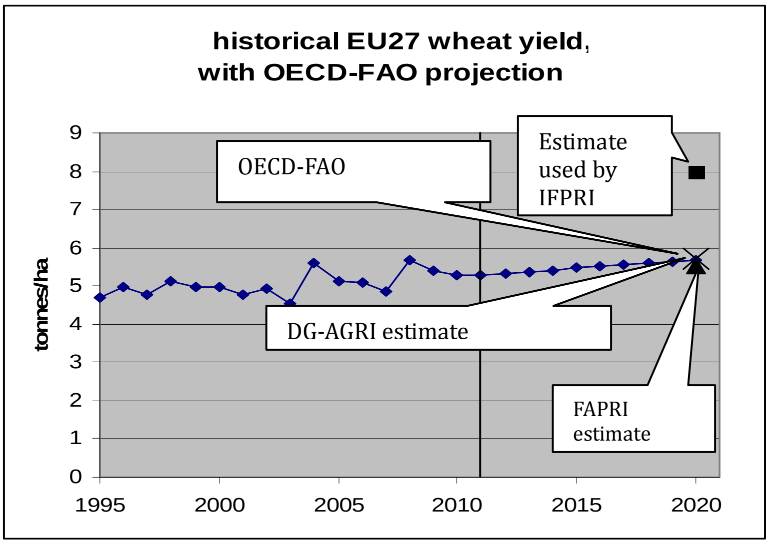
15 IFPRI assumed that yields in the New Member States would catch up with those in EU15 by 2020. Whereas the JRC agrees that technology will tend to catch up (even though the 'yield gap' has so far increased in absolute terms since accession), the average rainfall in NMSs (which is the main determinant of maximum crop yields) will not. Furthermore, IFPRI had an excessively optimistic estimate of EU annual yield increase, and applied this to the abnormally high yield in 2004.

16 European Commission, Directorate-General for Agriculture and Rural Development, 2011,"Prospects for agricultural markets and income in the EU 2011–2020".

17 OECD-FAO, www.oecd.org/site/oecd-faoagriculturaloutlook/.

Figure 2. EU wheat yield (historical and OECD-FAO projection)



In this new scenario, **only the EU27 wheat yield has been reduced** in the baseline 2020 scenario from 8 t/ha in the 2011 report to 5.5 t/ha. The base year (2008) remains the same but it has been exogenously reduced over the simulation period to reach the OECD-FAO target in 2020.

The resulting ILUC area and emissions **for wheat ethanol** are somewhat higher than in previous analysis (Table 3). This result is not surprising considering that only the EU27 wheat yield is modified, keeping all other crop yields unchanged.

Table 3. ILUC emissions and cropland area change in IFPRI report 2011 and *EU wheat yield corrected* scenario

	Annualised ILUC (gCO_{2eq}/MJ of EU Consumption, 20 years)		Cropland area change (ha/TJ)	
	IFPRI report 2011	2020 EU wheat yield corrected	IFPRI report 2011	2020 EU wheat yield corrected
Ethanol Wheat	14	17	1.39	1.67

4.2 Avoiding expansion of major crops onto “other oilseeds” in the EU

Preventing expansion of arable crops onto olive plantations greatly increases ILUC.

The ILUC results presented in the IFPRI 2011 report [Laborde, 2011] were significantly lower than the 2010 results [Al-Riffai et al., 2010], especially for cereals. In the 2011 version of MIRAGE, IFPRI changed the reallocation among crops using a new calibration procedure, which resulted in an increased mobility of land among crops. With this new calibration wheat and maize production (in particular) can more easily expand by displacing other crops.

An analysis of the results showed that in the 2011 report, the expansion of crops for biofuel production at the expense of other crops and especially “other oilseeds” (mainly in EU) was considerably larger than the ILUC area for some biofuels. Furthermore, most “other oilseeds” area in EU was olive groves (more than 4Mios ha). It turned out that between 2010 and 2011 the new calibration had made it easier to switch land allocation between cereals, major oilseeds and “other oilseeds”. It can be considered unlikely that arable crops would easily replace olives. To see the magnitude of this effect, IFPRI was requested to exclude any expansion of other cropping activities into the “other oilseeds” category for the EU. This may not still be an entirely satisfactory assumption, as it is reasonable to assume that increased demand from biofuels indeed increases pressure to convert other oilseeds and would therefore lead to some expansion. However, this is counterbalanced by more expansion in the model onto ”other oilseeds” in the rest of the world, and onto crops like vegetables and fruit, which is also questionable. For a rigorous assessment, a deeper land reclassification would be needed, which is part of future work.

Changing this assumption proves to have a slight effect on the final ILUC emissions for key EU commodities such as sugar beet, cereals and rapeseed (as shown in Figure 3 and Figure 4).

Figure 3. Annualised ILUC emissions (gCO_{2eq}/MJ of EU consumption, spread over 20 years) in IFPRI report 2011 and *No expansion of major crops into "other oilseeds" in EU* scenario

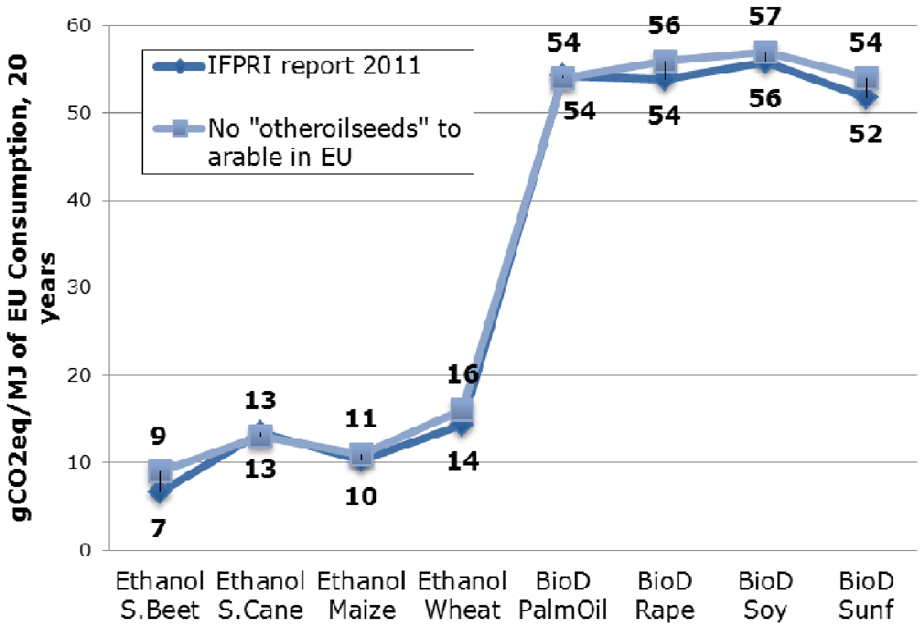
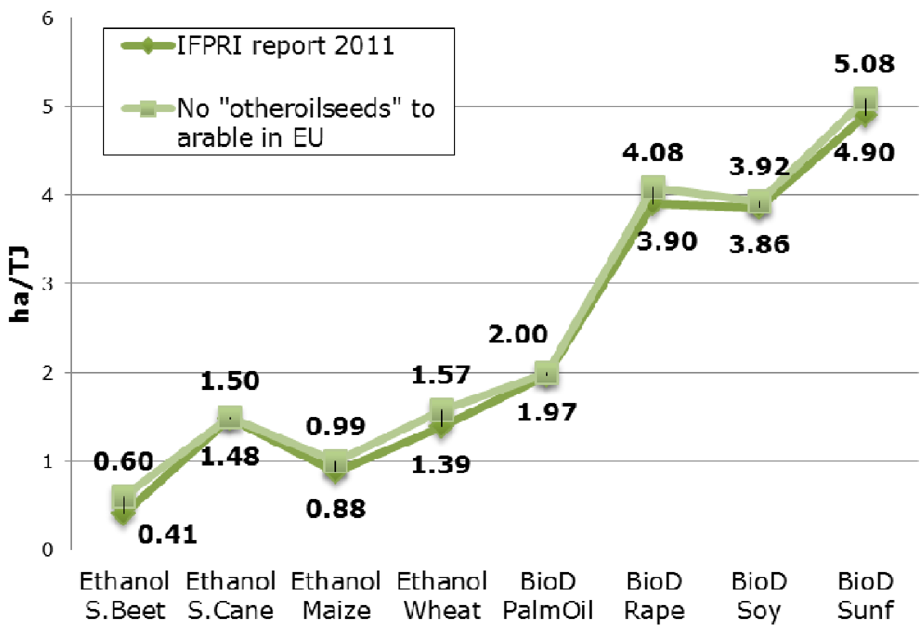
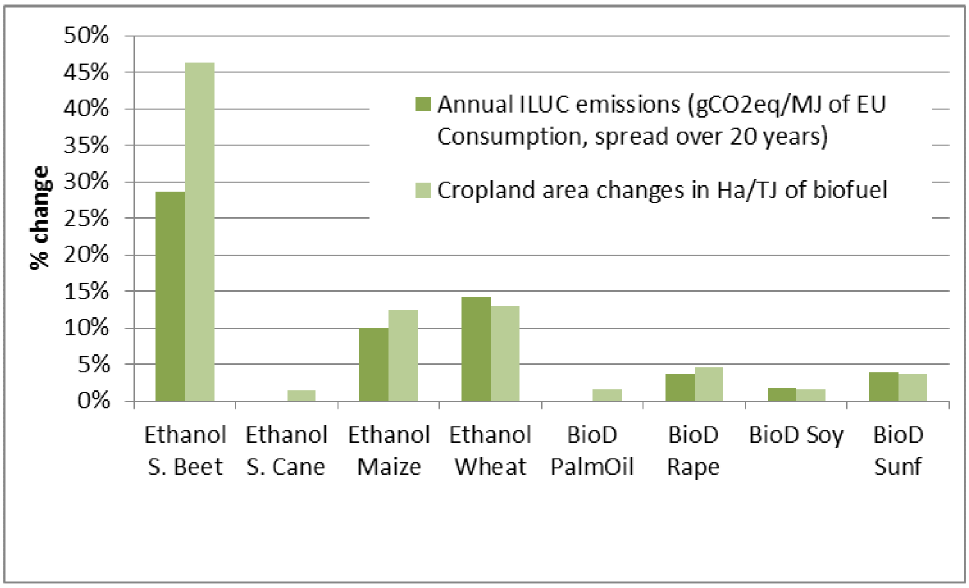


Figure 4. Cropland area change (ha/TJ of biofuel) in IFPRI report 2011 and *No expansion of major crops into "other oilseeds" in EU* scenario



The graph below (Figure 5) shows the percentage change in GHG emissions and total cropland area in the "No expansion of major crops into "other oilseeds" in the EU scenario compared to the values in the 2011 analysis.

Figure 5. Percentage changes of ILUC emissions and cropland in *No expansion of major crops into "other oilseeds" in EU* scenario compared to IFPRI report 2011



ILUC emissions increase (from 0% to 29% depending on the crops, with the highest change in the sugar-beet scenario) if the assumption that oilseeds like olive can be replaced in the EU by cereals is changed.

4.3 Reduction in food consumption

Agro-economic models, like IFPRI-MIRAGE, start off by assuming that biofuel demand will cause an increase in crop consumption. This results in increased prices for crops, which cause both *supply* to increase (through an increase in yields and area) and *competing demand* in the other sectors (mainly food and animal feed) to decrease. The biofuel-induced reduction in food consumption translates into lower estimates of ILUC emissions from biofuels.

IFPRI's model gives ILUC emissions from an increase in crop demand

The IFPRI-MIRAGE model of ILUC is a full economic model of both supply and demand[18]. If biofuel demand increases demand for a crop, the crop price increases and this causes a reduction in consumption (for food) as well as an increase in crop supply. So the model concludes that less extra crop needs to be grown than is needed to supply the extra demand for the biofuel. The rest of the crop needed for biofuel production comes from a reduction in demand from other competing sectors, principally food consumption (see footnote 7). Through this effect, part of the biofuel production comes free of ILUC.

18 The same is true for most other economic models used for ILUC.

Whether or not biofuels should be attributed lower ILUC estimates due to this reduction in food consumption is an ethical decision, which would have to take into account where, and which type of, food consumption is estimated to be reduced. In support of policy decisions/discussions, it is in any case relevant to quantify the magnitude of this effect.

Therefore, the JRC asked IFPRI to re-run the model whilst holding food consumption constant. There are several ways of doing this. It was specified that the consumption of each crop should be fixed separately, in order to also eliminate "food quality changes" whereby higher food prices cause a switch, for example, from vegetables to corn or from meat to a diet with less meat (saving crop area, and reducing ILUC). One alternative approach would have been to keep the intake of e.g. calories constant, which would have still allowed for changes in consumption between different food categories. This "weaker" approach is likely to lead to smaller increases in ILUC estimates..

Results: ILUC emissions are increased for most crops except sugar beet and rapeseed

Figure 6 and Figure 7 below show how much this correction increases ILUC emissions and area. Compared to the 2011 report scenarios, several crops, except sugar beet and rapeseed, show an increase in GHG emissions.

For rapeseed, the increase in GHG emissions is almost negligible, while the total area devoted to cropland increases by more than 1 ha/TJ (i.e. there is a large reallocation of land type in total cropland, and cropland changes occur in areas with lower carbon stocks).

Surprisingly, in the case of ethanol from EU sugar beet, freezing food demand actually reduces ILUC area and emissions, according to the MIRAGE results. Freezing food consumption results in larger increases in sugar price, and this induces higher sugar crop yields. It seems likely that this effect has been over-estimated, with the surprising result that sugar crop area outside the EU significantly *decreases* when food consumption is frozen compared to the 2011 report scenario, and to such an extent that overall world sugar beet production area hardly changes.

To compound this effect, MIRAGE projects that the increase in sugar area in the EU is largely absorbed by reductions in production areas for crops such as 'other oilseeds' (see the discussion of that assumption in section 4.2), so that the overall increase in EU crop area is tiny, and smaller than the surprising and large decrease in sugar area in the rest of the world.

It has to be noted that also for rapeseed oil-biodiesel, emissions remain almost unchanged in the "freeze food consumption" scenario. In the IFPRI 2011 results, diverting rapeseed oil from food to fuel leads to higher use of palm oil for food, and this results in higher LUC emissions. When food consumption is frozen, there is no increase in palm oil, and although much more rapeseed must be grown, this is all on mineral soils with relatively low LUC emissions (see more details in Appendix 1).

Figure 6. Annualised ILUC emissions (gCO_{2eq}/MJ of EU consumption, spread over 20 years) in IFPRI report 2011 and *Freeze food consumption* scenario

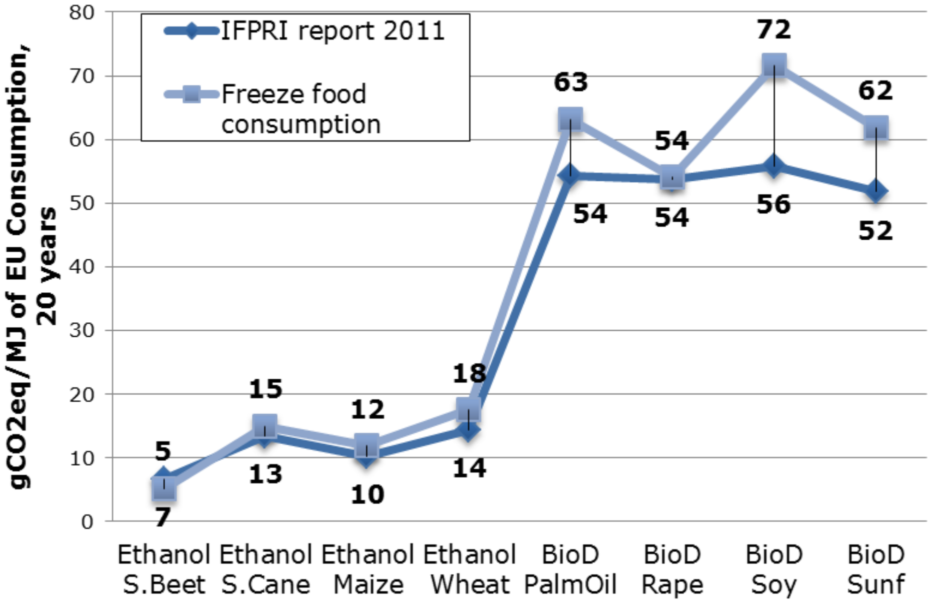
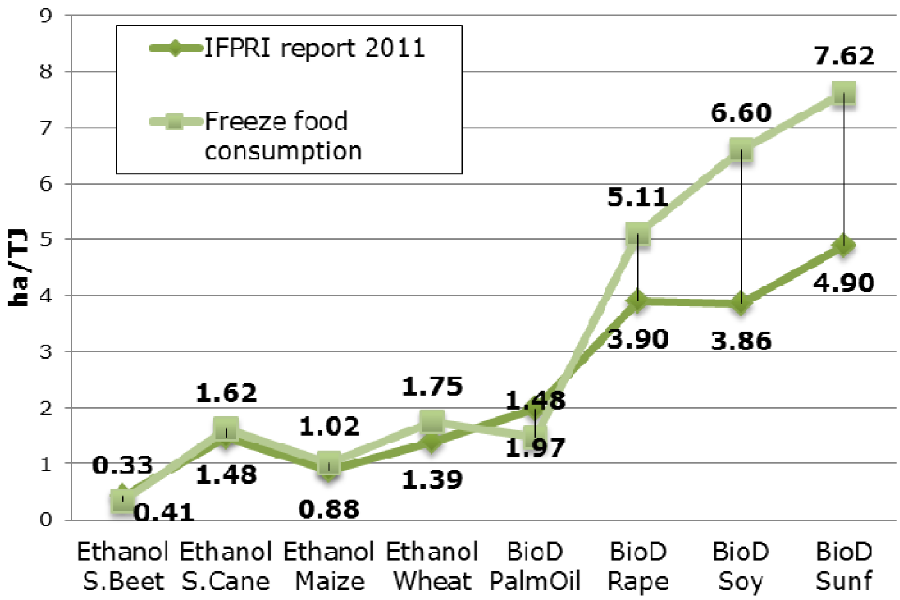


Figure 7. Cropland area change (ha/TJ of biofuel) in IFPRI report 2011 and *Freeze food consumption* scenario



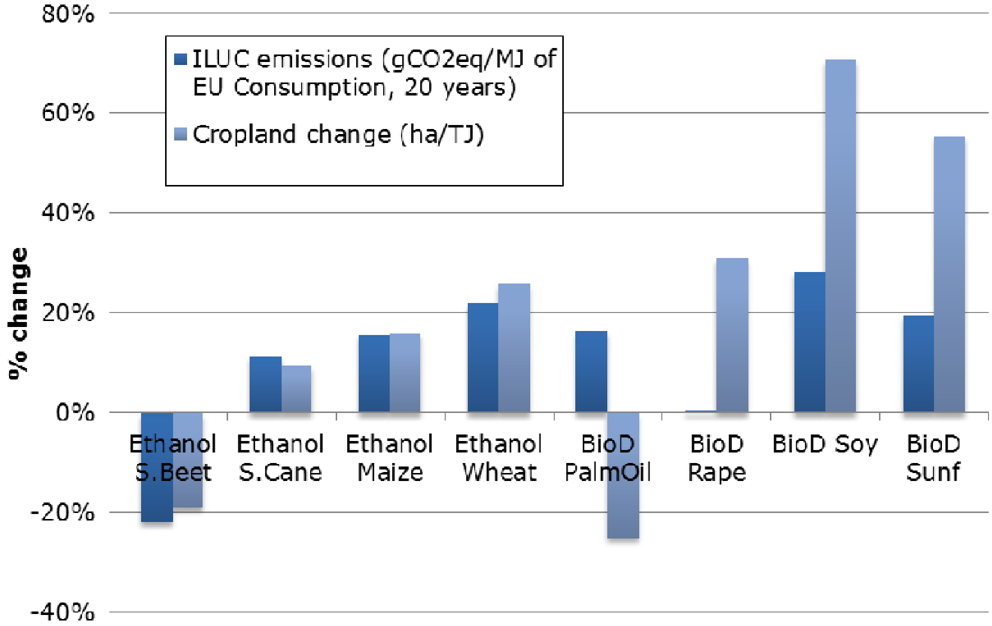
The graph below (Figure 8) shows, in percentage terms, the changes in GHG emissions and total cropland areas when food consumption is frozen in the IFPRI-MIRAGE model.

As discussed above, ILUC emissions increase (from 10% to 30%, depending on crop type) if food consumption is maintained constant, with the exception of sugar beet (soybean is the crop with the largest relative change). What is evident from Figure 8 is that in particular for oil crops the change in areas is much higher than the change in GHG emissions.

IFPRI explain this in the report delivered to the JRC *[Deason and Laborde, 2013]:*

"A change in land use under alternative scenarios is not always driven by a simple increase (decrease) in cropland, but also by the reallocation of this cropland".

Figure 8. Percentage changes of ILUC emissions and cropland in *Freeze food consumption* scenario compared to IFPRI report 2011



Some explanation for the marginal oilcrops scenarios as reported in the draft IFPRI report delivered to the JRC [Deason and Laborde, 2013]:

Rapeseed:

" Under the constant food use scenario, carbon released from forest biomass and carbon released in mineral soil actually increase considerably (by 39% and 29% respectively), however this is almost completely off-set by the decrease in carbon released from Palm extension on Peatland. This also implies that under this scenario, the LUC coefficient for rapeseed will be less dependent on the assumptions concerning palm oil production (share on peat lands and annual emissions of peat) as fixing final and intermediate food uses does not allow the rapeseed diverted away from food uses to be replaced by Palm oil."

Sunflower:

"Similarly, the positive change in LUC for Sunflower Oil results from large increases in the carbon released from forest biomass and carbon released in mineral soil (by 40% and 51% respectively), but much of this is off-set by a reduction the gCO_2/MJ *emitted by Palm extension on Peatland (which decreases by 79%)".*

Soybean:

"Soybean Oil, which exhibits the largest increase in LUC under this scenario, follows the same pattern as these other vegetable oils, with increases in carbon emissions from deforestation and cultivating cropland, which are somewhat off-set by decreases in emissions from Palm extension on Peatland.

PalmOil:

"For Palm Oil, this pattern is reversed, with carbon emissions from forest biomass and mineral soil decreasing under the constant food consumption (which makes sense given the overall decrease in global cropland), while this decrease is more than offset by a sizable (36%) increase in emissions from Palm extension on Peatland.

In order to see why it would be the case that these emissions increase despite an overall decrease in cropland area, one might guess that despite the overall area decrease, an increase in area for Palm production releases carbon from Peatland.

[…]Despite the global decrease in cropland, the IndoMalay region exhibits an increase in cropland which almost entirely due to an increase in area for Palm production.

This explains the increase in LUC coefficient via Palm extensions on Peatland, even while total crop area decreases. Furthermore, the global decrease in overall cropland under this scenario despite a sizable increase in Palm production makes sense since palm has very high yield in terms of veg oils by ha, therefore a shift towards palm production from other oilseeds will require less total area.".

5. Summary of results and conclusions

This work presents and discusses the results of new runs of MIRAGE model modifying some assumptions in the previous work carried out for the Commission.

The results of these new analyses confirm that the ILUC emission values reported in the Commission's policy proposal may be conservative. Other studies, like a recent working paper by Gohin, 2013[19], hint at changes to be made which may lead to lower values. However, as discussed in detail in Appendix 2, the conclusions of this paper are questionable.

IFPRI presented the model changes in the form of "sensitivity analyses", where the changes are firstly made one at a time, and the effects on the results are seen one by one, and secondly they are run simultaneously to show the "cumulative" effects.

Table 4 and Table 5 compare the IFPRI report 2011 results in terms of ILUC emissions and ILUC area respectively with the results of the 3 main sensitivity analyses run by IFPRI in 2013 and presented in this report. They include:

1. Correction of the EU wheat yield projections ("*2020 yields corrected*" scenario).
2. Avoided extension of arable crops into "other oilseeds" area in the EU ("*No expansion of major crops into "other oilseeds" in the EU"* scenario);
3. Food consumption maintained constant per food category ("*Freeze food consumption*" scenario).

The modifications made by IFPRI in response to the specific requests from the JRC concerning the assumptions and parameters in their model result in increased ILUC emissions compared to the 2011 values, especially for EU ethanol (Table 4 and Table 5). Each individual correction changes ILUC emissions:

[19] Gohin, A. , 2013. Le changement d'affectation des sols induit par la consommation européenne de biodiesel: une analyse de sensibilité aux évolutions des rendements agricoles. Working Paper SMART-LERECO n.13-07.
http://www6.rennes.inra.fr/smart/Media/Working-papers/WP13-07

- if the modelled EU 2020 wheat yield is brought in line with OECD-FAO projections, ILUC emissions for wheat-ethanol increase by 15%; however for other crops they are unaffected or even reduced.
- emissions vary from 0% to +29% depending on the crop if the assumption that the crop category "other oilseeds" including olives in the EU can be replaced by cereals is removed.
- emissions vary from -20% to +30%, depending on the crop, if food consumption is kept constant.

ILUC coefficients for vegetable oils remain larger in magnitude than those for ethanol crops under all scenarios.

In terms of crop area, the changes in percentage are larger than in terms of GHG emissions (see Table 5 and Appendix I for more details).

Running the three effects simultaneously to give "cumulative" results is necessary.

ILUC emissions have also been re-calculated considering the three main changes altogether, i.e. running the model combining them simultaneously.

The cumulative results are shown in two steps:

1) In a first step, the correction on the EU wheat yield according to the OECD-FAO projection for 2020 and the avoided expansion into other oilseeds in Europe are run simultaneously. Results in terms of emissions and cropland change are shown in the second last lines of
Table 4 and Table 5.

2) In a second step, the three changes are run altogether. The freezing of food consumption is added to the changes applied in the previous step. Results in terms of emissions and cropland change are shown in the last rows of the same tables.

The combined effects bring higher LUC emissions (as could be expected) compared to the individual changes.

Correcting the assumption on wheat yield and excluding expansion of cereals into other oilseeds in the EU (Step 1), ILUC emissions increase by a range of 9-14 gCO_{2eq}/MJ for sugar crops, 12-19 gCO_{2eq}/MJ for cereals crops and 52-56 gCO_{2eq}/MJ for vegetable oils. Stronger effects are noted for wheat and rapeseed coefficients. This result is logical since they are the main crops affected by the modifications.

The corresponding percentage increases in terms of ILUC emissions (from 0% to almost 34%) and cropland expansion (from 0% to more than 33%) with respect to the 2011 LUC values are shown in Figure 9.

Adding the food consumption effect, the increases are even higher (last rows of Table 4 and Table 5). The range of ILUC emissions for the crop groups becomes: 7-16 gCO_{2eq}/MJ for sugar crops, 13-23 gCO_{2eq}/MJ for cereals and 56-72 gCO_{2eq}/MJ for vegetable oils.

The corresponding percentage increases in terms of ILUC emissions (from 3% to almost 62%) and cropland expansion (from -24% to +72%) with respect to the 2011 LUC values are shown in Figure 10.

Table 4. Effect of IFPRI model corrections on ILUC EMISSIONS

Annualised ILUC emissions (gCO_{2eq}/MJ of EU Consumption, spread over 20 years)								
	Sugar crops		Cereals		Vegetable oils			
	Ethanol S. Beet	Ethanol S. Cane	Ethanol Maize	Ethanol Wheat	BioD PalmOil	BioD Rape	BioD Soy	BioD Sunf
IFPRI report 2011	7	13	10	14	54	54	56	52
1. 2020 wheat yields corrected	6	14	10	17	54	53	55	50
2. No *"other oilseeds"* to arable in EU	9	13	11	16	54	56	57	54
3. Freeze food consumption	5	15	12	18	63	54	72	62
STEP 1 - Combining 1. 2020 yields corrected and 2. No *"other oilseeds"* to arable in EU	9	14	12	19	55	55	56	52
STEP 2 - Combining STEP 1 and 3. Freeze food consumption	7	16	13	23	63	56	72	62

Table 5. Effect of IFPRI model corrections on ILUC AREA

Cropland area changes in Ha/TJ of biofuel								
	Sugar crops		Cereals		Vegetable oils			
	Ethanol S. Beet	Ethanol S. Cane	Ethanol Maize	Ethanol Wheat	BioD PalmOil	BioD Rape	BioD Soy	BioD Sunf
IFPRI report 2011	0.41	1.48	0.88	1.39	1.97	3.90	3.86	4.90
1. 2020 wheat yields corrected	0.35	1.50	0.85	1.67	1.95	3.80	3.82	4.66
2. No *"other oilseeds"* to arable in EU	0.60	1.50	0.99	1.57	2.00	4.08	3.92	5.08
3. Freeze food consumption	0.33	1.62	1.02	1.75	1.48	5.11	6.60	7.62
STEP 1 - Combining 1. 2020 yields corrected and 2. No *"other oilseeds"* to arable in EU	0.53	1.52	0.96	1.85	1.99	3.98	3.88	4.84
STEP 2 - Combining STEP 1 and 3. Freeze food consumption	0.48	1.66	1.13	2.31	1.50	5.30	6.66	7.55

Figure 9. Percentage changes of ILUC emissions and cropland in Step 1 - Combining "2020 yield corrected" and "No other oilseeds to arable in EU" scenario compared to IFPRI report 2011

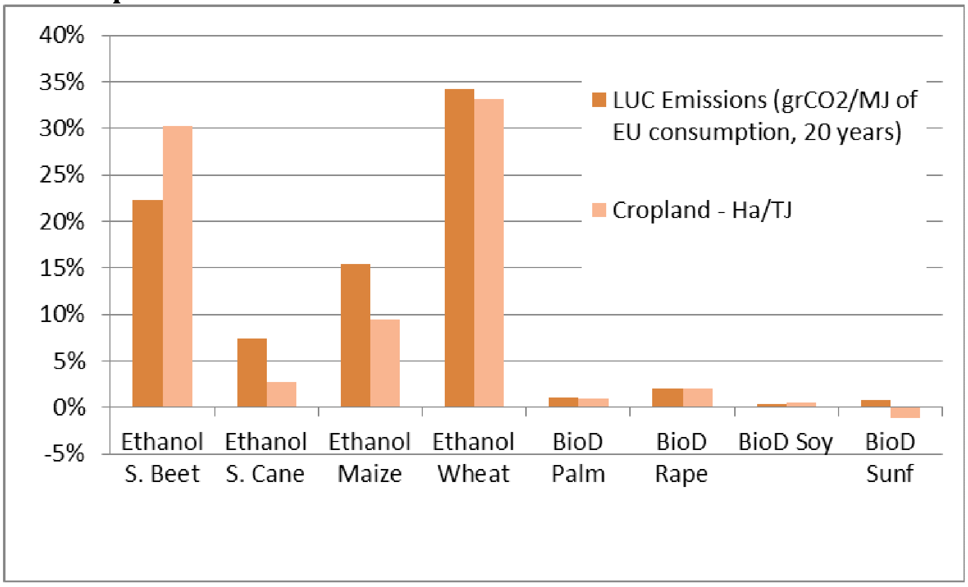
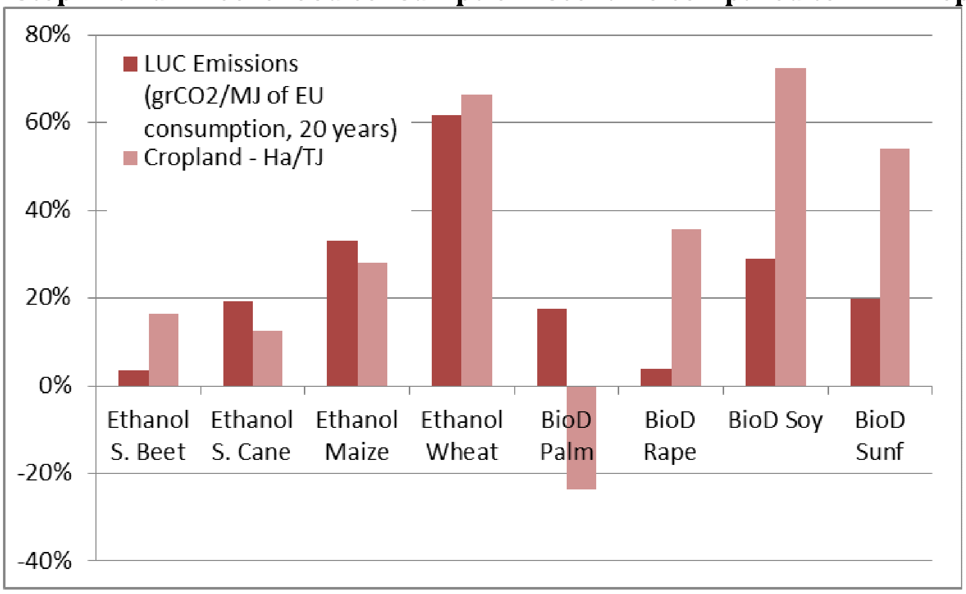


Figure 10. Percentage changes of ILUC emissions and cropland in Step 2 - Combining "Step 1" and "Freeze food consumption" scenario compared to IFPRI report 2011



6. Further research

The IFPRI-MIRAGE model is a very sophisticated model that has been optimized for modelling ILUC from EU biofuels.

However, due to the inherent complexity of the issues, many parameters and assumptions contribute to the model results.. and there are still several issues which would need to be further investigated in the model and which could affect ILUC results moderately in either direction:

- The role of the yield elasticity parameter is fundamental in estimating ILUC (see discussions about Gohin, 2013 paper in Appendix 2). Further research to better calibrate this parameter should be carried out.
- For a given increase in crop price, the yields seem to increase too much compared to the area. Especially for **sugar crops and cereals**, **most of the extra production comes from yield increase.** This gives some strange results. For example, an increase in sugar price caused by fixing sugar consumption for food in the sugar-beet ethanol scenario results in such a high increase in sugar-cane and beet yields that the total cane area actually shrinks. Fixing this anomaly would probably **increase** ILUC results for ethanol.
- Substitution of one vegetable oil by another is done on the basis of equal price. This can mean that more extra vegetable oil can be produced than is needed for biodiesel. A more realistic approach involving quality premiums for some oils would probably **reduce** ILUC emissions from EU biodiesel. IFPRI derive the amount of biofuels and by-products from processing from econometrics, and they do not add up in terms of mass. This is the subject of an on-going discussion with IFPRI,. This would require a detailed analysis, and a change would probably moderately reduce ILUC emissions.
- Although we have changed IFPRI's 2011 assumption that a “main” arable crop can expand as easily at the expense of “other oilseed” (olive trees, in EU) as another arable crop, MIRAGE still makes this assumption for fruit and vegetables everywhere. These assumptions need to be re-examined by crop and region to exclude areas of orchards and olives, for example, which may be displaced with more difficulty, whilst allowing expansion onto cotton, for example. In order to proper assess this issue, and after preliminary investigations, it has been concluded that the number of land categories in the model should be expanded. The net effect could go in either direction.
- The assumed prices of biofuel by-products may be out of date. Updating prices may moderately reduce ILUC estimates.
- Overall (among countries and crops), the crop yields in 2020 assumed in the IFPRI modelling exercise (based on 2009 projections) are significantly higher than most recent projections. Crop yields should be updated; ILUC results would probably increase.
- The rate of technical improvement of yields should also depend on crop price (as well as the component of the yield reacting to price via the use of inputs). However, IFPRI argues that the time delay between research and yield change is

so long that there would be no effect on the results.

- It may be possible to improve the modelling of forest conversion to cropland, taking into account the value of the wood, which could increase deforestation rates in the baseline, and thus decrease ILUC emissions.
- In the MIRAGE model, fallow and abandoned land are either considered as “set aside” cropland under a policy conservation program or treated as extensive pasture land. Some sensitivity analysis could be envisaged, possibly with different policy assumptions (in terms of conservation, set-aside, or afforestation options) or productivity level for these lands.
- Sensitivity of the land expansion elasticity into forest could also be examined (some have suggested that it might be relatively too easy for crops to expand into forest in the model, as this happens to the same extent as on grassland and pasture).
- The fraction of palm oil expansion onto peat forest, and the resulting emissions, should be reviewed in the light of new data. Also, the amount of peatland emissions MIRAGE attributes to new palm oil plantations on existing plantations/cropland (rubber etc) should be verified, as currently palm oil expansion on existing agricultural land is attributed the same emissions as peat land conversion. In addition, the emissions for peatland conversion should be revised (most likely upwards).
- Competitive uses of biomass like for green chemistry, bio-based products (bio-based polymers, lubricants, surfactants) etc. are not considered in this analysis, and should be included in future investigations.

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http://www6.rennes.inra.fr/smart/Media/Working-papers/WP13-07

Appendix 1: overview of the sensitivity analysis for the 1st Generation biofuels

As part of the package "sensitivity analysis", IFPRI ran 8 different scenarios, which can be divided in 4 different groups:

1) The scenarios which freeze food consumption (***Food fixed all uses***, ***Food fixed final consumer***). The most relevant is the one in which the model is able to fix a larger quantity of food, which is the Food all uses scenario. In this scenario, food is maintained constant in final (household direct demand) and intermediate uses (agro-food sector demand). This is the scenario discussed in Section 4 (Freeze food consumption).
2) A scenario in which co-products from marginal biofuel production are not injected in the livestock sector (***No Co-products***).
3) The scenarios which modify yields: in three scenarios, the EU wheat yield (ONLY) has been changed in different ways:
    - *in the **2020 EU wheat yield corrected*** which is the scenario commented in Section 4.2, the EU wheat yield has been reduced in the baseline (2020) so as to be the same as the OECD-FAO target;
    - in the ***Modified yield wheat EU***, the EU wheat yield has been changed not in the baseline, but in the base year (2008) from 7.9 t/ha to 5.5 t/ha, resulting in a value of 5.6 t/ha in 2020 from exogenous technical change;
    - in ***Flat yield wheat EU*** scenario, there is no exogenous yield increase for wheat in the EU between 2008 and 2020, so it stays at 7.9 t/ha (instead of increasing to 8.0 t/ha).
    - Finally, in the scenario ***Flat yield***, no exogenous yield increase has been imposed for all crops and all regions.
4) The scenario ***No Expansion into other Oilseeds in EU*** in which IFPRI has excluded any expansion of other cropping activities into this "other oilseeds" category for the EU (see Section 4.2)..

Figure I and Table I show the ILUC emissions for all the alternative scenarios run in the sensitivity analysis. Table II provides the percentage change compared to the IFPRI 2011 results.

From IFPRI report to the JRC:
"We can see that ILUC coefficients for vegetable oils remain larger in magnitude than those for ethanol crops under all scenarios." [Deason and Laborde, 2013].

The largest change occurs in the the Flat Yield scenario, where no exogenous yield increase has been imposed for all crops and all regions between 2008 and 2020.

The food effect goes from no impact in the oil-rape scenario (0% change compared to the 2011 report) to a maximum of 28% in the oil-soybean scenario and a negative effect in the ethanol beet scenario.

The co-products affect mainly the ethanol feedstocks: the LUC values increase by 46% and 43% respectively in the ethanol-maize and the ethanol-beet scenarios.

Figure I. Annualised ILUC emissions (gCO_{2eq}/MJ) in 2020

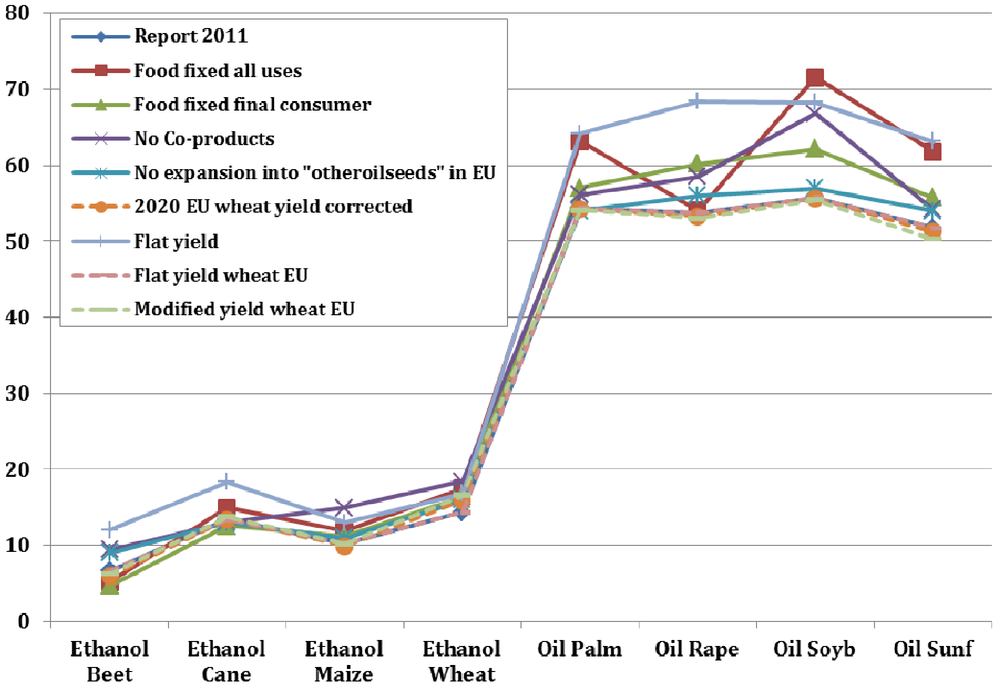

Table I. Annualised ILUC emissions (gCO_{2eq}/MJ) in 2020

	Ethanol S.Beet	Ethanol S.Cane	Ethanol Maize	Ethanol Wheat	BioD Palm Oil	BioD Rape	BioD Soy	BioD Sunf
IFPRI Report 2011	**7**	**13**	**10**	**14**	**54**	**54**	**56**	**52**
Food fixed all uses	5	15	12	18	63	54	72	62
Food fixed final consumer	5	13	11	16	57	60	62	56
No co-products	9	13	15	18	56	59	67	54
No expansion into “otheroilseeds” in EU	9	13	11	16	54	56	57	54
2020 EU wheat yield corrected	6	14	10	17	54	53	55	50
Flat yield	12	18	13	17	64	68	68	63
Flat yield wheat EU	7	13	10	14	54	54	56	52
Modified yield wheat EU	6	13	10	16	54	53	56	51

Table II. Percentage changes (compared to IFPRI report 2011)

	Ethanol S.Beet	Ethanol S.Cane	Ethanol Maize	Ethanol Wheat	BioD Palm Oil	BioD Rape	BioD Soy	BioD Sunf
Food fixed all uses	-22%	11%	16%	22%	16%	0%	28%	19%
Food fixed final consumer	-29%	-6%	9%	14%	5%	12%	11%	8%
No co-products	43%	-3%	46%	28%	3%	9%	20%	5%
No expansion into “otheroilseeds” in EU	29%	0%	10%	14%	0%	4%	2%	4%
2020 EU wheat yield corrected	-6%	2%	-1%	15%	0%	-1%	0%	-3%
Flat yield	81%	37%	27%	17%	18%	27%	23%	22%
Flat yield wheat EU	0%	0%	0%	0%	0%	0%	0%	0%
Modified yield wheat EU	-10%	0%	-3%	11%	0%	-1%	0%	-1%

Another way of looking at the results is to consider the world cropland change after the shocks (Figure II, Table III and Table IV).

In this case, the food consumption and co-products effects are more evident.

From IFPRI report to the JRC-IET:
"We see that for the most part, increases (decreases) in the ILUC coefficient for a given policy shock tend to be highly correlated (R2=0.60 for all scenarios, and an average coefficient of 8 tons of CO2 per ha of cropland) with increases (decreases) in total cropland, as one might expect given that increasing area devoted to crops will tend to release more CO2 through carbon released by forest biomass (in the case where forest is replaced by cropland), released from mineral soil (as the land is used for crops) and by Palm extension on Peat (in the case where the additional cropland is in the IndoMalay region and is used for Palm). There are, however, some outliers, indicating that a change in LUC under alternative scenarios is not always driven by a simple increase (decrease) in cropland, but also by the reallocation of this cropland."
[Deason and Laborde, 2013].

Figure II. Cropland change (ha/TJ)

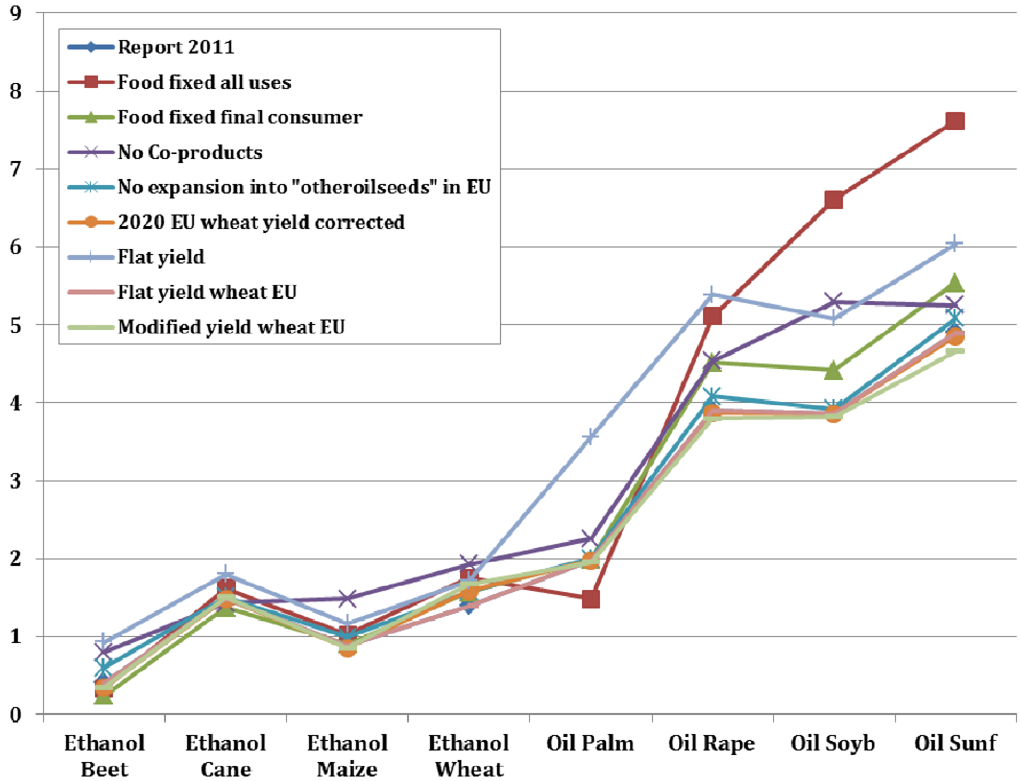

Table III. Cropland change (ha/TJ)

	Ethanol S.Beet	Ethanol S.Cane	Ethanol Maize	Ethanol Wheat	BioD Palm Oil	BioD Rape	BioD Soy	BioD Sunf
IFPRI Report 2011	0.405	1.478	0.876	1.387	1.973	3.900	3.865	4.899
Food fixed all uses	0.328	1.616	1.016	1.746	1.478	5.112	6.604	7.620
Food fixed final consumer	0.240	1.372	0.900	1.566	1.985	4.518	4.415	5.539
No co-products	0.794	1.429	1.485	1.922	2.256	4.535	5.297	5.250
No expansion into "otheroilseeds" in EU	0.60	1.50	0.99	1.57	2.00	4.08	3.92	5.08
2020 EU wheat yield corrected	0.346	1.504	0.853	1.669	1.954	3.797	3.820	4.663
Flat yield	0.930	1.798	1.168	1.715	3.560	5.386	5.080	6.041
Flat yield wheat EU	0.403	1.479	0.875	1.393	1.973	3.897	3.864	4.892
Modified yield wheat EU	0.345	1.481	0.850	1.579	1.974	3.866	3.857	4.853

Table IV. In terms of % cropland area changes (compared to IFPRI report 2011)

% change	Ethanol S.Beet	Ethanol S.Cane	Ethanol Maize	Ethanol Wheat	BioD PalmOil	BioD Rape	BioD Soy	BioD Sunf
Food fixed all uses	-19%	9%	16%	26%	-25%	31%	71%	56%
Food fixed final consumer	-41%	-7%	3%	13%	1%	16%	14%	13%
No co-products	96%	-3%	70%	39%	14%	16%	37%	7%
No expansion into "otheroilseeds" in EU	46%	1%	13%	13%	1%	5%	1%	4%
2020 EU wheat yield corrected	-15%	2%	-3%	20%	-1%	-3%	-1%	-5%
Flat yield	130%	22%	33%	24%	80%	38%	31%	23%
Flat yield wheat EU	-1%	0%	0%	0%	0%	0%	0%	0%
Modified yield wheat EU	-15%	0%	-3%	14%	0%	-1%	0%	-1%

1) Freeze food consumption

From IFPRI report to the JRC-IET:
"In this scenario, rather than allowing new demand for crops that result from the higher biofuel demand to be supplied by diverting them away from food consumption or intermediate use in food production, here the initial levels of these crops, but also the processed products, used in final and intermediate food consumption are constrained to be constant. Nevertheless, the feedstuff consumption of the livestock industry is not fixed. We see that this has very different effects on the LUC coefficients for each policy shock. Notably, all crops experience an increase in the LUC coefficient relative to the 2012 report scenario, with the exception of Ethanol Beet. Rapeseed oil exhibits almost no change in LUC coefficient while the remainder of the crops display some increase in their coefficients with Soybean Oil showing the largest increase at 28.4% of the LUC coefficient." [Deason and Laborde, 2013].

The results of freezing food consumption for three scenarios ('oil rape', 'oil palm' and 'ethanol wheat') have been examined in detail.

Marginal scenario: 'Oil rape'

Why don't ILUC emissions change when food consumption is fixed in this scenario?

ILUC emissions are almost the same in the 2011 report and in the scenario in which food consumption is fixed. That is because when food consumption is frozen in all applications, rapeseed oil cannot be diverted from the food sector, and palm oil production does not increase to replace rapeseed oil.

In the 2011 report, we observe a huge increase in palm fruit used in the crushing sector, which does not occur in the new run. In the new scenario, there are larger increases in rapeseed and rapeseed oil production, which determine an increase in the carbon emissions from mineral soil and managed forest. However, these increases are totally compensated by the *decrease* in emissions from peatland related to the decrease in palm oil production (Table V).

From IFPRI report to the JRC-IET:
"Under the constant food use scenario, carbon released from forest biomass and carbon released in mineral soil actually increase considerably (by 39% and 29% respectively), however this is almost completely offset by the decrease in carbon released from Palm extension on Peatland. This also implies that under this scenario, the LUC coefficient for rapeseed will be less dependent on the assumptions concerning palm oil production (share on peat lands and annual emissions of peat) as fixing final and intermediate food uses does not allow the rapeseed diverted away from food uses to be replaced by Palm oil." [Deason and Laborde, 2013].

Table V. Difference in $MtCO_{2eq}$ between *Food fixed all uses* and IFPRI report 2011 – Oil rape shock

		$MtCO_2eq$ (sum over years)
Biomass change	Primary forest	-1.504
Biomass change	Managed forest	12.284
Biomass change	**Total forest**	**10.781**
Carbon in mineral soil		**5.930**
Total land use emissions		-0.421
Peatland emissions from Indonesia – Malaysia		**-17.132**

However, if we look at the results in terms of land use change (ha/TJ), cropland expansion is much larger (+31%) when food consumption has been fixed (Table VI).

Table VI. Land use change in IFPRI Report 2011 and *Food fixed all uses* scenarios– Oil rape shock

	IFPRI Report 2011 Ha/TJ	Food fixed all uses Ha/TJ
Pasture	-1.387	-1.658
SavnGrasslnd	-0.594	-0.635
Cropland	**3.900**	**5.112**
Other	0.004	0.003
Forest_managed	-1.869	-2.812
Forest_primary	-0.054	-0.009
Forest_total	-1.923	-2.822

Marginal scenario: Oil palm

In the marginal palm oil scenario, the cropland area increase is lower than in the IFPRI 2011 report because, as IFPRI explains in the report, despite a sizable increase in palm production and area (Table VII), since palm has very high yields in terms of vegetable oil per ha, a shift towards palm production from other oilseeds will require lower total area.

Table VII. Land use change (ha/TJ) in IFPRI Report 2011 and *Food fixed all uses* scenarios – Oil palm shock

	IFPRI Report 2011 Ha/TJ	Food fixed all uses Ha/TJ
Wheat	-1.127	-0.624
Maize	-0.961	-0.688
Sugar_cb	-0.087	-0.048
Soybeans	1.883	0.608
Sunflower	1.080	0.219
Rapeseed	1.064	0.108
PalmFruit	**3.891**	**5.155**
Rice	0.010	0.015
OthCrop	-1.383	-1.363
OthOilSds	-1.537	-1.298
VegFruits	-0.859	-0.606
Pasture	-0.910	-0.945
SavnGrasslnd	-0.124	0.239
Cropland	**1.973**	**1.478**
Other	0.003	0.003
Forest_managed	-0.938	-0.837
Forest_primary	-0.004	0.061
Forest_total	-0.942	-0.776

Therefore, the carbon emissions from forest biomass and mineral soil decrease under the fixed food consumption scenario. However, this decrease is more than offset by the increase in emissions due to the palm extension on peatland. This leads to an overall increase in annualised ILUC compared to the IFPRI 2011 report (Table VIII).

Table VIII. ILUC emissions in IFPRI report 2011 and *Food fixed all uses* scenario - Oil palm shock

	IFPRI 2011 report (gCO_{2eq}/MJ)	Food fixed all uses (gCO_{2eq}/MJ)
Annualised carbon release from forest biomass (gCO_{2eq}/MJ)	13	12
Annualised carbon release from carbon in mineral soil (gCO_{2eq}/MJ)	9	7
Annualised carbon release from Palm extension on Peat (gCO_{2eq}/MJ)	33	44
Annualised LUC (gCO_{2eq}/MJ of EU Consumption, 20 years)	54	63

Marginal scenario: Ethanol Wheat

From IFPRI report to the JRC-IET:
"For the other ethanol crops (apart from sugar beet), the increases in LUC coefficients follow a similar pattern to those of the (non-palm) vegetable oils. That is, the LUC coefficient increases result from an increase in carbon emissions from forest biomass and mineral soil which is partially o←set by a decrease in emissions." [Deason and Laborde, 2013].

In this scenario, the increase in LUC emissions (+22%) is driven by the increase in carbon emissions from forest biomass and mineral soil, only partially compensated by a decrease of palm fruit on peatland.

The larger cropland expansion (+26%) is mainly due to an increase in wheat production in response to the increase in biofuel production, not compensated in this case by the decrease in demand by the food sector.

Table IX. Land use change (ha/TJ) in IFPRI report 2011 and *Food fixed all uses* scenario – Ethanol wheat shock

	IFPRI Report 2011 ha/TJ	**Food fixed all uses ha/TJ**
Wheat	7.642	7.886
Maize	-0.735	-0.819
Sugar_cb	-0.064	-0.091
Soybeans	-0.867	-0.683
Sunflower	-0.275	-0.135
Rapeseed	-0.907	-0.788
PalmFruit	0.199	0.110
Rice	0.014	0.012
OthCrop	-0.861	-0.917
OthOilSds	-2.240	-2.270
VegFruits	-0.520	-0.559
Pasture	-0.544	-0.751
SavnGrasslnd	-0.121	-0.072
Cropland	**1.387**	**1.746**
Other	0.003	0.001
Forest_managed	-0.739	-0.956
Forest_primary	0.014	0.033
Forest_total	-0.725	-0.924

---

2) No Co-products

In IFPRI-MIRAGE the increase in crop demand driven by biofuel demand is partly compensated by the return of co-products to the animal feed sector.

It turned out that when biofuel by-products are used as animal feed, this roughly canceled the effect on the livestock sector of the increase in price of other crops fed to animals.

Of course, if the by-products are not returned, the livestock sector tends to consume more other crops, and this increases ILUC. The effect turns out to be strongest for ethanol from cereals, and is zero for cane-sugar ethanol as there are no animal-feed by-products to start with.

From IFPRI report to the JRC-IET:
"In this scenario, coproducts from marginal biofuel production are not allowed to be used, so that some of the mitigating LUC effects of biofuel which allowed relatively lower LUC coefficients in the 2012 report are no longer present. More specifically, the assumption in this scenario is that the availability and total use of coproducts by the whole economy is not affected by the marginal production of biofuel. Excess production of coproduct from the marginal crop are stored and supply deficit from other displaced crops are compensated by inventory released."
[...] "Looking only at difference in levels between this scenario and the 2012 report not only for the LUC coefficient, but also for the changes (in gCO_2/MJ of EU Consumption, 20 years) of the three different kinds of emissions, we see that we have the same general story for all feedstocks except sugar cane, namely an increase in emissions of CO2 from forest biomass and from mineral soil, with a slight decrease in emissions from Palm extension on Peatland." [Deason and Laborde, 2013].

Marginal scenario: Oil rape

In this scenario we are mainly interested in looking at what happens in the animal feed sector when co-products are not injected in it.

First of all, it should be borne in mind that the animal feed demand in IFPRI is covered by different sources of supply:
- direct use of crops (livestock sector);
- co-products of the biofuel and other industries (e.g. sugar sector);
- part of the crushing sector.

From the IFPRI results, we can compare the changes in the direct demand of crops by the livestock sector and by the crushing sector in the two scenarios (2011 report and no co-products) to the baseline.

After the shock (which implies an increase in biofuels demand completely absorbed by rapeseed oil), we observe a decrease of the demand of crops by the livestock sector (compared to the baseline) in the 2011 report. This decrease is partly compensated by the demand increase in the crushing sector and the increase in co-products in the biofuel sector.

In the no co-products scenario, there is still a decrease in crop demand from the livestock sector after the shock (compared to the baseline) which is, however, lower than in the IFPRI 2011report , as the last column in Table X shows.

The animal feed sector, which cannot use co-products, is demanding more crops (direct use) and crushed crops (especially soybean).

Table X. Crops demand in IFPRI report 2011 and *No Co-products* scenarios – Oil rape shock

	No Co-products (Marginal – Baseline)		IFPRI 2011 Report (Marginal – Baseline)		No Co-products – IFPRI report 2011	
	Livestock (tonnes)	**Crushing (tonnes)**	**Livestock (tonnes)**	**Crushing (tonnes)**	**Livestock (tonnes)**	**Crushing (tonnes)**
Maize	-536,009		-677,744		141,736	
OilPalm	2,407	68	2,450	72	-44	-5
OilRape	-3,146	-15	-3,044	-15	-103	-0
OilSoyb	1,652	3	1,475	24	177	9
OilSunf	158	14	163	15	-6	-1
OthCrop	33,269		-71,426		104,695	
OthOilSds	-39,791		-45,069		5,278	
PalmFruit	-22,591	2,664,441	-22,552	2,767,355	-39	-102,914
Rapeseed	-140,117	2,446,725	-142,593	2,486,441	2,476	-39,716
Rice	121,441		70,769		50,672	
Soybeans	-294,500	1,189,696	-241,480	907,206	-53,021	282,490
Sugar_cb	-3,479		-3,164		-316	-
Sunflower	-33,876	90,249	-36,418	309,147	2,542	-18,898
VegFruits	323,250		36,373		286,877	
Wheat	-689,261		-757,645		68,383	
Total	**-1,280,596**	**6,591,211**	**-1,889,904**	**6,470,247**	**609,308**	**120,964**

Therefore, there will be a larger cropland expansion in the No co-products scenario (4.5 ha/TJ) compared to the report scenario (3.9 ha/TJ), mostly compensated by a decrease in pasture land and managed forest (Table XI).

Table XI. Land use change (ha/TJ) in IFPRI report 2011 and *No Co-products* scenarios – Oil rape shock

	No Co-products ha/TJ	**IFPRI Report 2011 ha/TJ**
Wheat	-3.415	-3.436
Maize	-1.630	-1.735
Sugar_cb	-0.291	-0.230
Soybeans	3.872	2.858
Sunflower	1.522	1.648
Rapeseed	10.694	10.907
PalmFruit	1.606	1.708
Rice	-0.002	-0.004
OthCrop	-2.424	-2.611
OthOilSds	-3.482	-3.261
VegFruits	-1.916	-1.943
Pasture	-1.654	-1.387
SavnGrasslnd	-0.749	-0.594
Cropland	**4.535**	**3.900**
Other	0.004	0.004
Forest_managed	-2.058	-1.869
Forest_primary	-0.078	-0.054
Forest_total	-2.136	-1.923

In terms of emissions, the additional cropland expansion will result in more emissions from forest and mineral soil, determining a final increase in emissions of 4.7 gCO_{2eq}/MJ of biofuels.

3) Yield changes

If crop yields are high in the baseline, less crop area expansion is required to produce the same amount of feedstocks for biofuels.

Yield projections used in the IFPRI 2011 report are far more optimistic than any in the versions of either the DG-AGRI or OECD-FAO outlooks. In the case of wheat, IFPRI assumes a 51% yield increase between 2010 and 2020, which is a factor 7 times higher than in the DG-AGRI 2011 outlook. This explains why in the sensitivity analysis, a modified wheat yield for the EU has been included.

Four different scenarios have been run with a modified yield.

In three scenarios, the EU wheat yield has been changed:

1) In the 2020 ***EU wheat yield corrected***, it is the baseline 2020 yield wheat EU which has been reduced to 5.5 t/ha from 8 t/ha used in the 2011 report. In this scenario the value is not changed in the base year (7.2 t/ha) but it is exogenously reduced in the 2020 baseline. This will affect the ethanol wheat scenario in terms of LUC emissions (17 gCO_2/MJ instead of 14 gCO_2/MJ in the IFPRI 2011 report).

> ***From IFPRI report to the JRC-IET:***
> *"The increase in the LUC coefficient for Wheat is the result of increased emissions from forest biomass and carbon from mineral soil and to a smaller degree, an increase in carbon emissions from Palm extension on Peat. The first two sources of emissions result from an increase in cropland globally, with almost all of this due to an increase in area for Wheat, and decreased total forest area. The only other crop which experiences an increase in area is Palm, which explains the increase in emissions from Palm extension on Peat. The increase in area for wheat production is accounted for by increases in each region, with the largest increases in EU27 and CIS regions." [Deason and Laborde, 2013].*

2) In the ***Modified Yield Wheat EU***, the EU27 wheat yield is modified in the base year (2008) from 7.9 t/ha to 5.5 t/ha. This will result in a yield for EU wheat of 5.6 t/ha in 2020 in the baseline from exogenous technical change.
Again this scenario will affect mainly the result in the ethanol wheat scenario.

3) In the scenario ***Flat Yield***, the assumption is that there is no exogenous technological progress in yield from 2008 to 2020, which will reduce the yield of each crop in each region and will result in cropland expansion.

> ***From IFPRI report to the JRC-IET:***
> *"This will have the effect of generally reducing yield (relative to the yields projected in the 2012 report) for each crop and each region, though it will have a relatively larger impact for countries whose yields had been projected to grow more than others." [Deason and Laborde, 2013].*

This scenario is not relevant because it is not technological progress which is under discussion but the change in yield due to the price increase.

4) The ***Flat Yield Wheat EU*** is a sub-scenario of the previous one, where only the wheat yield in the EU27 does not increase through exogenous technological progress. This analysis is not relevant.

> ***From IFPRI report to the JRC-IET:***
> *"In this scenario (which is a sub-scenario of the case when exogenous yield increases are fixed for all products in all regions), the yield for all products and regions is assumed to undergo the exogenous technological progress assumed in the 2012 report, with the exception of wheat production in EU27."[Deason and Laborde, 2013].*

Appendix 2: Comments to the paper "Le changement d'affectation des sols induit par la consommation européenne de biodiesel: une analyse de sensibilité aux évolutions des rendements agricoles" Working Paper SMART-LERECO N° 13-07, Gohin, A. (2013)

This working paper makes a review of the values reported in literature of changes in yields assumed by economic models to assess LUC effects induced by EU biodiesel consumption. According to the author, crop yield evolutions in economic models (referring in particular to IFPRI, 2011 results) are very often lower than the observed and expected evolutions. The author concludes that with a consistent calibration of these parameters, ILUC emission estimates could be largely reduced ((by around 80% in the long run). Noteworthy, the working paper emphasizes the role of the yield elasticity parameter in estimating ILUC, illustrating the analysis with simulations using the GTAP-Biof model with alternative calibration strategies, and showing that ILUC coefficients can be reduced by two-thirds under new assumptions. The issue raised in the paper is relevant but the quantitative result proposed is highly disputable.

It is well known that ILUC estimates depend very much on the relative elasticity of crop area and yield on price. However, the claim in [Gohin 2013] that models systematically underestimate the fraction of additional crop from yield increase (compared to area increase) appears to be based on some misunderstandings and misinterpretations.

- In the paper, the ratio of Δyield/Δarea from historical evolution is repeatedly confused with the Δyield/Δarea due to price increase. Of course, historically the yield tends to increase more, because a large part of the increase reflects technological improvement, which happens irrespective of price. But what is important for determining ILUC is the second ratio, which reflects the difference between crop area in a biofuel scenario and in the baseline[20]. By confusing one with the other, the author misleadingly claims to show that the ratio in the models is too low.
- Indeed, usually, one cannot see any indication of yield elasticity from historical data, because generally there is little overall trend in real prices, and there is a large effect of technical learning with time. However, when there **have** been large changes in prices, the historical data show almost no yield response.
    - o after the CAP reform of the 1990s, crop prices fell but yields continued to increase.
    - o EUROSTAT data shows that EU farm-gate rapeseed prices rose by 80-100% between the 2001-2003 period and the 2010-2012 period; production increased by 79%, but although the area increased by 72%, the yield only increased by 7%, a slower rate of increase than in the

[20] This misunderstanding may explain the surprise [Gohin 2013] expresses that Laborde "like the other authors" has a higher proportion of yield in the crop production increase going from 2008 to 2020 baseline than going from the 2020 baseline to the 2020 biofuel scenario. Similarly, the author thinks that FAPRI apply no exogenous technical progress to yield when they simulate biofuels policy.

previous decade.

Therefore, from historical trends, the conclusion that at least 1/3 of the supply response of oilseed production in the EU results from yield increase does not seem justified.

- In his "recalibration" of GTAP-BIO, the author simply takes an elasticity of substitution from the OECD-AGLINK model and applies it to GTAP. This is not correct because the models have totally different structures, and so the elasticities have to be calibrated separately. There is no reason to consider that the calibration based on the elasticity of substitution consistent with the OECD modelling work (2001), taken independently from the rest of the model, is relevant.
- In this way, the author arrives at a yield-price elasticity for oilseeds of 3.15 (which means that a price increase of 1% would increase the yield by 3.15%) . Of course, using this parameter in a GTAP run results in a very low ILUC area.
- However, in a previous review of nine econometric papers, the author concluded that the yield elasticity of EU oilseeds was only about 0.54, and qualified this value by stating[21] that it was clearly higher than the average of the econometric literature as well as higher than the values adopted by other models (<0.2) [Gohin and Bureau 2006][22]. Therefore, his proposal of a value of 3.15 is surprising.

[21] The exact quote is "C'est très clairement supérieur à la moyenne des élasticités trouvées dans la littérature économétrique et également aux valeurs adoptées dans d'autres modèles synthétiques de simulation (inférieures à 0,2).".

[22] Gohin and Bureau 2006, "Analyse de la réponse agrégée des rendements pour les principales cultures arables en Europe", March 2006, OECD.

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