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The effects of increased demand for biofuel feedstocks on the world agricultural markets and areas

Outcomes of a workshop
10-11 February 2010, Ispra (Italy)

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1. Background

The European Commission (EC) is debating internally how to address indirect land use change (ILUC) emissions in biofuels legislation. The Directives 2009/28/EC (Renewable Energy Directive) and 2009/30/EC (Fuel Quality Directive) contain provisions on monitoring and limiting the possible ILUC effects, but also give the Commission the task to further explore the issue, in order to establish the most appropriate mechanism for minimising ILUC: *"the Commission shall, by 31 December 2010, submit a report to the European Parliament and to the Council reviewing the impact of indirect land-use change on greenhouse gas emissions and addressing ways to minimise that impact. The report shall, if appropriate, be accompanied by a proposal, based on the best available scientific evidence, containing a concrete methodology for emissions from carbon stock changes caused by indirect land-use changes".*

If you grow biofuels crops on uncultivated land, you will cause direct land use change. If you use crops grown on existing arable land for biofuels instead of food, this will cause ILUC because of the necessity to replace the food. Models do not specify where the extra production comes from; they just calculate the total change in crop area for a given increase in biofuel or crop demand. The models thus estimate simply land use change (LUC) and LUC emissions.

Different life cycle studies of biofuels have different ways to account for the release of carbon stored in the above ground flora and below ground (as soil organic carbon - SOC) resulting from the conversion of land, either directly or indirectly, due to increased biofuels production. Because the avoided land or land opportunity cost cannot be readily identified, agro-economic models are used to simulate the effects. The objective of modelling is to estimate the land use change in the real world, not how little land might be converted in the best possible scenario.

A simple substitution model of displaced crops tends to provide a high estimate of the LUC impacts because such an analysis does not take into account the competition for land and shifts in consumer behaviour (of course it is tonnes of crop production which are displaced, not hectares) The level of detail of direct and indirect land use emissions may vary greatly among studies. Factors also considered in such models include differential agricultural yields, assumptions on yield improvements, land rents, global changes in deforestation correlated to agricultural growth, and other factors.

In support to this discussion, the JRC, in collaboration with EEA and OECD, organized an international workshop in Paris in January 2009, bringing together worldwide experts and modellers to discuss various modelling approaches and to develop a joint platform for comparing results between different modelling groups. The outcome of the two days of discussions allowed the identification of the main modelling challenges (e.g. accounting of co-products, estimates of elasticities, global availability of marginal land etc.), current gaps in modelling and future steps to take[1].

The discussions in Paris, identified the necessity of verifying to what extent ILUC emissions differ by crop (for example, between the cereals sector and the vegetable oils sector) and within those sectors by geographical origin. Legislators need to understand how ILUC differs between

[1] Outcomes of these expert discussions have already been discussed in the interim report “Modelling Indirect Land Use Change Effects of Biofuels Policy” delivered in October 2009. They can also be found at http://re.jrc.ec.europa.eu/biof/html/proceedings_luc_paris.htm

biofuels from different feedstocks and regions. In fact, if ILUC emissions are to be added to "direct" emissions in legislation, we need to know this quantitatively for all biofuels/feedstocks. Nevertheless, to compare model results we at least need to compare the results vs. baseline per unit quantity of biofuel.

For these reasons it was proposed to carry out a survey of marginal calculations from various models/methods developed by the relevant consortia in the EU and the US, to compare results from marginal shocks along the lines of recommended common scenarios, as discussed in Paris. For modelling the GHG efficiency of different feedstocks, the experts agreed during the workshop that the "extra biofuels" scenarios should optimally be marginal increases in demand for different biofuels-feedstock in different regions. These results would be relatively easy to compare between scenarios.

Different baselines are part of the differences in the world-view reflected in different models. Therefore, to save time, the JRC asked the modellers to run these marginal calculations against the existing baseline of the models, without requiring them to be aligned beforehand. In fact, up to the limits of biofuels policy in the EU and the US, the ILUC effects per unit of biofuels are fairly constant (i.e. models are rather linear - see discussion on linearity in chapter 4), and it does not make much difference what the level of biofuels demand is in the baseline scenario.

2. The marginal scenarios

Ideally, one would like a marginal tonnes of GHG/toe biofuels for every biofuel from every feedstock. However, some models are not capable of defining one feedstock: they can only deal with policy drivers. Others can only deal with one crop at a time. So there was no exact set of scenarios that all the models could work on, given the time constraints, and differences between model structures and baselines. JRC negotiated the most disaggregated results which each model was capable of providing within the time-frame. This was on the basis that it is easier to aggregate results than disaggregate them.

The modellers were requested to run scenarios in their models corresponding as closely as possible to the following specification.

Marginal runs against existing baseline of the following scenarios:

A marginal extra ethanol demand in the EU

B marginal extra biodiesel demand in the EU

C marginal extra ethanol demand in the US

D marginal extra palm oil demand in the EU (for biodiesel or pure plant oil use)

Other additional relevant scenarios (e.g. marginal extra ethanol from Brazilian sugar cane) could also be included.

Experts were asked to report results *per marginal toe (tonne of oil equivalent) of biofuel*. The size of the shock was left to the discretion of the modellers, on the provision that it was small enough to allow linear behaviour to be assumed, whilst large enough to allow easy visualization of the results. In practice, most modellers chose shocks of around 1 Mtoe.

It was not possible to co-ordinate the time-frames of the models, because some models work year-by-year, whereas others give a shock to a model of the world agro-economic system which is set in time. However, all results were for between 2010 and 2020. Between 2010 and 2020 world arable area is projected to increase by around 0.25%. Models estimate the extra area using (usually linear) elasticity functions which will give higher area changes if the cultivated area is higher, but only by ~0.25% on average. Of course in some parts of the world particular areas of high or low C stock may become converted in the baseline between 2010 and 2020, but the overall effect on emissions must be regarded as negligible compared with the enormous uncertainties elsewhere.

If the model showed that an increase in the marginal biofuel in EU leads to decreases in biofuels use in other countries, these interactions were not suppressed. However, the change in global biofuel consumption was reported to provide a devisor representing the net increase in biofuel use.

Certain intermediate results and model characteristics from the marginal calculations were also requested, to help explaining differences in the final results. Not all models could answer all the questions we asked. All these data are expressed as marginal effects per toe of the biofuel in question. Some of the indicators below need figures aggregated for different crops. It was then suggested they be expressed as an equivalent amount of cereals, based on the yield ratio of the each crop to that of the most common cereals crop on the same land. However, most modellers simply reported mass-averaged results.

Reporting requirements

A. Price changes per crop per region dealt with in the model

B. Yields per crop per region (at least for biofuels crops)

C. Where applicable, area changes per crop per region per land use type.

D. For different crops and regions, the ratio of the average yield on the new land (marginal yield) to the average yield of existing land of the same crop within the region. An explanation of whether this value is assumed or calculated.

E. The type and quantity of by-products produced

F. The relations used to determine market substitutions between animal feeds.

G. If possible, an estimate of the overall percentage of the extra feedstock demands recovered by co-products (different crops aggregated as cereals-equivalents). If possible, this should also be done on a land equivalent basis, as a forthcoming draft protocol will elaborate.

H. Report the percentage change in (cereal-equivalent) food consumption compared to baseline, broken down by region

I. Estimate of how much of the net feedstock demand for biofuels that is met by reduction in food consumption, how much by yield intensification, and how much by area expansion (all in cereals equivalents).

J. The precise formulas relations used to calculate price-induced yield changes

K. If the model includes price-driven yield intensification, what GHG emissions are ascribed to this?

L. Where applicable, how much of the total change in GHG emissions (compared to baseline) come from incremental yields and how much from land use change.

M. If the model includes LUC emissions, what are the assumptions on carbon release or foregone carbon sequestration made in deducing LUC emissions from conversion of different land use types?

N. An explanation of how the model predicts which types of new lands will come into agricultural use

O. A summary of the proportion of land use changes that the model predicts will derive from different regions and ecosystem types. (Again a draft protocol will suggest common typologies for comparison purposes.)

P. For models that restrict replacement areas based on existing trade patterns, a description of the nature of that restriction (and the calculated effect if available)

The above request of calculation was circulated within the most relevant experts and modelling groups, and the following partial equilibrium (PE) and general equilibrium (CGE) models could be included in this exercise:

- GTAP (CGE)
- AGLINK-COSIMO (PE)[2]
- DART (CGE)
- FAPRI-CARD (PE)
- IFPRI-IMPACT (PE)
- CAPRI (PE)
- LEITAP (CGE)

Results of these studies were discussed during a workshop organized by the JRC in Ispra on 10th and 11th of February 2010. Chapters 3 to17 present the outcomes of the workshop, highlighting main results of the studies and the key points raised in the discussion.

Reports delivered to the JRC from the various experts, as well as all calculation sheets are also available for internal use of the Commission at the JRC Biofuels Thematic Programme Interest Group on CIRCA (http://circa.europa.eu). External (non-EC) access may also be granted on request.

Detailed descriptions of the models and results can be found in the JRC-IE report “Indirect Land Use Change from increased biofuels demand - Comparison of models and results for marginal biofuels production from different feedstocks”.
Available to download at: http://re.jrc.ec.europa.eu/bf-tp/

The following chapters provide a summary of each presentation and slides presented by the speakers.

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[2] Results of AG-LINK simulations as reported by OECD were included in the first Interim Report of this study: “Modelling Indirect Land Use Change Effects of Biofuels Policy” (October 2009). Even if OECD couldn’t participate to this workshop, results of marginal calculations with OECD / AG-LINK are included in the comparison exercise in the JRC report: Indirect Land Use Change from increased biofuels demand.

3 Marginal Emissions and ILUC (Robert Edwards – JRC-IE)

When prices increase due to biofuels demand, more intensive crops tend to displace less intensive ones. Figure 1shows an example of crop displacement for cereals in the EU, but displacements also occur across continents, and by-products can cause displacements in the other direction. The displacement is not on the basis of equal area but of equal tonnes of cereals (in this case).

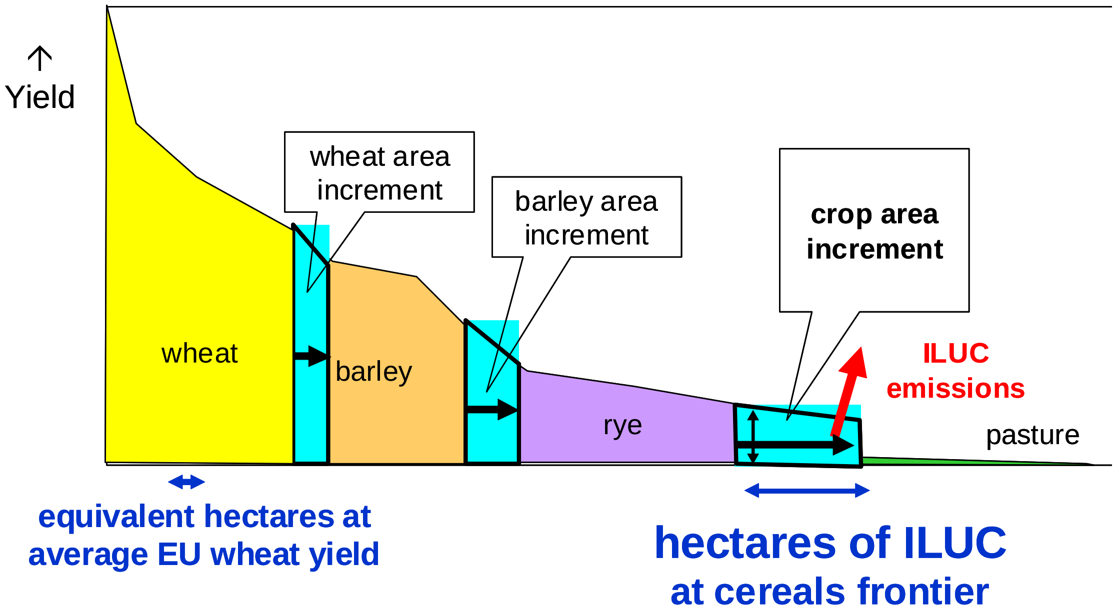

Figure 1 EU cereals displacement due to increased demand

The extra production comes from 4 sources, each of which can contribute to the marginal extra emissions per extra ton of crop production.

1. **intensification for higher yields**
   As crop price increases, the economically-optimum spending on all inputs ($ per tonne of crop) increases, and this in general can be expected to mean higher emissions per tonne of crop.
2. **intensive crops displacing less intensive ones**
   Changing crops to a more intensive one may moderately increase or decrease the emissions per tonne of cereals (in this example); there is no general rule. In general one can expect a small loss of soil carbon. The shift to poorer land will reduce the average yield for both the more-intensive and the less-intensive crop, and this will tend to increase average emissions for both crops.
3. **annual emissions from farming the newly-planted areas**
   The emissions from farming the existing area are used as a proxy for those on the newly-converted land, because there are rarely any data available on emissions from farming at the frontier of cultivation. In general one expects the poorer yields on the new areas to cause higher emissions per tonne of crop, but this may not hold where the displacements are across frontiers.

4. **emissions from converting more land to cropland**
   The area of land use change depends on the yield of the crops at the frontier of cultivation, not particularly on the crop which is used for biofuel feedstock, as discussed below.

None of these emissions corresponds to the average annual GHG emissions from farming existing areas, which are the only farming source of emissions that is known with any certainty. The difference between these and the sum of emissions from sources 1 to 4 above have become lumped together as “indirect emissions”.

Crop Displacement effects

Let us take the example where wheat area is increased but the production of the less intensive crops stays the same, and (for the sake of argument) let us assume there is no increase in yield due to price. In the example of the slide above, the area on the graph represents tonnes of crop production. To keep the production of all the other crops unchanged, the tonnes of barley lost to wheat cultivation must be recovered from rye, and so on. At the frontier of crop cultivation, the extra land converted (displacement along x-axis) depends on the extra tonnes of wheat and the *yield of crop(s) at the frontier of crop production* (of course this frontier is not generally a continuous line on the map, but is mostly land around existing cultivation which it is not quite economic to farm). At the frontier, low-yield crops will predominate over highly-intensive crops which require good land.

Most agro-economic models calculate land use change per region by summing the land used for each crop in that region. The area per crop may be corrected for the difference in yield for *that crop* between “new” and “old” land *for that crop*, but no account is taken of the effects of crop displacements. Since the crops used by biofuels, tend to be intensive ones, land use change is underestimated by ignoring crop displacements.

The general rule that extra biofuels demand comes from the more intensive crops is not true for soybeans which can displace maize, a more intensive crop. In this case the average yield of soybean and maize can increase as a result[3].

The same can be said for rapeseed and sunflower seed, which can displace wheat). However, then the lost cereals production must be compensated somewhere else. It is anyway the yield of the crops at the frontier of cultivation which is important for ILUC.

Why did JRC ask for marginal scenarios?

Since models are mostly forced to assume linear behaviour (see below) the results should be additive between:

- different biofuels in different amounts
- different crops and by-products

Legislators need to understand how ILUC differs between biofuels from different feedstocks and regions. In fact, if an ILUC adder is used in legislation, we need to know this quantitatively for all biofuels/feedstocks. Anyway, to compare model results we at least need to compare the results vs. baseline per unit quantity of biofuel.

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[3] Comment by DG-AGRI

How were the marginal scenarios chosen?

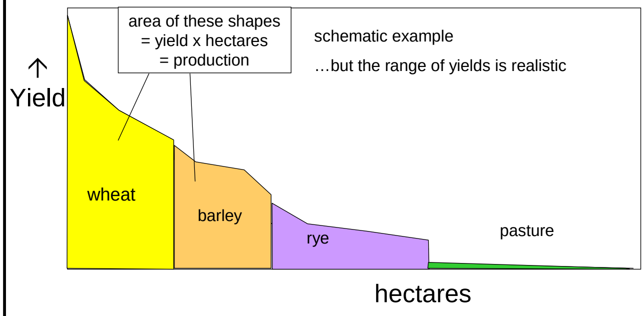
If one wishes to compare models with the aim of improving the models by seeing where they disagree, it is desirable to align the baseline scenarios of the models. One outcome of the JRC-EEA-OECD conference in Paris 2009 on ILUC model comparison was thus an initiative to align baselines between some European models. However, that exercise would not be finished in time for our purposes, and only a few modelling groups were involved (all from Europe), and that would exclude US models. However, for the purposes of calculating ILUC for a marginal increase in biofuel production, it is not necessary to have the baselines aligned, especially if the models are essentially linear. Indeed the choice of baseline scenario is part of the variety of world-views reflected in the models.

Ideally, one would like a marginal tonnes GHG/toe biofuels for every biofuel from every feedstock. However, some models are not capable of defining one feedstock: they can only deal with policy drivers. Others can only deal with one crop at a time. So there was no exact set of scenarios that all the models could work on, given the time constraints, and differences between model structures and baselines. JRC negotiated the most disaggregated results which each model was capable of providing in the time-frame. This was on the basis that it is easier to aggregate results than disaggregate them.

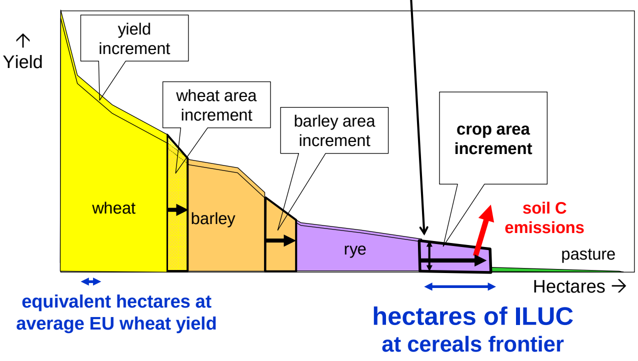
Marginal emissions and **I**ndirect **L**and **U**se **C**hange

- ILUC is caused by crop displacements…

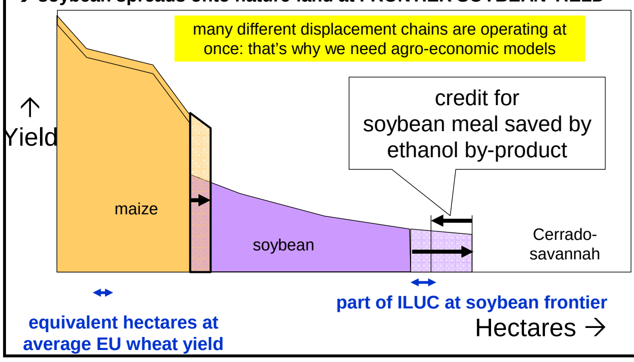
Crops displace other crops in a sort of hierarchy of intensiveness



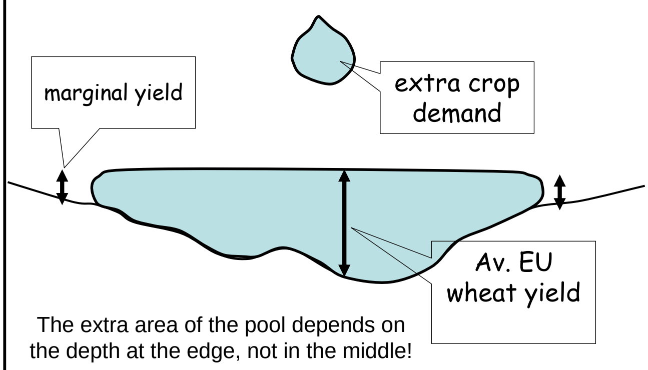
Area of ILUC from extra EU-wheat demand:
depends on **yield at the frontier of cultivation**,



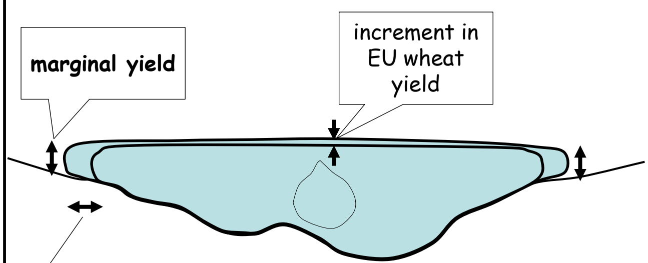
Displacements are also international and between crop types:
e.g. extra EU wheat demand for ethanol
→ higher cereals price
→ maize replaces wheat for feed
→ maize expands onto soybean (e.g. in US)
→ soybean spreads onto nature-land at FRONTIER SOYBEAN YIELD



- To add different crops, you can use crop-value
- Then we can think of a value-weighted world crop pool:



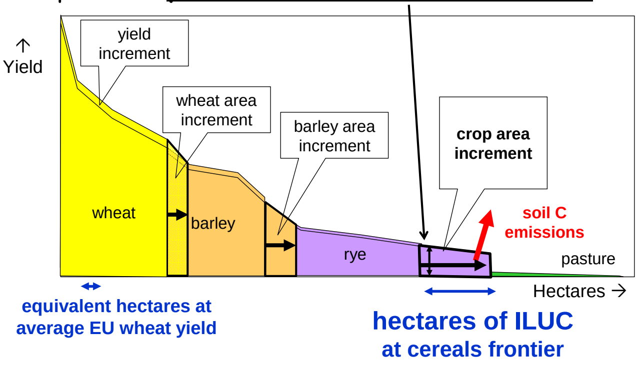
- adding a drop of demand to the world crop droplet:



The incremental area of ILUC depends on the yield at the **edge** of cultivation!

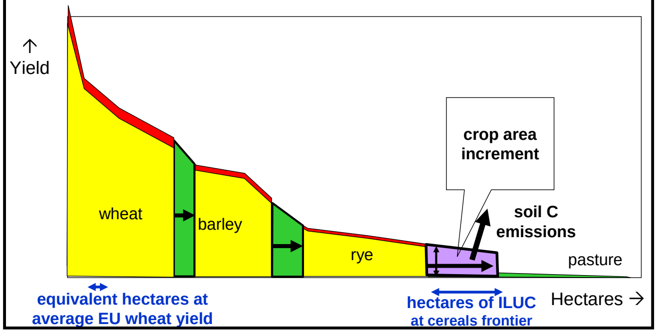
where were we?...

Area of ILUC from extra EU-wheat demand:
depends on **yield at the frontier of cultivation**,



The marginal GHG emissions come from:

1. intensification for higher yields
2. intensive crops displacing less intensive ones
3. Annual emissions from farming newly planted area
4. Emissions from indirect land use change



The marginal GHG emissions come from:

1. intensification for higher yields
2. intensive crops displacing less intensive ones
3. Annual emissions from farming newly-planted area
4. Emissions from indirect land use change

So none of the extra emissions due to biofuels demand come from the existing annual emissions on the existing land!

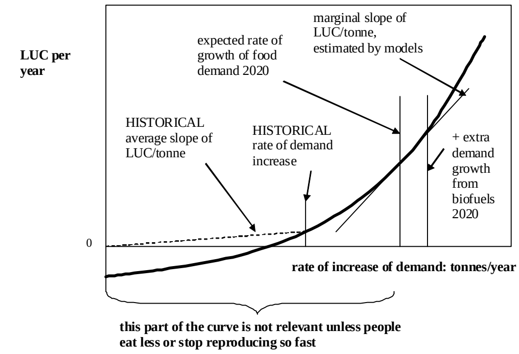
...but that is all we know about!

this may not change emissions-per-tonne much

this *might* be similar to annual emissions-per-tonne from farming the existing area

-**Conclusion**: *at the least*, we should add to the existing average annual emissions:
marginal emissions from intensification for higher yields
emissions from indirect land use change

IS ILUC LINEAR?
It depends critically on rate of demand growth



IS ILUC LINEAR?
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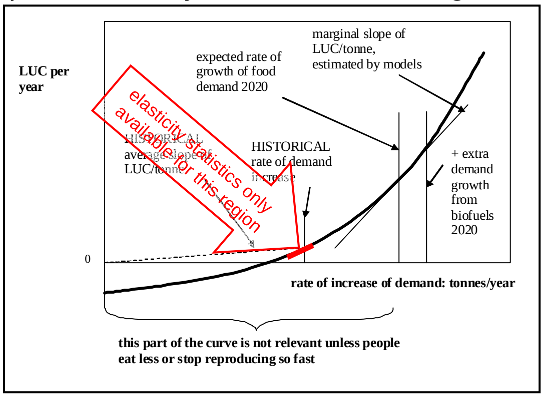

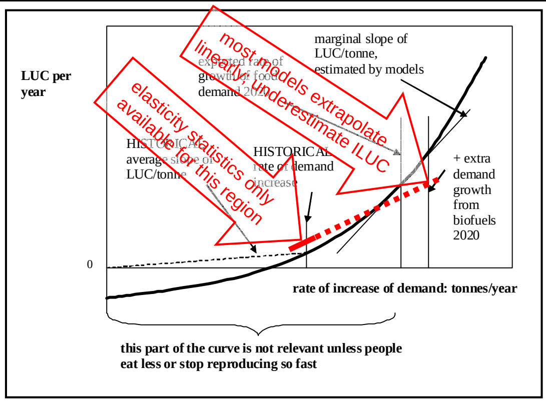

...but non-linearity (apart from quotas etc.) can only be introduced with hypotheses, not from statistics

WHY MARGINAL SCENARIOS?

- Since models are mostly forced to assume linear behaviour (= constant elasticities), their results should be additive between:-
  - different biofuels
  - different crops and by-products
- Legislators need to understand how ILUC differs between biofuels from different feedstocks and regions
- If an ILUC adder is used, we need to know this quantitatively for all biofuels/feedstocks
- Anyway, to compare model results we at least need to compare the results *per unit quantity* of biofuel, vs. baseline

WHAT MARGINAL MODELING COULD BE DONE PRACTICALLY?

- Time constraints
- Model differences
- Differences between model baselines
  - Paris conference resulting in on-going baseline alignment between *some* models
  - if a model is linear, it's not important per Mtoe biofuel
  - part of the difference in world-view between models
- We negotiated the most disaggregated marginal calculations which the models could do in time.

(easier to aggregate results than disaggregate them afterwards)

Statistical database is short-term

- Model parameters (elasticities) are wherever possible estimated from historical statistical data
- The principle variation in this is good/bad harvests: a SHORT TERM variation. So short-term parameters tend to be used to model longer-term responses.
- Short term responses are:
  - more concentrated geographically
    - e.g. buffering by stock changes; remote farmers only respond to sustained price changes
  - more confined to individual crops (e.g. wheat)
    - e.g. it takes time for food processors to adjust to alternative crops
- So model results are generally **too localized** and **too concentrated on the feedstock crop**

Conclusion

- Models differ widely in the geographical distribution of the LUC
- However, the total ha of increased crop area per toe biofuels is much more consistent
- If you don't grow extra crops in one place, you have to grow them in another!

What matters to the ha/tonne result?

LUC (ha)= feedstock per toe biofuel

x

1-(fraction of feedstock from less food consumption) 0.9 to 0.45

x

1-(fraction saved by by-product) 0.7 to 0.5

x

% area change / % yield change

x

1 / average crop yield — FAOSTAT av. cereals+oilseeds yield 2008 = 2.75 t/ha

x

average crop yield / frontier crop yield 1/0.66 to 1

TOTAL CARBON FLOWS	
biofuel	**fossil fuel**
Car exhaust CO2	Car exhaust CO2
Refining emissions	Refining emissions
Annual CO2 fixed by photosynthesis in cornfield - (GHG from farming)	Annual CO2 fixed by photosynthesis in cornfield - (GHG from farming)
(CO2 fixed by intensification) - (GHG from extra inputs)	
(annual CO2 fixed by on new cropland compared to before) – (GHG from farming extra land) – (GHG from land use change)	

4. Calculation of marginal biofuel scenarios with the DART model (Bettina Kretschmer & Sonja Peterson, Kiel Institute for the World Economy)[4]

The Kiel Institute for the World Economy (IfW) calculated marginal biofuel scenarios with the DART (Dynamic Applied Regional Trade) model. The DART model is a multi-region, multi sector, recursive dynamic CGE model. The CGE framework includes international linkages between energy and agricultural markets.

The model includes 19 countries/regions representing the global economy linked via bilateral trade flows. There are 20 production sectors including energy sectors, agricultural sectors (containing the most important energy crops) and manufacturing and service sectors. The model was run between 2004 and 2007 using the GTAPv7 database. Full employment of production factors are taken into account including labour and capital (mobile across sectors within regions, immobile internationally) and land (input in agricultural production and fixed endowment). Land Use Change (LUC) is not directly covered. However, in DART, agricultural land area is assumed fixed; the model describes competition for land between wheat, other grains, oilseeds, milk and "rest of agriculture", and estimates land rents, which are the drivers for ILUC. The model includes production technologies for first-generation biofuels: ethanol and biodiesel.

The feedstock inputs for ethanol are sugar beet/sugar cane, maize and wheat, whilst for biodiesel the feedstock inputs are oilseeds and vegetable oil. Initial feedstock shares are based on 2005 production data. In the model biofuels are produced from 2005 onwards, calibrated by biofuel production data for 2007. The calculation of mark-ups is based on the quality ratio between biofuels and fossil fuels and the difference in production cost. Mark-ups together with input and fuel prices determine the competitiveness of biofuels versus fossil fuels. For Brazil, the only country where biofuel production is competitive, the mark-up is calibrated to match the observed biofuel production in 2005.

The most important biofuel trade flows are taken into account where Brazil (ethanol) and Malaysia/Indonesia (biodiesel) are the sole exporters due to uncertain development of other export potentials.

Marginal scenarios

In the A1/B1 scenarios (see Table 1) the DART model produces an extra unit of ethanol/biodiesel where it is cheapest in the EU using the cheapest feedstock.

[4] Results of this study were already presented in the first Interim Report of this study: "Modelling Indirect Land Use Change Effects of Biofuels Policy" (October 2009). This summary also includes new updates received by the experts as a follow-up of the workshop. The full text is available on CIRCA.

Table 1 DART marginal scenarios

Scenario		Extra production of	Region
Scenario A	Scenario A1	Ethanol	EU
	Scenario A2	Ethanol	each MS
	Scenario A3	Wheat ethanol	each MS
Scenario B	Scenario B1	Biodiesel	EU
	Scenario B2	Biodiesel	each MS
Scenario C		(Corn) ethanol	USA
Scenario D		Biodiesel (from vegetable oil)	Germany

In the A2/B2 scenarios the model is forced to produce more biofuel in each EU member state with each region's additional production requirement corresponding to the share in 2007 EU biofuel production (see Table 2). The first two columns represent biofuel production in 2007 (Mtoe). The last two columns are the additional production requirements corresponding to each countries' share in 2007 EU biofuel production.

Table 2 Biofuel production in 2007 and additional production requirements.

	Production (mtoe)		calibrated share	
	Biodiesel	Ethanol	Biodiesel	Ethanol
Germany	2,54	0,20	6,9	0,7
UK+Ireland	0,13	0,01	0,60	0,04
France	0,77	0,29	2,00	1,00
Scandinavia	0,16	0,04	1,05	0,40
Benelux	0,08	0,01	0,30	0,07
Mediterranean	0,71	0,21	0,80	0,48
Other EU	0,62	0,15	1,20	0,43
USA	1,33	12,50	1,20	3,20
other OECD	0,01	0,48	0,02	0,33
Brazil	0,57	10,86	3,20	20,00
China	0,26	0,94	0,40	1,00
India	0,06	0,13	0,38	0,48
Malaysia/Indonesia	0,71	0,00	4,70	0,00
EU27	5,02	0,90		

To analyze scenarios A3 and D, the DART model was adjusted with separate production functions for biofuel from each feedstock. The variables in DART that are reported include changes in price, yield, food consumption and others such as sectoral land inputs. Price changes are reported as change of 2007 prices in the marginal scenario relative to the 2007 benchmark price. Yield changes are reported as change in tonne of crop output per hectare in one region. Food consumption is reported as percentage change plus absolute consumption changes in value terms at 2004 prices.

Results:

Increased ethanol production:

Under scenario A1 additional ethanol production in the EU leads to increased ethanol production in Scandinavia. The price of sugar beet used as a feedstock increases in Scandinavia by nearly 0.45 percent. Energy and fuel prices decrease because of higher subsidies on biofuels that are necessary to increase higher production levels. In scenarios A2/A3 the effects across the feedstock are more balanced and fuel process fall less.

The land area for sugar beet is more than doubled in Scandinavia but in the EU the effects are small (see Table 3). The land expansion mainly comes from other agricultural sectors including vegetables, other grains and cattle. Yield increases in Scandinavia increase significantly but across the EU changes in yield are minor. *JRC comment: these results indicate that the model needs to be adjusted to correspond closer to agricultural reality).* In scenarios A2/A3 yield increases drop in Scandinavia but increase in other regions. World food consumption decreases across all agricultural sectors.

Table 3 Land area change: Ethanol production +1Mtoe

	Sectoral land area changes 2007					
	SCA		EU	EU	EU	EU
	Bau	A1	Bau	A1	A2	A3
WHT	4,16%	4,03%	5,84%	5,83%	5,90%	6,35%
GRO	7,42%	7,18%	6,71%	6,69%	6,74%	6,68%
OSD	1,38%	1,33%	4,17%	4,17%	4,16%	4,14%
C_B	2,97%	6,03%	2,59%	2,79%	2,62%	2,58%
MLK	11,22%	10,89%	6,25%	6,23%	6,24%	6,21%
AGR	72,84%	70,53%	74,45%	74,30%	74,34%	73,97%
SUM	100%	100%	100%	100%	100%	100%

<u>Increased Biodiesel production:</u>

Under scenario B1 additional biodiesel production is met by increased production in the Mediterranean region. The percentage changes in land area are much more moderate in the Mediterranean region compared to the changes in Scandinavia reported in scenario A1 (see Table 4). This indicates that the oil seed sector area is more is more significant than sugar beet area in Scandinavia. Under scenario B2, land expansion is less because of imports of vegetable oil from Germany. Yield changes are much less pronounced in the biodiesel scenarios than the ethanol scenarios. World consumption losses across the agricultural sectors are limited.

Table 4 Land area change: Biodiesel production +1Mtoe

	Sectoral land area changes 2007				
	MED		EU	EU	EU
	Bau	B1	*Bau*	B1	B2
WHT	2,25%	2,24%	5,84%	5,83%	5,83%
GRO	3,85%	3,83%	6,71%	6,70%	6,70%
OSD	8,47%	8,80%	4,17%	4,26%	4,22%
C_B	0,86%	0,85%	2,59%	2,59%	2,59%
MLK	4,44%	4,42%	6,25%	6,24%	6,24%
AGR	80,14%	79,86%	74,45%	74,36%	74,40%
SUM	100%	100%	100%	100%	100%

Land area change: biodiesel production +1Mtoe

<u>Increased biodiesel production in Germany:</u>

In scenario D production of biodiesel from palm oil in Germany is increased. Vegetable oil imports increase alongside production increases, resulting in little change in area, yield, prices or consumption. The trade reaction is a result of the stronger trade in vegetable oils than other feedstocks.

Increased US corn ethanol production:

In scenario C US ethanol production was increased using corn exclusively as a feedstock input. Yield changes are in a similar range of EU changes in scenarios A2 and A3. However, the price effects are more substantial relative to the effects reported in the EU (see Table 5). Some effects on consumption prices are found on the EU market but these are smaller than in the scenarios that increase biofuel production in the EU. There are greater consumption losses in the US than compared to the EU scenarios.

Table 5 Land area change: US corn ethanol production +1Mtoe

	Price changes		Land area change		Yield changes		Changes in final consumption	
			USA	USA				
	EU	USA	Bau	sc C	EU	USA	EU	USA
WHT	0,01%	0,39%	4,09%	4,04%	0,01%	0,14%	0,00%	-0,38%
GRO	0,01%	0,34%	16,11%	16,42%	0,01%	0,13%	0,00%	-0,33%
OSD	0,03%	0,29%	9,49%	9,44%	0,01%	0,14%	-0,02%	-0,28%
C_B	0,01%	0,28%	1,29%	1,28%	0,01%	0,14%	0,00%	
VOL	0,01%	0,13%					0,00%	-0,12%
Other AGR	0,01%	0,04-0,20%					0,00%	-0,19 to -0,03%
MLK			6,82%	6,80%				
AGR			62,20%	62,02%				
Fossil fuels	-0,01%	-0,02%						

Changes in Land Prices:

Increases in land prices that act as a common driver for agricultural sector process partly explain parallel price increases across the agricultural sector.

Sensitivity.

Sensitivity analysis runs were made under scenario *A2* where trade and substitution of primary factors were made less responsive. The analysis showed that altering the land substitution elasticity does have an impact. A 10% EU biofuel quota was simulated with the GTAPv6 and GTAPv7 datasets. Figure below shows the percentage prices changes from the 2020 policy scenario price to the 2020 benchmark using both datasets. The different price effects are a result of the change in economic structure because the elasticities are assumed to be all the same.

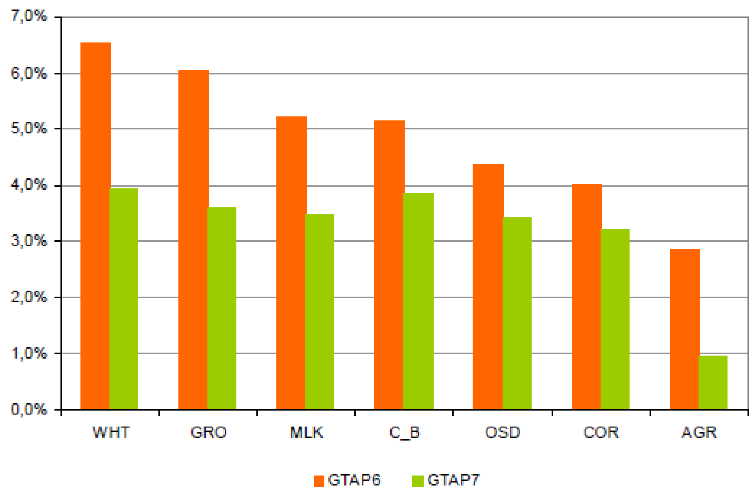

Figure 2 Price changes between 2020 policy scenario and benchmark.

Indirect land use.

DART assumes constant agricultural area, so cannot estimate LUC or emissions from LUC directly. However, DART does deliver price effects transmitted via intertwined global markets and location of increased biofuel production. ILUC is an outcome of international agricultural market effects, where the drivers are both energy and nutritional uses of biomass. Agricultural market effects are the outcome of interplay of biofuel policy and consumption growth.

Generally, and independently of the DART runs presented here, IfW believes that the global effect of ILUC needs to be reduced via local incentive setting, e.g. higher bonus for using degraded land, higher GHG mitigation requirements for biofuels or better forest protection legislation/enforcement. Ideally by accounting for GHG emissions from all agricultural goods ILUC would be transformed into direct LUC. An Interim measure would be sustainability criteria for further feedstocks and world regions.

Conclusions

The small effects under the scenarios are seen because of the flexible adjustment mechanisms in CGE models. Sensitivity runs have shown that decreasing the ease of substitution between land and other primary factors has a perceivable impact. Updating from the GTAPv6 (2001) database to the GTAPv7 (2004) provides significant differences:

- There is more international trade, more flexible adjustment and therefore maybe smaller effects;
- Land price increases area are smaller under GTAPv7: less important factor of production through mechanisation;
- The 10% biofuel scenario effects are also smaller under GTAPv7

Calculation of marginal biofuel scenarios with the DART model

Bettina Kretschmer, Sonja Peterson
Kiel Institute for the World Economy

Workshop on Effects of increased demand for Biofuels feedstocks on the world agricultural markets and areas,
JRC Ispra 10-11 Feb 2010

Outline

Introduction to DART

Introduction to DART

- Multi-region, multi-sector, recursive dynamic CGE model
  → sequence of single-period equilibria connected through capital accumulation and changes in labour supply
- CGE framework: international linkages and linkages between energy and agricultural markets
- 20 sectors and 19 countries/regions representing the global economy linked via bilateral trade flows
- Model horizon: *here:* 2004-2007, GTAP7 database
- Full employment of production factors
  - Labour and capital: mobile across sectors within regions, internationally immobile
  - Land: input in agricultural production, fixed endowment

DART sectors

Energy Sectors		Agricultural sectors	
COL	Coal Extraction		
GAS	Natural Gas	WHT	Wheat
CRU	Crude Oil	OSD	Oilseeds
OIL	Refined Oil Products	C_B	Sugar beet, sugar cane
DIS	Diesel (2 technologies)	GRO	Crops neglected
GLS	Motor gasoline (2 technologies)	MLK	Raw Milk
ELY	Electricity	MET	Meat products
		FRS	Forestry
Non-Energy Sectors		VOL	Vegetable oils and fats
ETS	Energy-intensive sectors in ETS	SGR	Sugar
CRP	Chemical Products	AGR	Rest of Agriculture
OTH	Other Manufactures & Services		

DART regions

EU and other Annex B		Non-Annex B	
DEU	Germany	BRA	Brazil
GBR	UK, Ireland	LAM	Rest Latin America
FRA	France	IND	India
SCA	Denmark, Sweden, Finland	CPA	China, Hong-Kong
BEN	Belgium, Netherlands, Luxemburg	MAI	Indonesia, Malaysia
MED	Greece, Italy, Portugal, Spain, Malta	PAS	Rest of Pacific Asia
REU	Rest of EU27	CPA	China, Hong-Kong
USA	United States of America	MEA	Middle East & North Africa
OCD	Rest industrialized OECD	AFR	Subsaharan Africa
FSU	Former Soviet Union		

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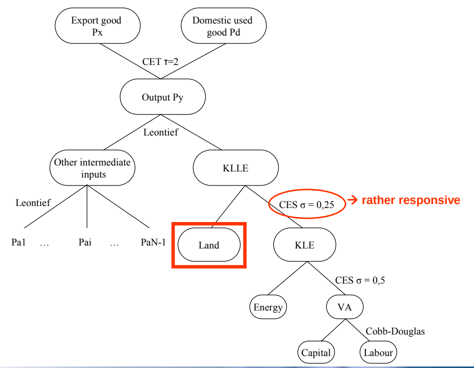
Production structure (non-fossil-fuel sectors)



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DART with biofuels

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DART with biofuels

- Inclusion of new production technologies for first-generation biofuels:
  - Ethanol from sugar beet/cane, corn, wheat
  - Biodiesel from oilseeds/vegetable oils
- Biofuel production from 2005 on, calibrated to 2007 production data (www.biofuels-platform.ch)
- Calculation of markups:
  - Based on quality ratio between biofuels and fossil fuels and difference in production cost
  - Markups together with input and fuel prices determine competitiveness of biofuels w.r.t. fossil fuels
- Biofuel trade:
  - Brazil (ethanol) and Malaysia/Indonesia (biodiesel) as sole exporters due to uncertain development of other export potentials

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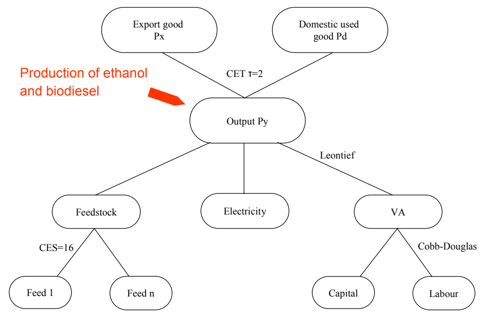
DART with biofuels



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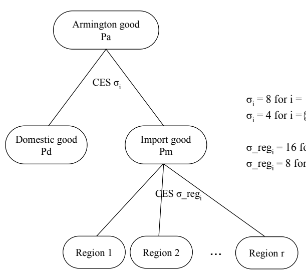
Armington aggregation



σ_i = 8 for i = {WHT,VOL,GRO, OIL, GSL}
σ_i = 4 for i ={ELY, remaining goods}

σ_reg_i = 16 for i = {WHT,VOL,GRO, OIL, GSL}
σ_reg_i = 8 for i ={ELY, remaining goods}

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Biofuel shares in 2007 (%)

	Production (mtoe)		calibrated share	
	Biodiesel	Ethanol	Biodiesel	Ethanol
Germany	2,54	0,20	6,9	0,7
UK+Ireland	0,13	0,01	0,60	0,04
France	0,77	0,29	2,00	1,00
Scandinavia	0,16	0,04	1,05	0,40
Benelux	0,08	0,01	0,30	0,07
Mediterranean	0,71	0,21	0,80	0,48
Other EU	0,62	0,15	1,20	0,43
USA	1,33	12,50	1,20	3,20
other OECD	0,01	0,48	0,02	0,33
Brazil	0,57	10,86	3,20	20,00
China	0,26	0,94	0,40	1,00
India	0,06	0,13	0,38	0,48
Malaysia/Indonesia	0,71	0,00	4,70	0,00
EU27	**5,02**	**0,90**		

Production data source: www.biofuels-platform.ch

Initial benchmark shares for different feedstocks but can be altered via high substitution elasticity (=16)

Marginal scenarios and results

Summary of scenarios

Scenario		Extra production of	Region
Scenario A	Scenario A1	Ethanol	EU
	Scenario A2	Ethanol	each MS
	Scenario A3	Wheat ethanol	each MS
Scenario B	Scenario B1	Biodiesel	EU
	Scenario B2	Biodiesel	each MS
Scenario C		(Corn) ethanol	USA
Scenario D		Biodiesel (from vegetable oil)	Germany

- *1* scenarios: extra EU production where it is cheapest
- *2* scenarios: production scaled up in each MS according to ist 2007 share in total EU production
- Adjusted DART versions with separate production functions for biofuel from each feedstock for *A3* and *D*

Variables of interest

Remarks: prices in 2004 normalized to 1, all input data in value terms (2004 billion US$)

Price changes: change of 2007 price in the marginal scenario relative to 2007 benchmark price

Yield changes: change in ton of crop output per hectare in *one* region

Food consumption: %change + absolute consumption changes in value terms at 2004 prices

Other: sectoral land inputs (out of total production), land prices

Results: ethanol production +1Mtoe

	Price changes			
	A1		A2	A3
	SCA	EU	EU	EU
WHT	0,29%	0,02%	0,04%	0,04%
GRO	0,41%	0,02%	0,02%	0,05%
OSD	0,15%	0,01%	0,02%	0,02%
C_B	0,46%	0,05%	0,04%	0,04%
VOL	0,04%	0,00%	0,00%	0,00%
Other AGR	0,06-1,12%	0,01-0,08%	0,01-0,05%	0,01-0,04%
Fossil fuels	-0,24 to -0,14%	-0,05 to -0,04%	-0,03%	-0,03%

- *A1*: All met by increased sugar beet based ethanol production in SCA
- Subsidisation of biofuels → fall in energy prices (no counter-financing of subsidy expenditures)

Results: ethanol production +1Mtoe

	Sectoral land area changes 2007					
	SCA		EU	EU	EU	EU
	Bau	A1	Bau	A1	A2	A3
WHT	4,16%	4,03%	5,84%	5,83%	5,90%	6,35%
GRO	7,42%	7,18%	6,71%	6,69%	6,74%	6,68%
OSD	1,38%	1,33%	4,17%	4,17%	4,16%	4,14%
C_B	2,97%	6,03%	2,59%	2,79%	2,62%	2,58%
MLK	11,22%	10,89%	6,25%	6,23%	6,24%	6,21%
AGR	72,84%	70,53%	74,45%	74,30%	74,34%	73,97%
SUM	100%	100%	100%	100%	100%	100%

- Strong %change in sugar beet area (>100%) in SCA scenario A1 but sugar beet area is relatively small

Results: ethanol production +1Mtoe

	Changes in final consumption			
	A1		A2	A3
	SCA	EU	EU	EU
WHT	-0,30%	-0,02%	-0,07%	-0,09%
GRO	-0,43%	-0,02%	-0,05%	-0,06%
OSD	-0,16%	-0,01%	-0,02%	-0,03%
C_B	-0,48%	-0,08%	-0,03%	-0,05%
VOL	-0,05%	0,00%	0,00%	0,00%
Other AGR	-1,13 to -0,08%	-0,05 to -0,01%	-0,05 to -0,01%	-0,05 to -0,01%
	Yield			
	SCA	EU	EU	EU
WHT	2,45%	0,12%	0,13%	0,10%
GRO	2,45%	0,14%	0,11%	0,08%
OSD	2,46%	0,06%	0,09%	0,07%
C_B	2,44%	0,26%	0,12%	0,09%

- Pronounced *yield changes* in SCA in scenario *A1*, much less in EU across scenarios
- World consumption loss across AGR sectors: -0,02 to 0,00%

Results: Biodiesel production +1Mtoe

	Price changes		
	B1		B2
	MED	EU	EU
WHT	0,06%	0,02%	0,02%
GRO	0,08%	0,03%	0,03%
OSD	0,10%	0,06%	0,02%
C_B	0,11%	0,02%	0,02%
VOL	0,03%	0,01%	0,01%
Other AGR	0,01-0,11%	0,00-0,03%	0,00-0,02%
Fossil fuels	-0,03 to 0,00%	-0,03 to - 0,02%	-0,03 to - 0,02%

- *B1*: All met by increased biodiesel production in MED
- Effects comparable to A scenarios w.r.t. order of magnitude

Results: Biodiesel production +1Mtoe

	Sectoral land area changes 2007				
	MED		EU	EU	EU
	Bau	B1	*Bau*	B1	B2
WHT	2,25%	2,24%	5,84%	5,83%	5,83%
GRO	3,85%	3,83%	6,71%	6,70%	6,70%
OSD	8,47%	8,80%	4,17%	4,26%	4,22%
C_B	0,86%	0,85%	2,59%	2,59%	2,59%
MLK	4,44%	4,42%	6,25%	6,24%	6,24%
AGR	80,14%	79,86%	74,45%	74,36%	74,40%
SUM	100%	100%	100%	100%	100%

- % changes in land area much more moderate for MED compared to SCA in A1: OSD area more important in MED than sugar beet area in SCA
- B2: less land expansion due to some imports of vegetable oil in Germany

Results: Biodiesel production +1Mtoe

	Changes in final consumption		
	B1		B2
	MED	EU	EU
WHT	-0,07%	-0,01%	-0,01%
GRO	-0,09%	-0,02%	-0,01%
OSD	-0,11%	-0,04%	-0,02%
C_B	-0,11%	-0,01%	-0,02%
VOL	-0,04%	-0,02%	0,00%
Other AGR	-0,12 to - 0,02%	-0,02 to - 0,01%	-0,02 to 0,00%
	Yield Changes		
	MED	EU	EU
WHT	0,25%	0,05%	0,04%
GRO	0,25%	0,06%	0,04%
OSD	0,24%	0,12%	0,26%
C_B	0,25%	0,05%	0,04%

- *Yield changes* much less pronounced than in ethanol scenarios
- World consumption loss across AGR sectors: -0,01 to 0,00%

Results: biodiesel production (veg. oil) in Germany +1Mtoe

	Price changes		Land area change		Yield changes		Changes in final consumption	
			DEU	DEU				
	DEU	EU	Bau	sc D	DEU	EU	DEU	EU
WHT	0,00%	0,00%	7,61%	7,61%	0,01%	0,00%	-0,02%	0,00%
GRO	0,00%	0,00%	6,58%	6,58%	0,01%	0,00%	-0,02%	0,00%
OSD	0,01%	0,00%	3,23%	3,25%	0,01%	0,00%	-0,03%	0,00%
C_B	0,00%	0,00%	3,85%	3,85%	0,01%	0,00%		0,00%
VOL	0,23%	0,01%					-0,24%	-0,01%
Other AGR	0,00-0,01%	0,00%					-0,02%	0,00%
MLK			6,02%	6,02%				
AGR			72,71%	72,69%				
Fossil fuels	-0,06 to -0,04%	-0,03%						

Vegetable oil imports increase along with production → little change in area, yield, prices, consumption (B1 and B2: little feedstock imports)

Results: US corn ethanol production +1Mtoe

	Price changes		Land area change		Yield changes		Changes in final consumption	
			USA	USA				
	EU	USA	Bau	sc C	EU	USA	EU	USA
WHT	0,01%	0,39%	4,09%	4,04%	0,01%	0,14%	0,00%	-0,38%
GRO	0,01%	0,34%	16,11%	16,42%	0,01%	0,13%	0,00%	-0,33%
OSD	0,03%	0,29%	9,49%	9,44%	0,01%	0,14%	-0,02%	-0,28%
C_B	0,01%	0,28%	1,29%	1,28%	0,01%	0,14%	0,00%	
VOL	0,01%	0,13%					0,00%	-0,12%
Other AGR	0,01%	0,04-0,20%					0,00%	-0,19 to -0,03%
MLK			6,82%	6,80%				
AGR			62,20%	62,02%				
Fossil fuels	-0,01%	-0,02%						

- *Yield changes* in the range of EU changes in scenarios A2 and A3
- *Price effects*, however, more substantial; some effects felt on European prices
- *Consumption*: greater losses in US compared to previous EU scenarios

Changes in land prices

Change in land prices 2007 policy compared to benchmark, 1mtoe extra production								
	DEU	GBR	FRA	SCA	BEN	MED	REU	USA
Scenario A1	0,04%	0,03%	0,03%	11,90%	0,08%	0,03%	0,03%	0,01%
Scenario A2	1,06%	0,07%	1,25%	0,48%	0,06%	0,17%	0,24%	0,00%
Scenario A3	0,84%	0,18%	0,75%	0,03%	0,02%	0,10%	0,44%	0,00%
Scenario B1	0,05%	0,05%	0,07%	0,05%	0,06%	1,15%	0,04%	0,04%
Scenario B2	0,37%	0,12%	0,17%	0,15%	0,05%	0,16%	0,24%	0,04%
Scenario C	0,05%	0,05%	0,05%	0,08%	0,07%	0,05%	0,04%	0,93%
Scenario D	0,04%	0,01%	0,01%	0,00%	0,01%	0,02%	0,00%	0,02%

- *Increases in land prices* that act as a common driver for agricultural sector prices → explain partly parallel price increases across agricultural sectors

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Share agricultural input in biofuel production out of total sectoral production

Scenario B2 (+1mt biodiesel)							
bench	DEU	GBR	FRA	SCA	BEN	MED	REU
OSD	43,4%	11,5%	14,2%	27,6%	20,9%	4,0%	10,9%
VOL	15,2%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
+1mtoe							
OSD	49,0%	13,2%	16,0%	31,4%	24,2%	4,6%	12,5%
VOL	17,3%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%

Scenario A2 (+1mt ethanol)							
bench	DEU	GBR	FRA	SCA	BEN	MED	REU
WHT	1,8%	0,2%	1,2%	0,0%	0,6%	1,5%	0,9%
GRO	0,0%	0,0%	1,2%	0,0%	2,1%	1,0%	0,0%
C_B	1,6%	0,0%	2,8%	3,9%	0,0%	0,0%	0,0%
+1mtoe							
WHT	3,8%	0,4%	2,4%	0,0%	1,4%	3,2%	1,9%
GRO	0,0%	0,0%	2,3%	0,0%	4,4%	2,2%	0,0%
C_B	3,4%	0,0%	5,9%	7,8%	0,0%	0,0%	0,0%

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Sensitivity runs scenario *A2*

EU price changes 2007 for additional 1mtoe ethanol split across MS						
	Inde(i,r)=0.25			armel(2,4)		
	base	armel(2,4)	armel(1,2)	Inde(i,ET)=0.15	Inde(i,ET)=0.1	Inde(i,r)=0.15
WHT	0,04%	0,03%	0,04%	0,06%	0,06%	0,10%
GRO	0,02%	0,03%	0,03%	0,05%	0,05%	0,08%
OSD	0,02%	0,02%	0,02%	0,04%	0,04%	0,05%
C_B	0,04%	0,04%	0,04%	0,08%	0,08%	0,13%
VOL	0,00%	0,00%	0,00%	0,01%	0,01%	0,01%
Other AGR	0,01-0,05%	0,01-0,05%	0,01-0,05%	0,01-0,08%	0,01-0,09%	0,01-0,13%
Fossil fuels	-0,03%	-0,04 to -0,03%	-0,04 to -0,03%	-0,04 to -0,03%	-0,04 to -0,03%	-0,04 to -0,03%

- We made trade and substitution of primary factors less responsive
- Altering land substitution elasticity does have impact

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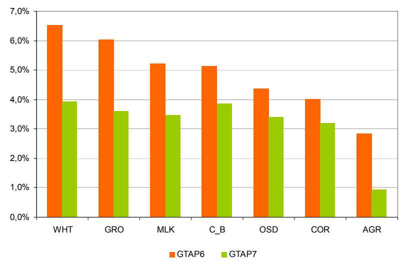
Concluding remarks

2020 price changes GTAP6 vs. GTAP7



- Simulation of 10% EU biofuel quota with both datasets
- %change 2020 policy scenario price to 2020 benchmark

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Intro DART
DART and bioenergy
Marginal scenarios
ILUC
Concluding remarks

Indirect land use change

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Intro DART
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ILUC – Our stance

- No detailed representation of factor land; what DART does deliver: price effects transmitted via intertwined global markets, location of biofuel production
- ILUC is an outcome of international agricultural market effects, drivers are both energetic and nutritious biomass use

➔ Global effect that needs to be reduced via local incentive setting, e.g.
  - ➔ Higher bonus for using degraded land, higher GHG mitigation requirements for biofuels
  - ➔ Better forest protection legislation/enforcement

Ideally: GHG accounting for all agricultural goods → this would transform all ILUC into direct LUC

Interim measure: Sustainability criteria for further feedstocks and world regions

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Intro DART
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Marginal scenarios
ILUC
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Concluding remarks

- Small effects due to flexible adjustment mechanisms in CGE models
- Sensitivity runs have shown that decreasing the ease of substitution between land and other primary factors has a perceivable impact
- Updating from GTAP6 (2001) to GTAP7 (2004):
  - More international trade → more flexible adjustment → smaller effects?
  - Land price increases smaller under GTAP7: less important factor of production through mechanisation (at least in EU/developed world?)
  - 10% scenario effects also smaller under GTAP7

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Thank you for your attention!

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Kretschmer, B., S. Peterson & A. Ignaciuk (2008). Integrating Biofuels into the DART Model. Kiel Working Paper 1472, Kiel Institute for the World Economy, Kiel, Germany.

Kretschmer, B. & S. Peterson (forthcoming). Integrating Bioenergy into Computable General Equilibrium Models – A Survey, *Energy Economics* (2009), doi:10.1016/j.eneco.2009.09.011.

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Table: Feedstock shares

	Biodiesel from				Bioethanol from		
	vegetable oil	rape seed	soya	palm	wheat	sugar beet/cane	corn
DEU	28%	72%			75%	25%	
FRA		100%			25%	50%	25%
GBR		100%			100%		
SCA		100%				100%	
BEN		100%			50%		50%
MED		100%			50%		50%
REU		100%			100%		0%
USA			100%				100%
BRA			100%			100%	
OECD		100%				50%	50%
MAI				100%			
CPA					100%		
IND				100%		100%	

* Note that the GTAP database does not differentiate between the different oil seeds. Yet, since all regions only use one type of oilseeds for biodiesel production it is always clear which feedstock is used.

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Table : Biofuel production in 2007 (mtoe)

	BDS mtoe	BET mtoe		BDS mtoe	BET mtoe
DEU	2.578	0.200	**BEN**	0.084	0.007
GBR	0.136	0.010	Belgium	0.008	0.000
UK	0.134	0.010	Netherlands	0.076	0.007
Ireland	0.002	0.000	**MED**	0.721	0.207
SCA	0.167	0.036	Spain	0.150	0.177
Finland	0.035	0.000	Portugal	0.156	0.000
Sweden	0.056	0.036	Italy	0.324	0.030
Denmark	0.076	0.000	Greece	0.089	0.000
FRA	0.778	0.294	Malta	0.001	0.000
REU	0.633	0.145	Cyprus	0.001	0.000
Latvia	0.008	0.009	**EU total**	5.096	0.899
Lithuania	0.023	0.010			
Poland	0.071	0.079	**USA**	1.349	12.446
Hungary	0.006	0.015	**FSU**	0.000	0.000
Slovakia	0.041	0.015	**BRA**	0.578	10.820
Slovenia	0.010	0.000	**MAI**	0.721	0.000
Check Rep.	0.055	0.017	**CAP**	0.268	0.935
Romania	0.032	0.000	**IND**	0.000	0.127
Bulgaria	0.148	0.000	**OECD**	0.065	0.479
Austria	0.238	0.000	**World**	8.364	25.177

Source: www.biofuels-platform.ch

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Table 2: Cost shares of bioenergy production

	Biodiesel from				Bioethanol from		
	veg. oil	soy	palm	rape	sugar cane/ beet	sugar cane Brazil	wheat/ corn
feedstock	0.80	0.76	0.73	0.79	0.62	0.59	0.62
electricity	0.04	0.04	0.05	0.04	0.15	0.17	0.15
capital	0.15	0.19	0.21	0.16	0.20	0.22	0.20
labor	0.01	0.01	0.01	0.01	0.03	0.02	0.03

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Markups	soy	palm	rape	sugar	sugar	wheat/co
	boil2	boil3	boil4	beth2	beth4	beth1
DEU	3,28	3,28	2,20	2,23		2,34
FRA	2,99	2,99	1,98	2,18		2,31
GBR	3,13	3,13	2,06	1,99		2,09
SCA	2,94	2,94	2,06	1,73		1,71
BEN	2,79	2,79	1,84	1,97		2,03
MED	3,04	3,04	1,81	2,04		2,02
REU	3,05	3,05	1,93	1,96		1,91
USA	1,55	2,96	2,96	2,38		2,19
FSU	6,94	6,94	6,94	3,96		3,96
BRA	1,13	1,69	1,69	1,27	0,91	1,27
LAM	2,21	1,71	1,71	2,51		2,58
OECD	2,82	2,82	1,97	2,27		2,33
MAI	2,13	3,38	2,13	5,59		2,14
PAS	4,10	3,70	4,10	6,39		2,66
CPA	4,10	1,32	4,10	2,14		2,66
IND	3,21	1,85	3,21	3,38		2,45
MEA	3,21	3,21	3,21	2,45		2,45
AFR	2,79	1,35	2,79	2,31		2,31

5. Effects of increased demand for biofuel feedstocks on world agricultural markets with CAPRI model (Ignacio Perez Dominguez, LEI).

CAPRI is a spatial agro-economic model explicitly covering supply, demand and trade of agricultural commodities at the global level, having links with other sectoral models (e.g. PRIMES for energy) and general equilibrium models (e.g. GTAP). It is specialised on modelling substitution effects between agricultural land uses in European agriculture and includes a rich variety of agro-environmental indicators, linked to nutrient flows in agriculture.

CAPRI is structured in two different interlinked modules:

1. World Market module: A globally closed model incorporating an Armington two-nested structure) for production, demand and trade in primary and secondary agricultural products, similar to DART or GTAP for the agricultural markets. It covers the whole world and produces market balances for around 40 countries and country aggregates and 60 agricultural commodities (raw and processed).

2. EU Supply module: optimisation template models for 270 Nuts2 regions in the EU27, Western Balkans, Norway and Turkey, capturing farming decisions in detail (crop shares, animal heads, yields, fertilizer use, feeding requirements for livestock) and including EU budget expenditure in agriculture.

These two modules are interlinked, following an iterative approach; the two models exchange supply and price variables until equilibrium is reached. As a result, production and land use is modelled at the regional level in the EU27 and market balances including bilateral trade for the EU and other world market players.

CAPRI modelling system

Global Spatial (Armington) Multi-Commodity Model is split into 40 countries in 28 trade blocks, 60 primary and secondary agricultural products, agricultural and trade policy measures. It includes in explicit quantitative terms and not only in value terms the tariff trade barriers, quotas, price differentiation for imports in bilateral agreements for agricultural commodities.

Regional Aggregate Programming Models: for the supply side there are circa. 270 regions for the EU27, Norway, Western Balkans and Turkey, with a detailed representation of farming decisions and CAP measures.

Indicators calculators: From the supply side, economic indicators are calculated such as market balances or farm balances with yields and land use (only) in the EU, nutrient balances and GHGs for different activities and simulations.

Integration of biofuels in CAPRI

Only first generation biofuels are considered in the model. Biofuel (first generation) demand is exogenously linked to policies or other projections. No explicit trade of biofuels is included, but what are included are feedstocks considering process commodities soy, maize, wheat, barley, oil cakes and oil seeds.

Processing of feedstocks to biofuels is explicitly modelled: ethanol is produced from wheat, coarse grains and sugar whilst biodiesel is produced from vegetable oils.

By-products are used in the feed industry in the EU: oil cakes from biodiesel (traded) going into the animal feed market and DDGS from ethanol production (currently not traded).

Scenario construction: demand shocks

For this exercise, CAPRI models the effects on EU agriculture of demand shocks in different parts of the world. That includes effects of land used and yields in the EU27. The results for the effects of demand shocks in the EU due to the implementation of the EU biofuel directive were reported in the first Interim Report (October 2009): “Modelling Indirect Land Use Change Effects of Biofuels Policy”. This second report concentrates on effects on EU of demand changes outside the EU.

The model was tested for 51 scenarios, constructed by expanding feedstock demand in selected world regions. The main world regions included in the analysis are: USA, Canada, Brazil and Argentina. The products included are: coarse grains, rapeseed, soya, oilseeds, oils, soya oil, and rapeseed oil.

A 1% and 10% excess demand shocks were modelled to check for linearity effects (confirmed) in EU market balances. Additional scenarios were considered: feedstock expansion in the whole world (EU not included) and feedstock expansion calculated separately for the four mentioned regions to check that they add up to the same thing. Some hypotheses were tested: such as linearity in the implementation degree of the EU directive (from 1-10% first generation biofuels, 50/50 diesel/gasoline); and additionality of the effects of multiple implementations of biofuel directives in non-EU countries. The results show the production, land use, imports and exports for the EU reported ‘at the margin’ (instead of average). The increase in demand is set as a quota while the price increases.

Marginal results

Marginal results in the EU for coarse grains demand increase in Rest of World (RoW) are shown in Table 6. Market balance effects in the EU: important increases in domestic production and exports (of similar size). At a shock of the ROW with 1% shift on grains demand, there is an effect on supply in EU of half of it. This leads also to a moderate decrease in demand and imports (of similar size 0.11 and 0.13 respectively) and an increase in exports (0.46 if scaled according to supply or 3.78 if not weighted). Multiplicators appear to be additive, so that the effects in the EU are independent of where the demand shock is performed (i.e. origin of a hypothetical excess of demand)[5]. The size of the market matters, independently of the origin of feedstock. These results reveal that the size of the market is important, since demand increases equally independent of the origin of products. The model is capable of distributing land change and yield increases in the EU. Aggregated marginal production effects in the EU can be decomposed in: 0.5 of land use expansion and 0.5 of yield increase.

[5] This hints at a weak functioning of tariff rate quotas (TRQs) in the range of scenarios performed (due to the lack of those or the calibration point being away from the fill-rate. The fill rates of these TRQs in the calibration point should be closely analysed.

Table 6 Marginal results in the EU for coarse grains (taken from presentation)

EU Grains Multiplicator	Supply	Demand	Imports (weighted)	Exports (weighted)	Imports	Exports
ROW	0.48	- 0.11	- 0.13	0.46	- 0.90	3.78
ABCU	0.23	- 0.03	- 0.08	0.18	- 0.54	1.49
Brazil	0.04	- 0.01	- 0.02	0.04	- 0.11	0.29
Canada	0.02	- 0.01	- 0.00	0.03	- 0.03	0.21
Argentina	0.02	- 0.01	- 0.01	0.01	- 0.08	0.11
USA	0.14	- 0.01	- 0.05	0.11	- 0.31	0.88

Marginal effects on land use due to cereals show that there is an average increase of 0.33 %, and there are regional differences in the EU of land use expansion due to cereals production between regions.

Marginal results for oils are shown in Table 7. The EU is not a major player in the world market for oils and therefore, domestic markets are much lower linked with the rest of the world. The increase in demand in the world is likely to affect the EU to a lesser extent. Therefore, the impact of a world increase by 1% in demand has a low impact in the EU. Market balance effects in the EU are a minimal increase in production and demand (due to processing revenues), and a minimal decrease in imports and some increase in exports.

Table 7 Marginal results in the EU for oils

EU Oils Multiplicator	Supply	Demand	Imports (weighted)	Exports (weighted)	Imports	Exports
ROW	0.09	0.03	- 0.01	0.04	- 0.01	0.28
USA	0.01	0.00	- 0.00	0.00	- 0.00	0.02
Brazil	0.00	0.00	- 0.00	0.00	- 0.00	0.02
Canada	0.01	0.02	0.01	0.00	0.01	0.01
Argentina	0.01	0.00	0.00	0.01	0.00	0.04

Marginal production effects on the use of additional land: Marginal production effects can be decomposed into 60-80% on land use expansion and 40-20% into yield increase. A demand shock of 1% oil in ROW leads to an expansion in EU of land use, on average of 0.14%, with some variation at the region level in the EU.

<u>Marginal effects on use of additional land</u>

A demand shock of 1% coarse grains in ROW lead to an expansion in EU of agricultural area on non-agricultural land which is currently not used for production and a reduction (fallow land) by 13.28% max, in some regions in the EU. There is a high expansion of production in the East European Countries. In the case of rapeseed and rapeseed oil, there is a similar, but much lower effect, to a maximum 0.14%.

Marginal results on main players

The effects of marginal demand shocks of soy (soy beans and soy oil) and coarse grains were investigated for the most important world players (Argentina, Brazil, Canada and USA). There are different patterns related to the structure to the demand and supply function in the trade model. The excess demand is covered by domestic production and trade, with quite large differences in the responses, depending on the market size and the net trade of these countries.

The substitution of soy oil by palm oil was not allowed, so the shock was on the soy and the demand for soy is covered by soy coming from different sources. This substitution is important, since the increase in oil demand might lead to an increase in the production of other food oil, such as palm oil, having higher yields and not soy oil.

Conclusions

An increased demand for coarse grains outside the EU (due to the ethanol policies) have an effect on domestic production of cereals in the EU (multiplicator 0.5) and exports (multiplicator 3.8).

An increased demand in the world for oils/oilseeds hardly affects EU markets (multiplicator 0.1) and exports (multiplicator 0.3).

Land use effects due to oil shocks, although low, are mostly on rapeseed area (multiplicator 0.14), as there is high substitution between different oilseeds in the EU (shifts to rapeseed from soy or sunflower). Oil processing distorts the whole picture due to the income in the processing industry.

There was noticed a fallow land conversion to agricultural land, especially for shocks on grains (multiplicator -0.15); there were no clear effects of shocks due to rapeseed oil.

Limitations

The model has no module to describe animal feed displacements outside the EU, so a pragmatic solution was adopted, and a shock of 0.7% was considered instead of 1% to account for by-products of the ethanol chain.

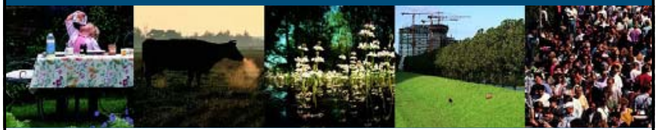
Crude oil price response is not included in CAPRI (a CES approach is under development, based on the AGLINK work).

Increasing shocks were applied to the model to find the limits of its stability. It showed instability at 10-20% shocks on demand for oils in the world, so it should only be used below this range. Moreover, TRQs seemed not to provoke non-linearities in the market effects.

Other limitations are the Armington assumption (expanding world trade of cereals and oils to non-traditional origins is not included in the analysis), there are no capacity constraints for processing, no sustainability criteria for production of biofuels and no substitution effects with palm oil are included in the analysis. Last but not least, yield reactions at regional level must be better understood (and elasticities reported).

Effects of increased demand for biofuel feedstocks on world agricultural markets

Ignacio Pérez Domínguez (LEI)



Motivation: "the storyline"

- Although biofuels present a fairly small share on energy consumption and economic value added (low share on energy markets and GDP)
- … they are of high relevance for agricultural markets (high substitution effects → so-called "ILUC")
- … are the only source of liquid fuels alternative to crude oil (importance of the transport sector),
- … and have a high weight on the policy agenda, due to their multiple dimensions: energy security, GHG savings/emissions, mitigation and re-vitalisation of agricultural areas.

Motivation: need for modelling

- Many quantitative analysis have responded to the challenge of modelling the economic and environmental effects of biofuel policies in different domains:
  - factor markets: land use change
  - development economics: "food for fuel", yield potentials
  - environment: climate change mitigation, sustainability
- This heterogeneity of approaches requires some harmonization of results (sometimes overlapping/contradictory at a first sight) → therefore the need for calculation of marginal effects on relevant indicators (out of sensitivity analysis or extrapolation exercises)
- In this "constellation" of approaches CAPRI specializes in modelling substitution effects between agricultural products in an open economy

Introduction to CAPRI

- CAPRI is a spatial agro-economic model of agricultural commodity markets at the global level
- Two interlinked modules:
  - Market module: A globally closed model for production, demand and trade in primary and secondary agricultural products
  - Supply module: regional NUTS II simulation models for EU27 which capture in detail farming decisions (crop shares, animal herds, yields, fertilizer use ..)
- Indicator calculators for production and market balances, land use in the EU, nutrient balances, etc.

CAPRI modelling system

Global Spatial (Armington) Multi-Commodity Model — 60 countries in 28 trade blocks, 50 primary and secondary agri. products, agricultural and trade policy measures

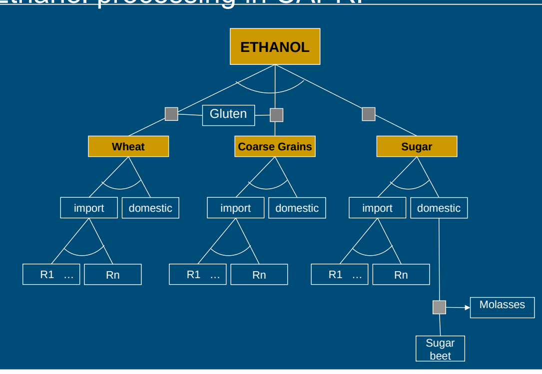
Regional Aggregate Programming Models — 250 regions for EU27 + Norway + Western Balkans + Turkey, detailed representation of farming decisions, CAP, …

Indicators calculators — Production and market balances, land use, nutrient balances and GHGs

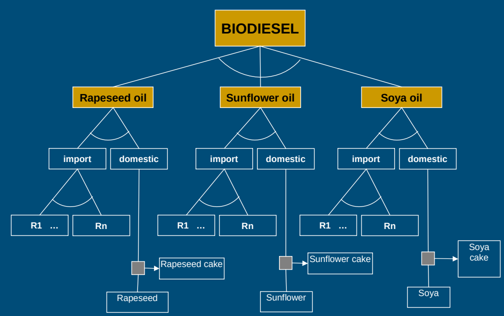
Integration of biofuel activities in CAPRI

- Only first generation biofuels considered
  - Biofuel demand is exogenous
  - No explicit trade of biofuels but feedstocks
- Processing of feedstocks to biofuels is explicitly modeled
  - Ethanol is produced from wheat, coarse grains and sugar
  - Biodiesel is produced from vegetable oils
- By-products are used in the feed industry:
  - Oil cakes from biodiesel (traded)
  - DDGS from ethanol production (currently not traded)

Ethanol processing in CAPRI



Biodiesel processing in CAPRI



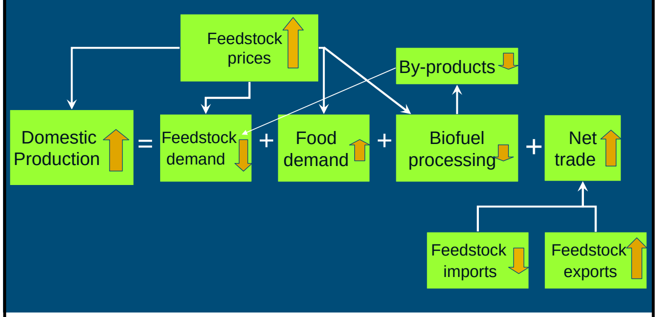
Scenario construction: demand shocks

- 51 scenarios are constructed by expanding feedstock demand in selected world regions:
  - Regions: USA, Canada, Brazil, Argentina
  - Products: coarse grains, rapeseed, soya, oilseeds, oils, soya oil, rapeseed oil
  - Demand expansion: 1% and 10% increases in demand (human consumption and processing) are modeled
- Additional scenarios are considered for:
  - Feedstock expansion in the whole world (EU not included)
  - Feedstock expansion in the 4 mentioned regions as an aggregate
- Results on production, land use, imports and exports for the EU are reported 'at the margin' (instead of average)

Scenario example: soya

Scenario Acronym	Product(s) shifted	Model parameters affected	% Shift	Comments
SOYA_1	Soybeans	Human demand	1% of domestic consumption	No processing assumed. No effects on feed markets captured. Tends to increase animal feed costs in Europe
SOYA_10	Soybeans	Human demand	10% of domestic consumption	
SOYASOYO_1	Soybeans	Processing demand	1% of domestic consumption	Processing to oil and cake explicitly modelled, effects on feed markets captured, only soya oil is used for biodiesel production as "human consumption". Tends to lower animal feed cost in Europe
	Soy oil	Human demand	equivalent to processing output	
SOYASOYO_10	Soybeans	Processing demand	10% of domestic consumption	
	Soya oil	Human demand	equivalent to processing output	

Expected economic reactions in the EU



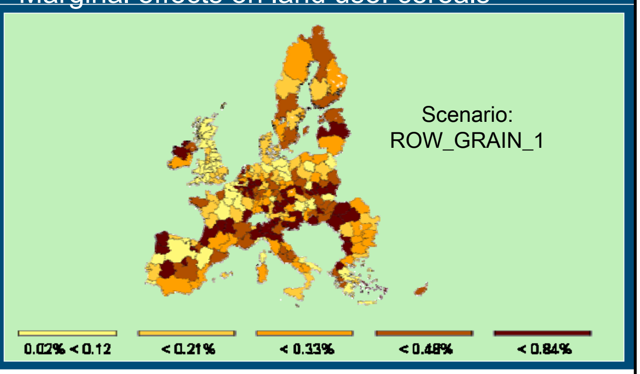
Marginal results in the EU for coarse grains

- Market balance effects in the EU:
  - important increases in domestic production and exports (of similar size)
  - moderate decrease in demand and imports (of similar size)
  - multiplicators are additive (effects independent of origin)

EU Grains Multiplicator	Supply	Demand	Imports (weighted)	Exports (weighted)	Imports	Exports
ROW	0.48	- 0.11	- 0.13	0.46	- 0.90	3.78
ABCU	0.23	- 0.03	- 0.08	0.18	- 0.54	1.49
Brazil	0.04	- 0.01	- 0.02	0.04	- 0.11	0.29
Canada	0.02	- 0.01	- 0.00	0.03	- 0.03	0.21
Argentina	0.02	- 0.01	- 0.01	0.01	- 0.08	0.11
USA	0.14	- 0.01	- 0.05	0.11	- 0.31	0.88

- Marginal production effects in the EU can be decomposed in:
  - 0.5 of land use expansion
  - 0.5 of yield increase

Marginal effects on land use: cereals



Marginal results in the EU for oils

- Market balance effects in the EU:
  - minimal increase in production and demand (due to processing revenues)
  - minimal decrease in imports and some increase in exports
  - regional additivity not tested

EU Oils Multiplicator	Supply	Demand	Imports (weighted)	Exports (weighted)	Imports	Exports
ROW	0.09	0.03	- 0.01	0.04	- 0.01	0.28
USA	0.01	0.00	- 0.00	0.00	- 0.00	0.02
Brazil	0.00	0.00	- 0.00	0.00	- 0.00	0.02
Canada	0.01	0.02	0.01	0.00	0.01	0.01
Argentina	0.01	0.00	0.00	0.01	0.00	0.04

- Marginal production effects can be decomposed:
  - 60-80% on land use expansion
  - 40-20% on yield increase

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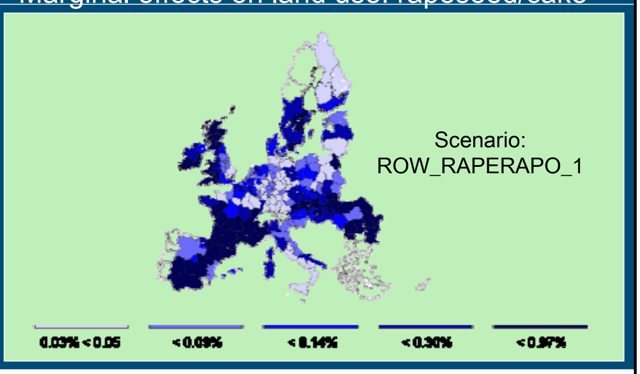
Marginal effects on land use: rapeseed/cake



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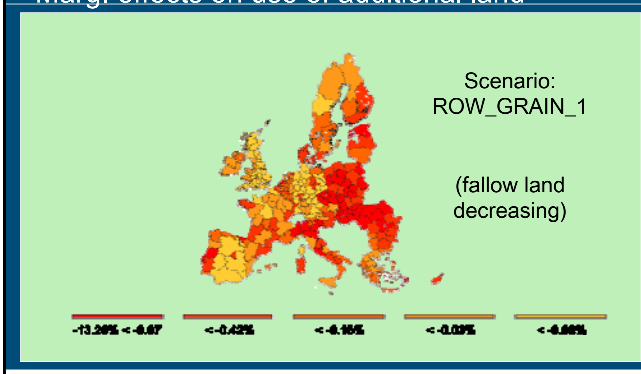
Marg. effects on use of additional land



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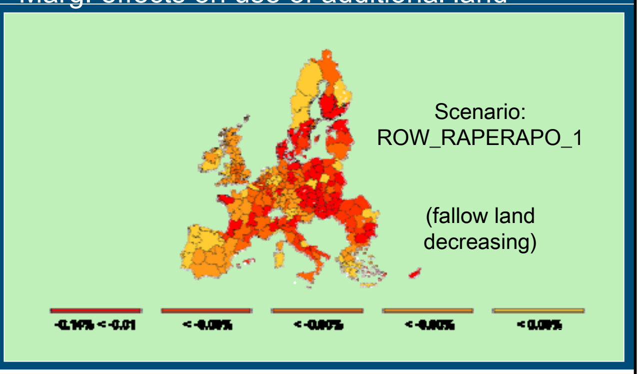
Marg. effects on use of additional land



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Marginal results on main players

- Marginal demand shocks on soya for most-important world traders are absorbed there:
  - In Brazil: 0.65% by domestic supply & 0.35% by trade
  - In Argentina: 0.85% by domestic supply & 0.15% by trade
  - In USA: 0.55% by domestic supply & 0.45% by trade
- Marginal demand shocks on coarse grains for most-important world players are absorbed there:
  - Argentina: 0.15% by domestic supply & 0.85% by trade
  - USA: 0.45% by domestic supply & 0.55% by trade
  - Canada: 0.30% by domestic supply & 0.70% by trade
  - Brazil: 0.65% by domestic supply & 0.35% by trade

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Some preliminary conclusions (I)

- Some "hypothesis" tested:
  - Linearity: in the implementation degree of the EU directive (from 1 to 10% first generation, 50/50 diesel/gasoline)
  - Additivity: in the effects of multiple implementation of biofuel directives in non-EU countries
- Excess of demand on coarse grains ('ethanol policies') might have a strong effect on domestic production of cereals in the EU (mult. 0.5) and exports (mult. 3.8)
- Excess of demand in the world for oils/oilseeds does not affect EU markets (mult. 0.1) and exports (mult. 0.3)

Some preliminary conclusions (II)

- Land use effects due to oil shocks mostly on rapeseed area (mult. 0.14) → substitution between oilseeds, oil processing distorts the picture
- Fallow land converted to agricultural land, especially for shocks on grains (mult. -0.15)
- Not clear the effect for shocks on oils (mult. -0.01)

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Limitations of the study

- Gluten feed not traded (by-products not included in this analysis, pragmatic solution explained in the paper, where 30% is taken out of the shock)
- Crude oil price response not included in CAPRI (a CES approach is under development, based on the AGLINK work)
- The model was "shocked to the limit" and revealed unstable when going far (10-20% shocks on demand for oils in the world), so the results can be only used within a certain range
- Other: Armington assumption, no capacity constraints, yield corridors, …

Workshop on "The effects of increased demand for biofuels feedstocks on the world agricultural markets and areas", 10/02/2010, Ispra
LEI WAGENINGEN UR

Thanks for your attention !

ignacio.perez@wur.nl

Workshop on "The effects of increased demand for biofuels feedstocks on the world agricultural markets and areas", 10/02/2010, Ispra
LEI WAGENINGEN UR

6. World Market Impacts of High Biofuel Use in the EU using CARD International models (Jacinto Fabiosa - Iowa State University -FAPRI) [6]

FAPRI-CARD is the same model used to generate the annual FAPRI agricultural outlook, widely used by agronomists and researchers throughout the world[7].

The econometric models of agricultural markets embedded in the CARD model cover various crops, livestock, dairy products, aggregate measures (inc. government costs, production expenditure and farm income), consumer price indices, federal crop insurance and value of agricultural exports. The biofuel and biomass models were added to include crop residues and switch grass. The models cover most parts of the world for grains, oilseeds and soybeans and soy products, palm oil and products, peanuts and products in different countries and biofuels mostly from first generation.

The Basic Crop Sector Model

The Basic Crop Sector Model, that includes feed and food grains, has various behavioural equations that define yield and area, comprising the domestic supply and stock changes. On the demand side, there are specific behavioural equations that represent food demand, feed demand, other demand (industrial biofuel use) and ending stock demand. There are net trade relations that include imports and exports. Policy parameterisation is an important part of the model, as being highly policy oriented. The demand function in the model includes demand for different products. The oilseed sector is fully disaggregated, and the model includes the crush demand which produces the meal and oil products, food demand for oil, feed demand for meals and industrial or biofuel demand for vegetable oil products. For the livestock there is a strong interaction between feed grains and livestock sector. The breeding stock is also modelled.

The Basic Biofuel Sector Model

The Basic Biofuel Sector Model covers the domestic supply, demand supply and trade. The domestic supply describes the production for biofuels, and includes a separation of capacity and capacity utilisation. The Basic Biofuel Sector Model is more detailed for the EU and the US, whilst other countries are less disaggregated. The demand side is not as disaggregated. The model allows imports and exports of biofuel products. By-products are fully treated by the effects on animal feed/livestock sectors.

Land Allocation Structure in the EU

There is a system of land allocation structure (particular in the EU and Brazil). The aggregated grains area harvested is determined by (and is) a function of aggregate grains revenue, livestock

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[6] Detailed report of the study and calculations sheets are available on CIRCA

[7] The Food and Agricultural Policy Research Institute (FAPRI) is a unique, dual-university research program, established in 1984 by a grant from the U.S. Congress. The Center for Agricultural and Rural Development (CARD) at Iowa State University develops the international side of the models, and the Center for National Food and Agricultural Policy (CNFAP) at the University of Missouri-Columbia develops the U.S. domestic component. This model is called the Food and Agricultural Policy Research Institute (FAPRI) model system when the work is performed by Iowa State and its partner institution at the University of Missouri. When Iowa State runs the model on its own, especially when changes in structure, parameters, and specifications are introduced, the model system is called the FAPRI-CARD Model.

revenue to capture the interaction of pasture and grain area, oilseeds revenue, sugar revenue and grains costs. This total grain area is then divided between different grains (wheat, barley and corn), land. The structure for oilseeds is similar. Thus the FAPRI-CARD model fully treats the interaction of livestock and arable sectors in competition for land and can model also changes in pasture/ranch area.

Yield Specification

Yield specification has significant impact on LUC. The yield equation has a new respecification to include intensification effects - that is, a price-induced yield response-as well as extensification effects that allow a yield drag when new land is put into production. Because of very limited data, most of the parameters were derived using information from yield gaps and availability of arable land to calibrate country-specific parameters.

Modelling Yields

The FAPRI-CARD model treats yield changes as follows:

Firstly, the model specifies a "technological frontier" yield, which increases with time, and depends on farm profitability. For example, for a given country-region and commodity, if the long-run ratio of farm revenue to farm costs increases by 10%, the fractional rate of yield improvement increases by an extra 0.61% per year. It can be argued, however, that farmers adapt their technology based on perception of where the trend is moving rather than responding to year to year price shocks.

Secondly, the actual yield is a fraction of the technology frontier yield. That fraction increases by 0.13% for each 10% increase in the current ratio of farm revenue to farm costs. Farmers achieve this by increasing their farm inputs to optimize profitability.

Thirdly, for each 10% total area expansion, the average crop yield decreases by 0.23%, because of expansion onto poorer land. The quoted elasticities are calibrated based on analysis of actual data from US farming, where most data is available.

DDGS Specification

Results are highly affected by the use of DDGS. Its consumption is modelled for different animals: beef, pork, poultry and dairy. Max inclusion rates were set, which is a limit varying from species to species, 50% for beef, 25% for pork, poultry, etc.

Displacement rates.

If a livestock producer uses DDGC at max of 50% of the ration, displacement rates show how much corn and soymeal it displaces. For beef, 1kg DDGS displaces 1.196 kg corn and zero soymeal. For dairy 1 kg of DDGS displaces 0.731 kg corn and 0.633 soymeal. If the sum of the ratios exceeds one this is because of better digestive efficiency of DDGS. In the model, there are efficiency gains assumed for beef and dairy. The displacement rates impact cost adjustments and substitution of feed grains and substitution of oil meals. Therefore, the model results are non-homogeneous, depending on what it is displaced.

There was a discussion about the displacements, whether there is an efficiency gain or a penalty for the DDGS use; there are several factors influencing this displacement. The model includes efficiency gains since DDGS proteins are in broken form, compared to corn since the nutrients are more accessible for digestion. There are different opinions on DDGS substitution, since

DDGS are less digestible and this may imply a penalty. However, the variability of the nutritional content, crude protein content of DDGS is 25% on average, but varies between, 18%-35%; this variability can discount the optimisation process. Typically, Californian dairy farmers run a linear program optimisation model every two weeks with 45 different ingredients, depending on the prices and this leads to a different mix of ingredients. Presently they do not use DDGS since there are better options due to market conditions.

Energy-Biofuel-Commodity Market Integration

Energy prices and crude oil prices impacts production costs of biofuels, but are also affects the demand for biofuel products due to the substitution of gasoline with ethanol. There is a feedback of the energy markets impacts on the production cost of feedstocks and the production of biofuel which determines the demand for feedstock.

Several models interact: livestock production, dairy production, food/feed demand for corn wheat, oilseeds, biofuels production. Those prices across food and feed grains, oilseeds, sugar, cotton, determine the allocation of land. All models are integrated. Everything impacts one another and therefore it is difficult to disentangle which one is causing what, even if the demand function is only expressed as a function of prices and income, it is impacted through price mechanisms.

Scenarios

Scenario 1 - High Wheat Ethanol Use in the EU - assumes 5% increase in EU ethanol use (a demand shock at 5% at the old price) starting from 2010.

The supply adjustment is only from domestic production: trade is fixed at baseline level and the stock is fixed at baseline level. Feedstock used is only wheat, while all other feedstocks are fixed at baseline level.

Scenario 2 – High Rapeseed Oil Biodiesel Use in the EU - assumes 5% increase in rapeseed EU biodiesel use. The feedstock comes only from rapeseed oil while the use of all other feedstocks fixed at baseline level: soy oil, palm oil demand are fixed at the baseline level, and all feedstock is forced to come from rapeseed oil. Supply adjustment is only from domestic production: trade is fixed at baseline level and the stock is fixed at baseline level. The model does not change trade, allowing consumption to change and allowing production to respond.

For both scenarios, since there is an expansion of demand, the new equilibrium will give a higher price that will moderate the expansion of demand. Even if we increase the demand by 5%, the new equilibrium will bring back the market to only 2.5%. The prices move along the new demand. This behaviour is explained by the fact that FAPRI-CARD is an econometric model and not a programming model, as compared to the GTAP-based models and CAPRI. This behaviour does not affect the final results because they are anyway reported per Mtoe of biofuel.

The EU ethanol baseline and the EU biodiesel baseline are set and the shock is at 5% at the original price. Consumption of those products was increasing over time. At the end of the period by 2023 the biodiesel use in the biodiesel scenario is increased by 169 million gallons and the ethanol use in ethanol scenario by 135 million gallons. Animal feeding practices are not homogeneous across the world. Wheat is the main source of digestible energy in the EU; whilst in Brazil and US it is corn. The protein sources in the EU are soy meal, but also rape meal (11%); whilst in Brazil and the US it is soy meal (95%). Therefore, it is very important for the impact on the feed market as to where the shock is applied.

Market Outcomes of High EU Wheat Ethanol

European Union

In the EU there is a shift in wheat use to ethanol production encouraging expanded wheat production. In the EU, ethanol production goes up by 3.42%, ethanol use goes up by 2.48%, DDGS production increases by 4.58%: 39 % of the extra wheat comes from expanded production of wheat, 35% from the reduction of wheat used for feed, 17% from lower food consumption of wheat and 9% from less exports. For a production increase of 42%, only 5% comes from yield increases and 95% comes from an increase in area, even with the price sensitivity of yield to changes in prices. The EU meat and dairy production decrease for beef, pork, poultry, dairy, since the sector loses competitiveness. The price of these products went up. The magnitudes are small, since the increase in wheat demand was 2 to 3%. The production of meat and dairy in the US and Brazil goes up.

There is an adverse impact on the oilseeds complex: there is reduced use of rapeseed oil as feedstock for biodiesel production and reduced area in favour of grains, as wheat is now more profitable. There is also reduced use of meal because wheat, representing 45% of the feed cost of livestock production, has become too expensive. There is a substitution of soy meal with DDGS which are produced in higher amounts. There are adverse impacts on animal-meat sector: lower animal production due to higher cost of production with wheat a dominant feed ingredient, higher imports and reduced exports.

United States

In the US there is a shift into wheat production and exports because the EU exports less wheat, which is used for ethanol. The impacts on oilseeds are mixed. There is reduced area in favour of grains, reduced exports of oilseeds because the EU loses competitiveness in meat favouring US due to higher production costs in EU. The US increases production of meat products, therefore the use of soy meal increases. In the animal-meat sector there are lower feed costs with lower price of soy meal, higher production and higher exports.

Market Outcome of High EU Rapeseed Oil Biodiesel

The impact of rapeseed is different. In the EU, there is an increase in rapeseed oil, an increase in import of rapeseed and rapeseed oil and an increase in production of rapeseed meal, therefore lowering the prices of meal. The livestock sector in the EU will benefit, since it gains competitiveness. The biofuel production is increased by 2.36%, the use of biofuel increases by 2.34% instead of 5% due to demand adjustments. This rapeseed oil comes from 31% increased production, 11% reduction of food use and a 57% increase in imports of rapeseed oil.

There is an increase in US production and an increase in exports; there are reduced exports in oilseed since in US the EU loses competitiveness in meat favouring the US. Rapeseed production goes up by 0.59%, the crush goes up by 0.28% and the import by 2.87% to produce more rapeseed oil in the EU. There is an increase in production, in feed use and net trade decline of rapeseed meal.

FAPRI-CARD Analysis

Jacinto F. Fabiosa

IOWA STATE UNIVERSITY

Presentation Outline

- FAPRI-CARD Modeling System
  - FAPRI background
  - General model background
  - Biofuel model background
- Market Impact Analysis
  - Scenario 1 – EU High Wheat Ethanol Use
  - Scenario 2 – EU High Rapeseed Oil Biodiesel Use

IOWA STATE UNIVERSITY

Center for Agricultural and Rural Development

- Vision - Leadership in economic analysis for agricultural, food, and environmental policy
- Organization
  - Divisions
    - Food and Nutrition Policy
    - Resource and Environmental Policy
    - Trade and Agricultural Policy
    - Agricultural Risk Management Policy
    - Science and Technology Policy
  - Affiliated Institutes
    - Food and Agricultural Policy Research Institute
    - Midwest Agribusiness Trade Reseach Center

IOWA STATE UNIVERSITY

FAPRI Mandate

- Established in 1984 by a grant from the U.S. Congress with the following objectives.
  - To prepare baseline projections for the U.S. agricultural sector and international commodity markets
  - To examine the major commodity markets and analyze alternative policies and external factors for implications on production, utilization, farm and retail prices, farm income, trade, and government costs
  - To aid development of effective risk management tools for crop and livestock producers, and to analyze how government policy affects risk management strategies

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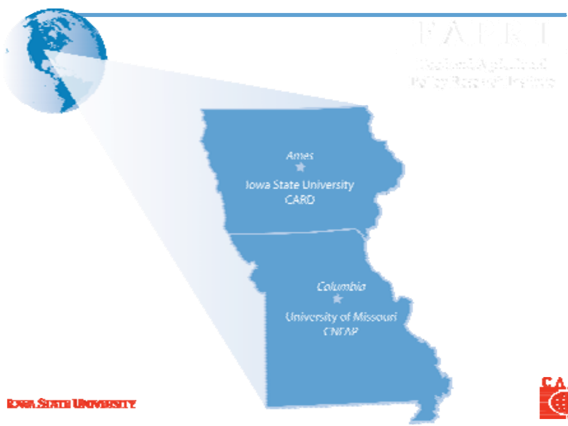
FAPRI Consortium



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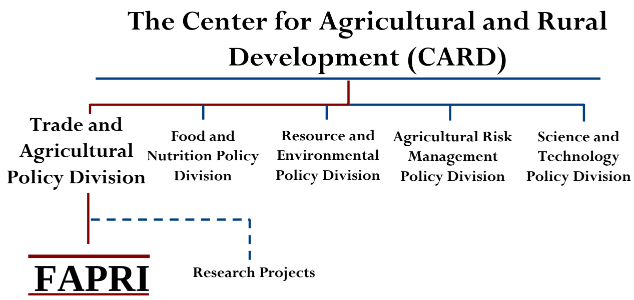
Organization of FAPRI at CARD



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- Fengxi Dong – Dairy
- Karen Kovarik – Systems Support
- Miguel Carriquiry – Oilseed & Biodiesel
- Kranti Mulik – Crop
- Ed Chavez (UA) and Seth Meyer (MO) – Rice and Cotton

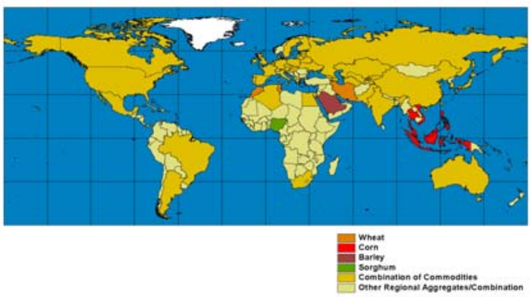
Econometric Models of Agricultural Markets

U.S. and International Models

Crops	Livestock	Dairy	Aggregate Measures	Other
Wheat	Cattle-Beef	Cheese	Government Costs	Consumer Food Exp
Corn	Swine-Pork	Butter	Cash Receipts	Value of Ag Exports
Barley	Poultry	Non-Fat Dry	Production Exp.	Federal Crop Insurance
Sorghum	Turkey	Milk	Farm Income	Biofuel
Soybeans	Eggs			
Rice				
Cotton				
Sugar				
Biomass				

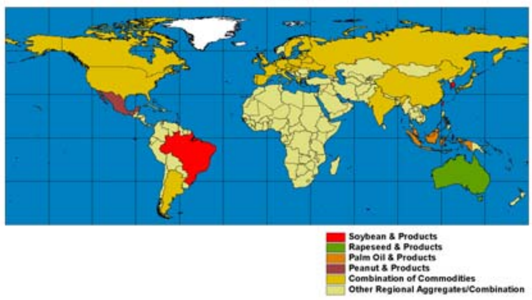
Country Coverage by Commodity

Grains



Country Coverage by Commodity

Oilseeds



Country Coverage by Commodity

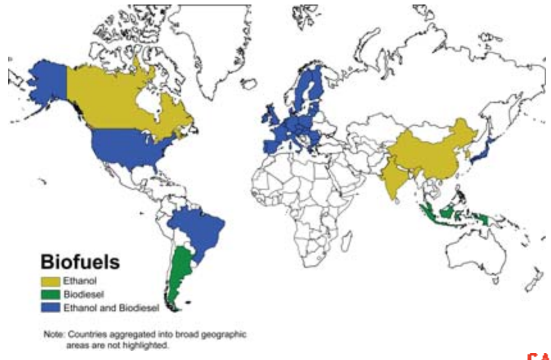
Livestock

Country Coverage by Commodity

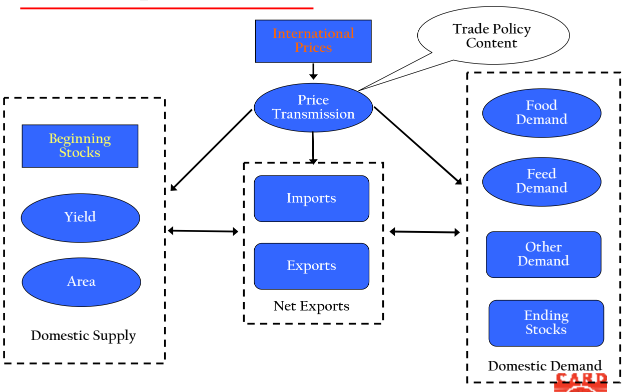
Dairy

Country Coverage by Commodity

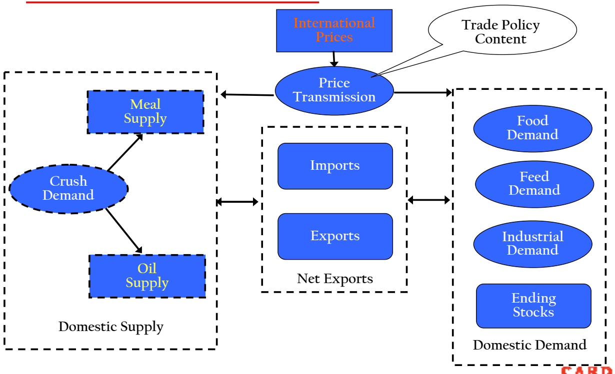
Country Coverage by Commodity



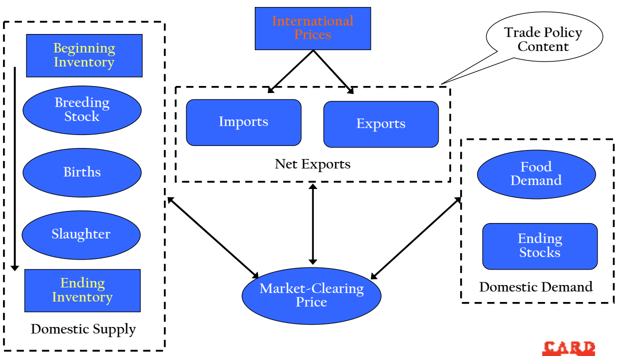
Basic Crop Sector Model



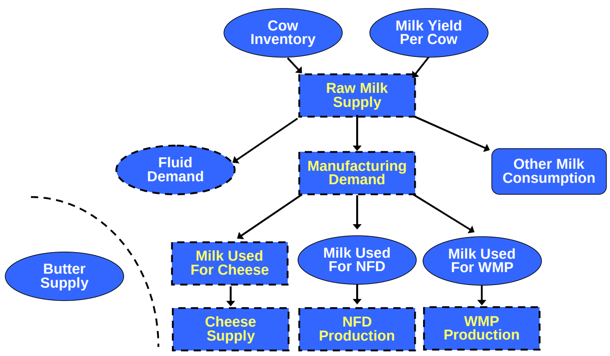
Derived Product Model: Oilseeds



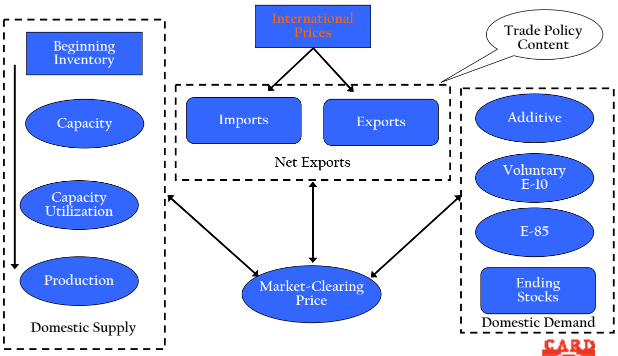
Basic Livestock Sector Model



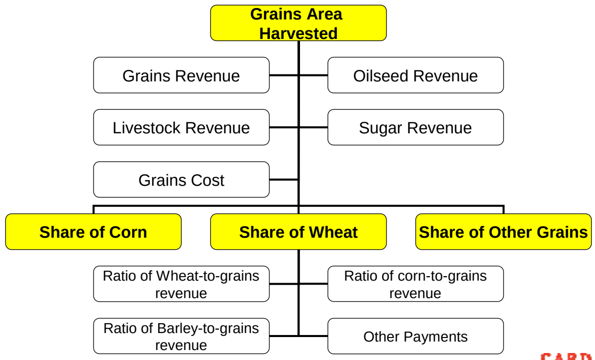
Dairy Product Supply



Basic Biofuel Sector Model

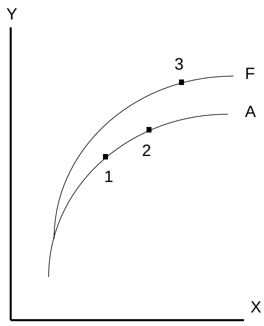


Land Allocation Structure in the EU



Yield Specification in the EU

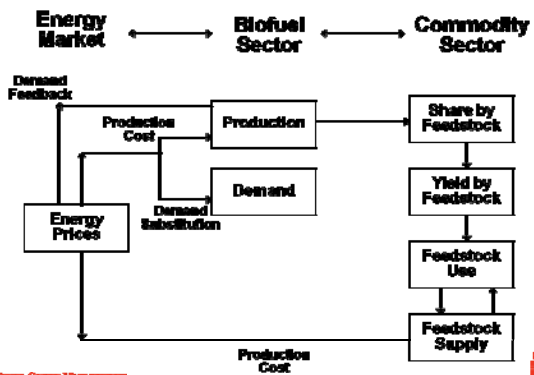
- Intensification
  - Allocative efficiency adjustment (short-run 0.013)
    - Current revenue-cost ratio
  - Technical efficiency adjustment (long-run 0.061)
    - Moving average revenue-cost ratio
- Extensification
  - Yield drag with area expansion (-0.023)



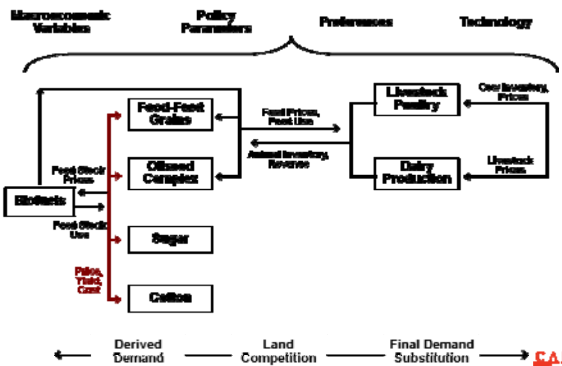
DDGS Specification

- Determining Variables
  - Adoption
    - 0.59, 0.46, 0.21, 1.00
  - Maximum Inclusion Rate
    - 50, 25, 25, 30
  - Displacement Rate
    - (1.196, 0) and (0.731, 0.633)
- Efficiency gains impact
  - Gain in ruminants
  - No gain in monogastrics
- Model Impact
  - Cost adjustment
  - Substitution of feedgrains
  - Substitution of oilmeals

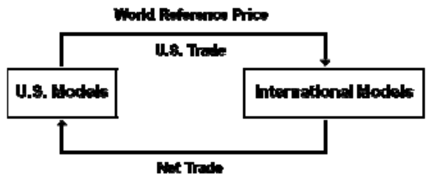
Energy-Bifuel-Commodity Market Integration



Model Interactions



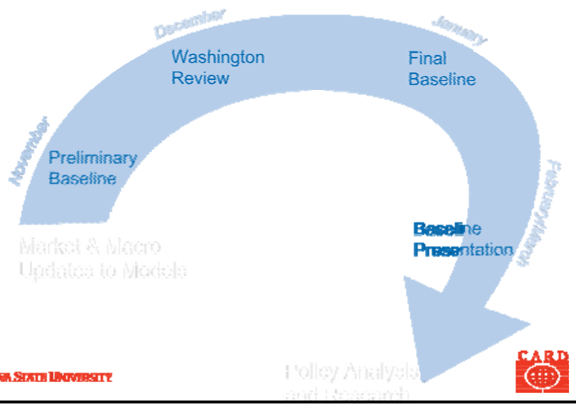
Model Solution



Exceptions

1. Dairy (Australian)
2. Ethanol (Brazil)
3. Biodiesel (Europe)
4. Rice (Thailand)
5. Barley (Canada)

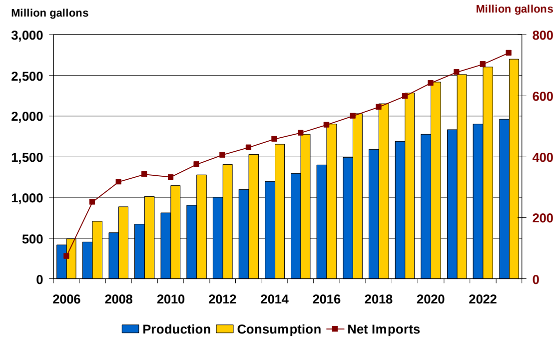
Baseline Process



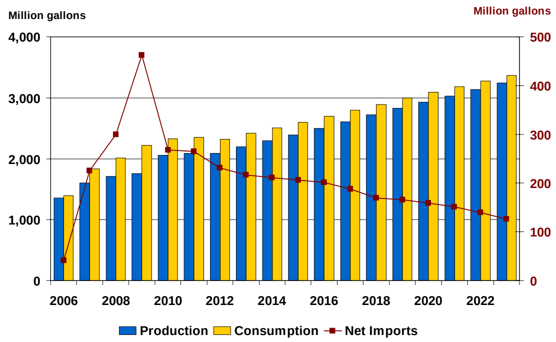
Scenarios

- Scenario 1 – High Wheat Ethanol Use in the EU
  - 5% increase in EU ethanol use
  - Supply adjustment only from domestic production
    - Trade is fixed at baseline level
    - Stock is fixed at baseline level
  - Feedstock only from wheat
    - Use of all other feedstocks fixed at baseline level
- Scenario 2 – High Rapeseed Oil Biodiesel Use in the EU
  - 5% increase in EU biodiesel use
  - Supply adjustment only from domestic production
    - Trade is fixed at baseline level
    - Stock is fixed at baseline level
  - Feedstock only from rapeseed oil
    - Use of all other feedstocks fixed at baseline level

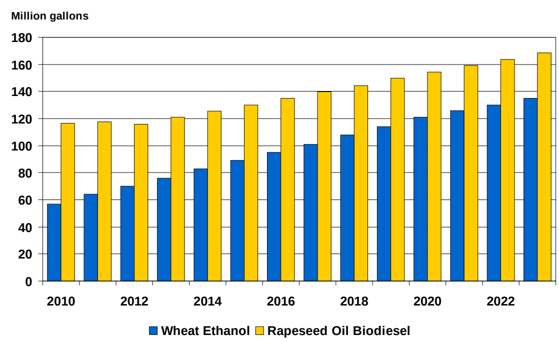
EU Ethanol Baseline



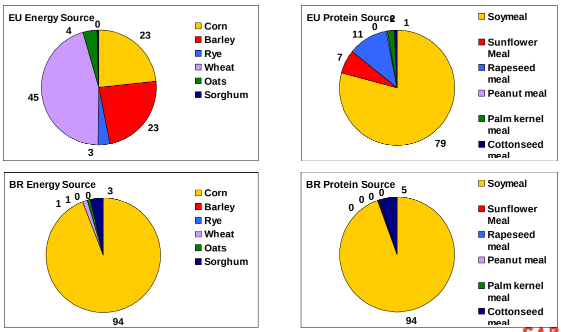
EU Biodiesel Baseline



EU Biofuel Shock: 5% Increase in Use



EU and Brazil Livestock Feed Ration



Market Outcomes of High EU Wheat Ethanol

European Union

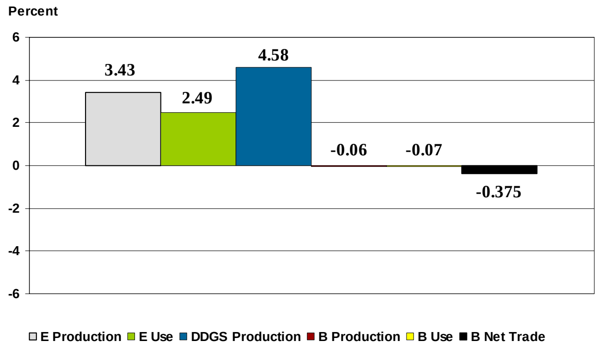
- Shift in wheat use to ethanol production encouraging expanded production.
- Adverse impacts on oilseeds complex
  - Reduced area in favor of grains
  - Reduced use (rapeseed oil) as feedstocks for biodiesel production
  - Reduced use of meal
    - Lower animal production
    - Substitution of meal with DDGS
  - Lower soymeal imports
- Adverse impacts on animal-meat sector
  - Higher cost of production with wheat a dominant feed ingredient
  - Lower production, higher imports, reduced exports

Market Outcome of High EU Wheat Ethanol

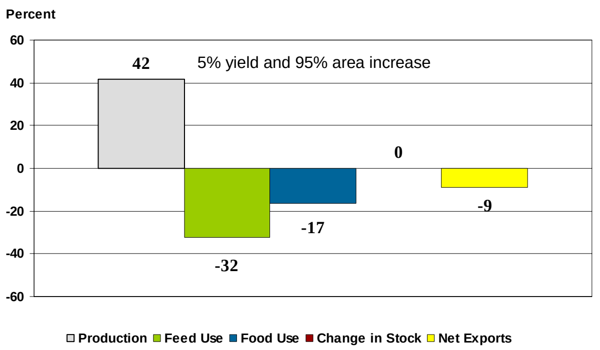
US

- Shift into wheat production and exports
- Impacts on oilseeds complex
  - Reduced area in favor of grains
  - Reduced exports
  - Increased use of meal
    - Higher animal production
- Impacts on animal-meat sector
  - Lower feed cost with lower price of soymeal
  - Higher production
  - Higher exports

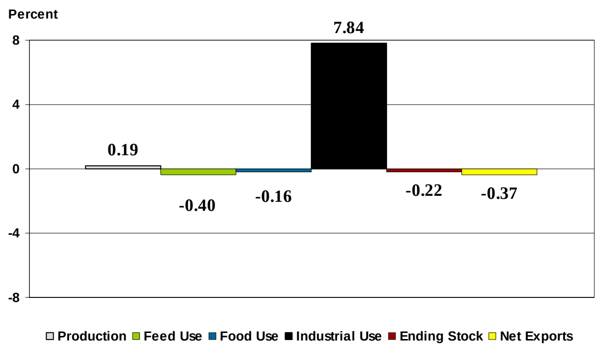
Impact on EU Biofuel Sector SI



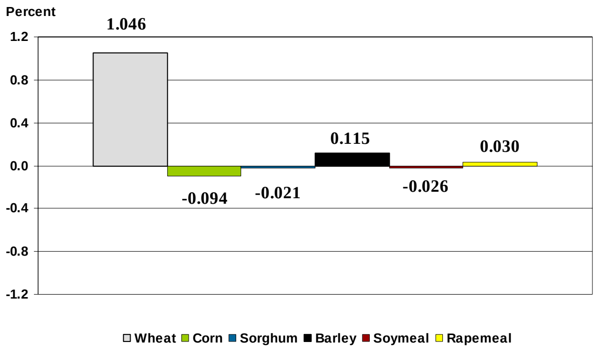
Sources of EU wheat ethanol feedstock increase



Impact on the EU wheat sector

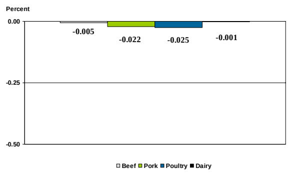


Impact on EU grains and oilseed prices

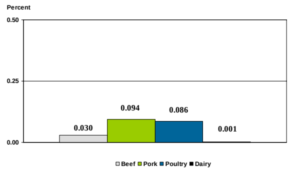


Impact on EU meat and dairy sector

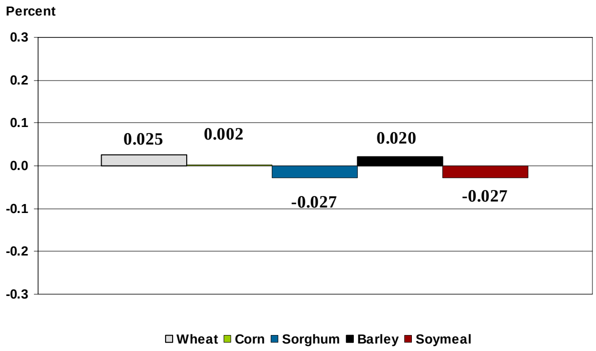
Production



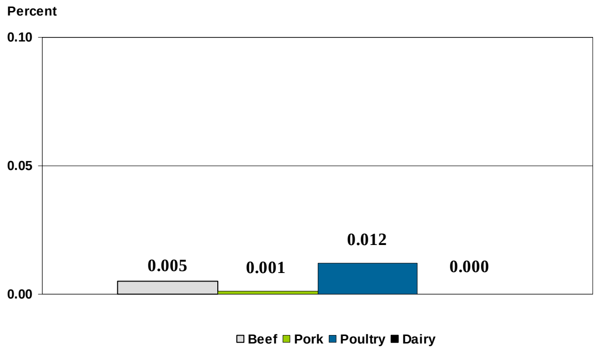
Prices



Impact on US grains and oilseed prices



Impact on US meat and dairy production



Market Outcomes of High EU Rapeseed Oil Biodiesel

European Union

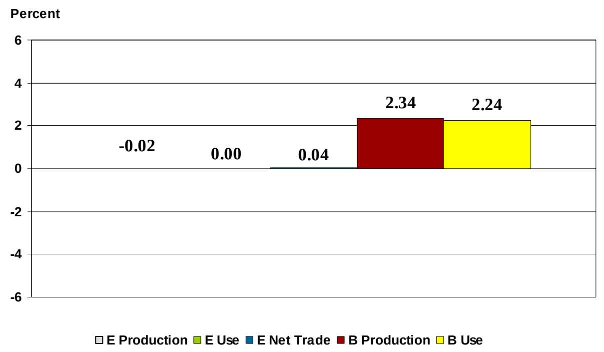
- Impacts on oilseeds complex
  - Shift in rapeseed oil use to biodiesel production encouraging expanded production
  - Increase imports of rapeseed, rapeseed oil.
  - Increased production of rapeseed meal, lower prices
- Impacts on animal-meat sector
  - Lower cost of production
  - Higher production, lower imports, reduced pork exports
- Impacts on grains
  - Reduced area in favor of oilseeds
  - Higher use of grains for feeds with higher animal production
  - Reduced exports

Market Outcome of High EU Rapeseed Oil Biodiesel

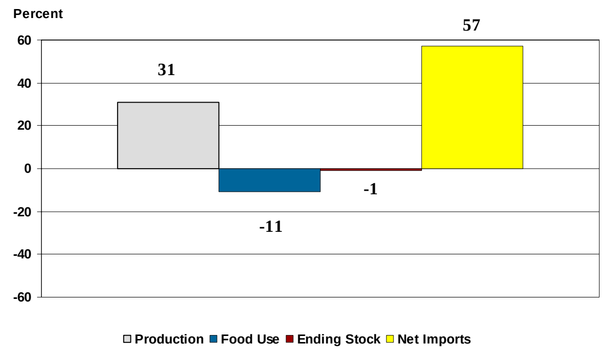
US

- Impacts on oilseeds complex
  - Soy Oil
    - Higher exports and prices
  - Soy Meal
    - Lower exports and prices
  - Soybean
    - Lower prices (dominant soymeal effect) and area
- Impacts on grains
  - Higher exports, prices, and area
- Impacts on animal-meat sector
  - Lower feed cost with lower price of soymeal
  - Higher production
  - Higher exports

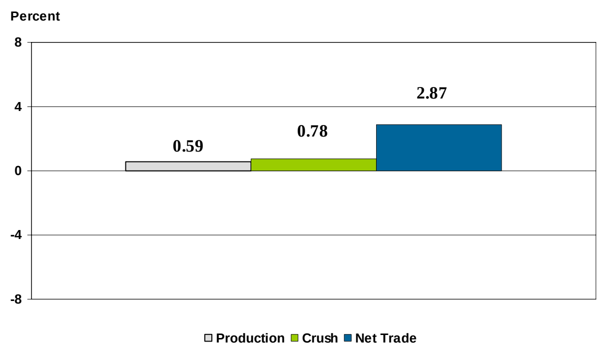
Impact on EU Biofuel Sector S2



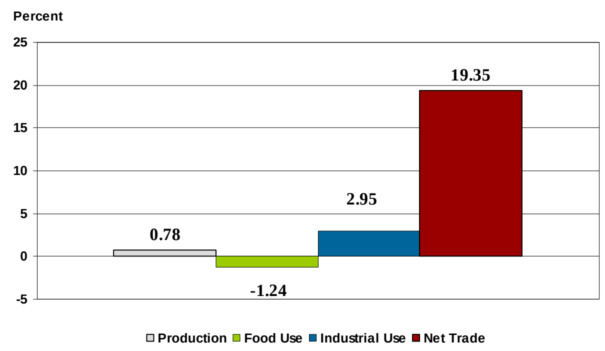
Sources of EU rapeseed oil biodiesel feedstock increase



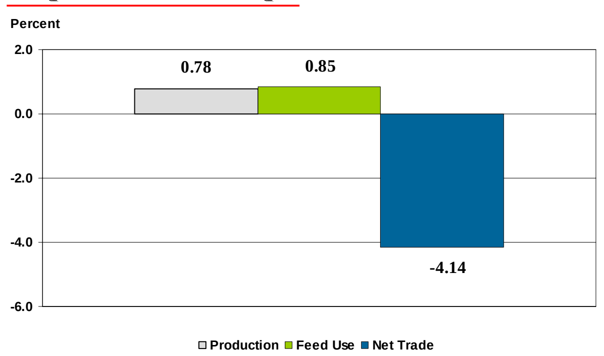
Impact on the EU rapeseed sector S2



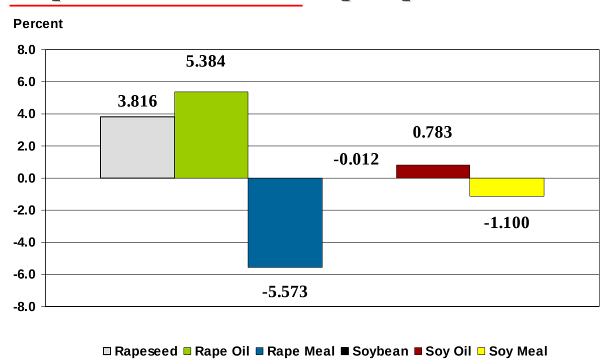
Impact on the EU rapeseed oil sector S2



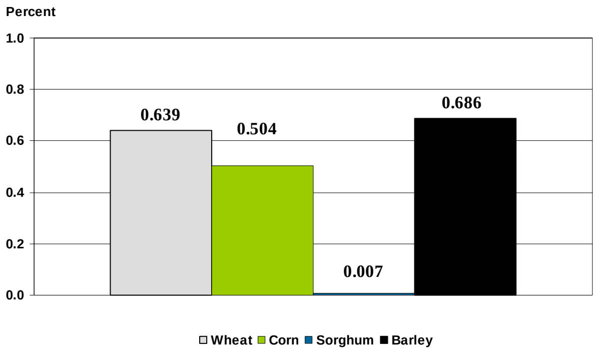
Impact on the EU rapeseed meal sector S2



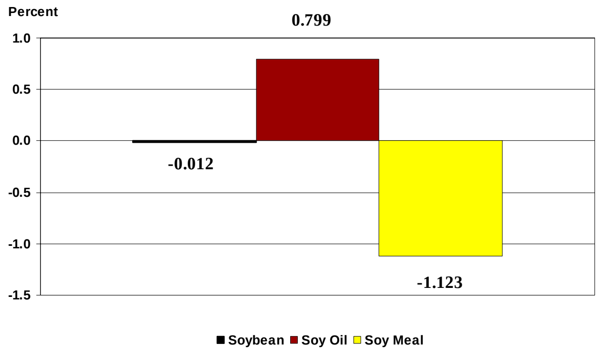
Impact on EU oilseed complex prices S2



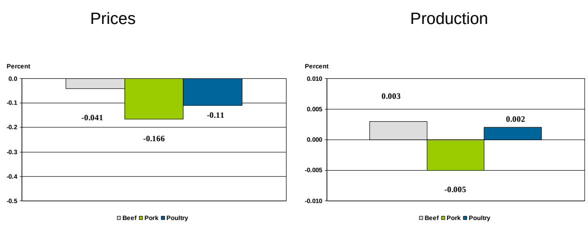
Impact on EU grains prices S2



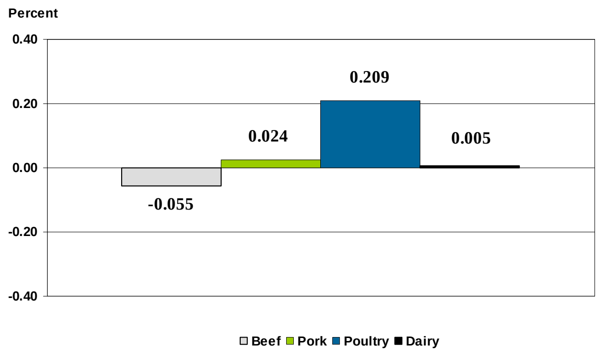
Impact on US soybean complex prices S2



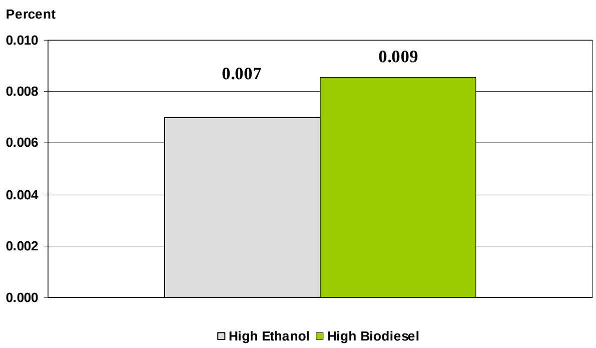
Impact on the EU meat sector S2



Impact on US meat and dairy production S2



Total land use impact



Thank You!

7. Carbon Implications of High Biofuel Use in the European Union (Jerome Dumortier - Iowa State University - FAPRI)[8]

The presentation showed the GHG emissions from the CARD agricultural simulation model used to calculate the effects of land dynamics on the carbon pool.

Questions raised by the EU

The model aimed to answer the following questions:

1) What are the consequences for carbon release or forgone carbon sequestration made from LUC emissions from conversion of different land-use types?

2) Which types of lands will come into agricultural production?

3) What proportion of LUC comes from different regions and ecosystems?

CARD Agricultural Outlook Model

CARD is a Partial Equilibrium Agricultural Model covering 35 countries/regions, 13 crops, and 3 major livestock categories. The area calculation is provided by the CARD Agricultural Outlook Model. Greenhouse Gas estimation from the Agriculture Simulation Model (GreenAgSiM) is an extension of the CARD Agricultural Model. What is important for GreenAgSiM are the area planted/harvested, livestock (number of heads) and the yields. The GreenAgSiM model is based on a static and proportional land allocation with no economic decision about land conversion. Results show that the model is very sensitive to parameters, such as yield.

GreenAgSiM Model

GreenAgSiM has two components: the agricultural production component and the land-use change component. The model accounts for greenhouse gases from the following sources: Agricultural Production and Land-Use Change. The agricultural production part covers enteric fermentation, manure management and agricultural soil management.

Previous runs of the GreenAgSiM Model showed large differences in emissions for very small changes in assumptions. The effect on emissions from changes of land use is much more substantial than the emissions from agricultural productions.

Data Requirements

Inputs from CARD Agricultural Outlook Model for LUC are area by crop and country. GreenAgSiM is an accounting model for carbon emissions. The economic decision of the land owner for various land use changes options is not included in the model at the moment.

GreenAgSiM includes 518 spatial units *i.e*. 50 states in the U.S., 27 countries in the EU, 23 states in Argentina, sub-national divisions for China, Russia, Indonesia and Brazil, etc. What is highly important are where the various crops are located in these countries and what types of eco-regions and ecosystems are in different regions. Land-use dynamics were assessed with Matlab®.

Disaggregation of cropland

The data provided by CARD is on a country basis: crop area by country, such as the acreage of soy in Brazil or area of corn in the EU. It is not known how these crops are spatially distributed

[8] Detailed report of the study is available on CIRCA

within the country, but this is particularly important in several countries such as Brazil, Indonesia or China. The disaggregation in GreenAgSiM is done on the basis of first administrative units in large countries. FAO Agro-Maps Database and Data from government agencies (e.g., statistical services) are also used to determine how a particular crop is distributed in a specific country. To determine the effect of agricultural expansion, it is assumed that regions which have a high proportion of agricultural activity are more likely to see a cropland expansion because the infrastructure is already in place. For example, suppose a country has two states, A and B. If the allocation of wheat area in that country is 80% in state A and 20% in state B, then an increase of 100 hectares would be allocated as 80 ha in state A and 20 ha in state B. Hence, the proportion of cropland in a particular state within a country is fixed (i.e. the coefficients are fixed over time), and smaller countries are grouped together.

The disaggregation is based on the land use for the production of a certain crop in different spatial units of a region as well as depending on different land uses, when the expansion of crop land occurs on native vegetation. This is fixed over time. Cropland for different crops was grouped together. Five land use categories are considered in the model: forest, shrub land, grassland, set-aside land, crop land for the transition over time of land use change.

Terrestrial Carbon Pool

To determine what kind of type of land there is in each unit, different databases are used: FAO Global Spatial Database of Agricultural Land-Use, GIS map of native vegetation, GIS map of global ecological zones and Soil map (FAO). The data sets and carbon stock are based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. For soil carbon (for all vegetation classes), the FAO Soil Map (20 t/ha, 40 t/ha, 80 t/ha) was used, considering medium input, full tillage and the top 30 cm of soil carbon.

Results

In the Scenario 1: **EU Wheat**, there is a large increase in land use in Brazil and in EU, where there is an increase in oats (0.121%) and wheat (0.178%). In general there is a moderate increase in crop area. Different countries, such as Brazil, are of greater interest, because it has a large carbon stock and is a major agricultural producer.

For the Scenario 2: **EU Rapeseed**, there are several countries of interest, due to the large increase in areas and large carbon pool: Brazil, India, and Other Asia.

The scenarios require 254 million litres of ethanol increase and 288 million litres of biodiesel. These lead to a difference in area harvested of 44,190 ha for ethanol and 83,966 ha for biodiesel. The CO_2 produced per litre of ethanol is 6.6 kg CO_2/l ethanol or 145 kg CO_2/ l biodiesel. Assuming an amortization of emissions over 30 years, this leads to emissions of 10 g CO_2/MJ for ethanol and 148 g CO_2/MJ for biodiesel[9].

The high emissions reported in the biodiesel scenario can be related to where the LUC occurs. In the biodiesel scenario the LUC will mainly occur in Asia, in particular India, from conversion of land with high organic content and conversion of forests. In contrast the ethanol emissions reported are half those reported by the IPCC for conversion of temperate pasture to cropland

[9] These results were updated by Jerome Dumortier of Iowa State University and differ from those shown in the presentation.

Issues

The model is based on a static and proportional land allocation with no economic decision about land conversion. Results are very sensitive to parameters, such as yield.

(Discussion) "This sort of approach implies soil carbon release is proportional to yield. Except for deserts and perhaps grasslands, there is no correlation between yields and carbon stocks. For example, peatlands (high in carbon stocks) are not particularly more productive (after draining) than other types of land."

Carbon Implications of High Biofuel Use in the European Union

Jerome Dumortier
Iowa State University

Overview

- Introduction
- CARD Agricultural Outlook Model
- Greenhouse Gases from Agricultural Simulation Model (GreenAgSiM)
  - Data
  - Model Assumptions
- Scenarios
- Results
- Discussion

Motivation for GreenAgSiM

- Fourth assessment report by the IPCC:
  - Anthropogenic greenhouse gas emissions (GHG) caused by agriculture: 13.5%
  - Anthropogenic GHG caused by forestry (including deforestation): 17.4%
- Post-2012 international climate change framework and change in U.S. climate policy
- *Science* article by Searchinger et al.
  - Importance of land-use change (LUC)

Questions raised by the EU

- What are the assumptions on carbon release or forgone carbon sequestration made in deducing LUC emissions from conversion of different land-use types?
- Which types of lands will come into agricultural production?
- Proportion of LUC from different regions and ecosystems.

CARD Agricultural Outlook Model

- CARD Agricultural Outlook Model
  - Partial equilibrium agricultural model
  - Coverage: 35 countries/regions, 13 crops, and 3 major livestock categories
  - Area planted/harvested
  - Livestock (number of heads)
  - Yield
- Greenhouse Gases from Agriculture Simulation Model (GreenAgSiM)
  - Extension of the CARD Agricultural Outlook Model

GreenAgSiM - Overview

- Accounting from greenhouse gas from the following sources:
  - Agricultural Production
    - Enteric Fermentation
    - Manure Management
    - Agricultural Soil Management
  - Land-Use Change
    - Large differences in emissions given small changes in assumption

GreenAgSiM – Data Requirement

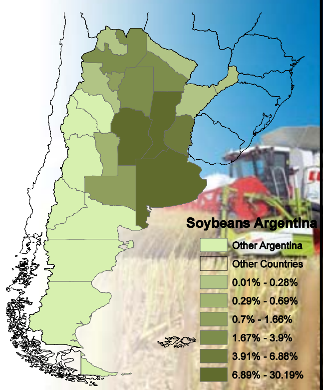
- Inputs from CARD Agricultural Outlook Model for LUC:
  - Area by crop and country
- 518 spatial units
  - i.e., 50 states in the U.S., 27 countries in the EU, 23 states in Argentina, etc.
  - Importance of spatial heterogeneity given different ecosystems
- Land-use dynamics assessed with Matlab®

Disaggregation of cropland

- Crop area by country from CARD Agricultural Outlook Model
- Disaggregation in GreenAgSiM:
  - First administrative units in large countries
  - FAO Agro Maps Database
  - Data from government agencies, e.g., statistical services
- Fixed coefficients over time
- Grouping of smaller countries

Example: Argentina and Soybeans

State	Coefficient
Buenos Aires	30.19
Catamarca	0.28
Chaco	3.90
Cordoba	28.82
Corrientes	0.11
Entre Rios	6.88
Formosa	0.03
Jujuy	0.05
La Pampa	1.66
Misiones	0.00
Salta	3.19
San Luis	0.69
Santa Fe	19.08
Santiago del Estero	3.49
Tucuman	1.63



Tracking Idle Cropland

- Idle Cropland
  - Last out – first in
  - Area in idle cropland/set-aside
  - Years in carbon sequestration

Land	Year 1	Year 2	Year 3	Year 4	Year 5
Cropland	50	55	45	40	50
Forest	100	95	95	95	95
Idle Land (1 year)	0	0	10	5	0
Idle Land (2 years)	0	0	0	10	5

Land Transition Matrix

From \to	Forest	Shrub	Grass-land	Set-aside	Crop-land
Forest	Yes/○	No	No	No	Yes/-
Shrub	No	Yes/○	No	No	Yes/-
Grassland	No	No	Yes/○	No	Yes/-
Set-aside	No	No	No	Yes/+	Yes/-
Cropland	No	No	No	Yes/+	Yes/○

Terrestrial Carbon Pool

- Components:
  - FAO Global Spatial Database of Agricultural Land-Use
  - GIS map of native vegetation
  - GIS map of global ecological zones
  - Soil map (FAO)
- Data source:
  - 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Forest Carbon Sequestration - I

- Carbon in standing biomass
- Forgone carbon sequestration
- Problem:
  - Age distribution of forest stand?
- Solution:
  - Old forest:
    - High standing biomass and low carbon sequestration
  - Young forest:
    - Low standing biomass and high carbon sequestration

Forest Carbon Sequestration - II

- Assumptions:
  - Age distribution (below and above 20 years):
    - 50/50
  - Sequestration period of 20 years
  - No deforestation in the U.S. and the EU
- Soil carbon (for all vegetation classes):
  - FAO Soil Map (20 t/ha, 40 t/ha, 80 t/ha)
  - Medium input and full tillage
  - Top 30 cm of soil carbon

Scenario 1: EU Wheat

- Countries of interest: Brazil and EU
  - Brazil: increase in cotton
  - EU: increase in oats (0.121%) and wheat (0.178%)
- In general:
  - Moderate increase in crop area
  - Noteworthy:
    - Large carbon stock in Brazil
    - Brazil as a major agricultural producer

Scenario 2: EU Rapeseed

- Countries of interest: Brazil, India, and Other Asia

	Rapeseed	Sunflower
European Union	0.588%	0.212%
India	0.808%	
Other Asia	0.728%	0.162%

Results

Scenario	EU Wheat	EU Rapeseed
Ethanol increase in million liters	254	288
Difference in Area Harvested (ha)	60879	83966
Difference in Emissions (in million tons of CO2 - equivalents)	5.03	66.95
CO_2 produced per liter of ethanol (in kg)	19.81	232.47
Energy Content (MJ/liter)	21.2	32.7
Emissions in grams of CO_2 per MJ (over 30 years)	31.15	236.97

Issues

- Static and proportional land allocation
  - No economic decision about land conversion
- Results are very sensitive to parameters
  - Yield
- Pasture
  - Expansion/Contraction
  - Livestock intensification/extensification
  - Reserve pool of cropland

8. The effects of increased demand for biofuel feedstocks on the world agricultural markets with partial equilibrium IMPACT model (Siwa Msangi - International Food Policy Research Institute (IFPRI) [10]

The presentation aimed at explaining the methodology used to calculate yield changes due to marginal impacts, resulting results on area changes and discussing further extensions which are underway on the IMPACT model.

Two main factors responsible for agricultural growth were identified: area expansion and intensification of land. Indeed, these are the two 'margins' along which expansion or substitutions can take place – either through more extensive displacement of the agricultural landscape or more intensive use of inputs. There might be constraints to one of these factors (e.g. limited availability of good quality land), which means production growth has to rely more on the intensification – this is illustrated by the land availability in Asia vs. Africa in Figure 3.

Either of these options have implications for the environment – loss of natural cover or forested area versus increased load of pesticides, fertilizer and water consumption.

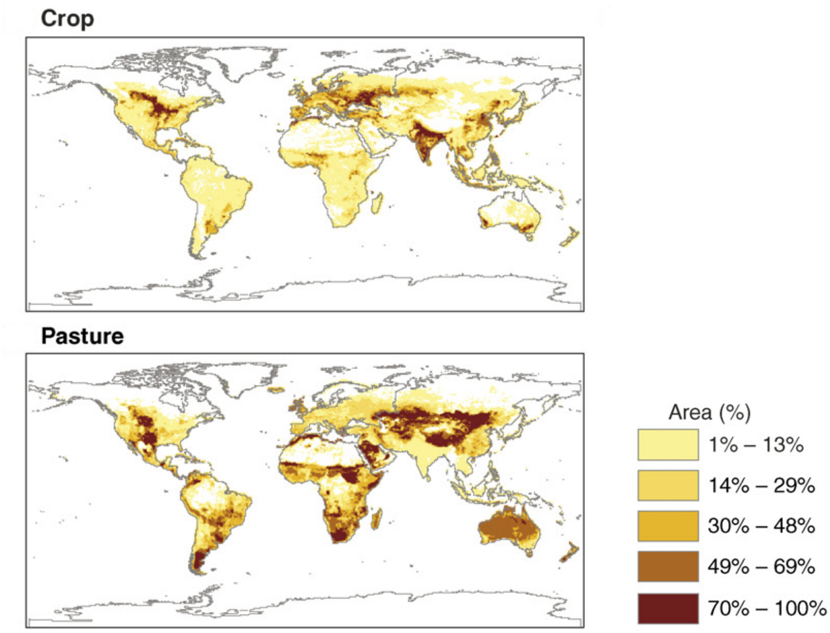


Figure 3 Global Land Areas from HYDE-3 LU data

These issues are, of course, relevant to the discussion on the sustainability of biofuels. As a result, IFPRI has been looking at these issues with a view to assessing the role of biofuels among other major 'drivers of change' in global food systems and to highlight issues that countries should pay attention to. In particular, two issues stand out:

- The tradeoffs or synergies of land competition between fuel and food (Food-vs.-fuel). Do biofuels 'crowd out' land needed for food production or can they actually 'crowd in' investments that can make a difference for the whole sector?

[10] Calculations sheets only are available on CIRCA

- The question of the 'indirect impacts' of biofuels, meaning the changes that the growth of biofuels in the US and EU induce in the rest of the world – mostly in terms of land use, which also raises concern about food security impacts.

The three key questions to answer are:

- What is the extent of crop area changes due to increased biofuel feedstock demand for key commodities?
- How much of the additional demand is met by yield change, versus area change?
- How much of the yield change is increased yield on (pre-) existing area and how much is due to yields achieved on new area?

None of these questions have yet been fully resolved. However, in order to answer these questions, the IMPACT model was developed (a partial equilibrium model for agriculture), with the following typical IMPACT-driven scenarios:

- Looking at the implications of socio-economic growth (income, population) on food/feed demand and other indicators mentioned above.
- Looking at the implications of adverse environmental conditions (water scarcity and climate change effects) on crop yield – and production
- Fairly simple trade liberalization or protection scenarios (with phased changes over time).
- Looking at implications of improved socio-economic conditions (access to clean water, secondary schooling for girls, rural roads etc,) on child malnutrition.

Figure 4 shows how the IMPACT model works. Different scenarios are created alongside the main shock of (exogenous) changes in demand for biofuel feedstocks (e.g. area growth and yield growth, population and GDP growth). The model then (endogenously) determines the effects of that shock for each scenario on the area and yield changes in different regions of the world, not only for those feedstock areas and yields.

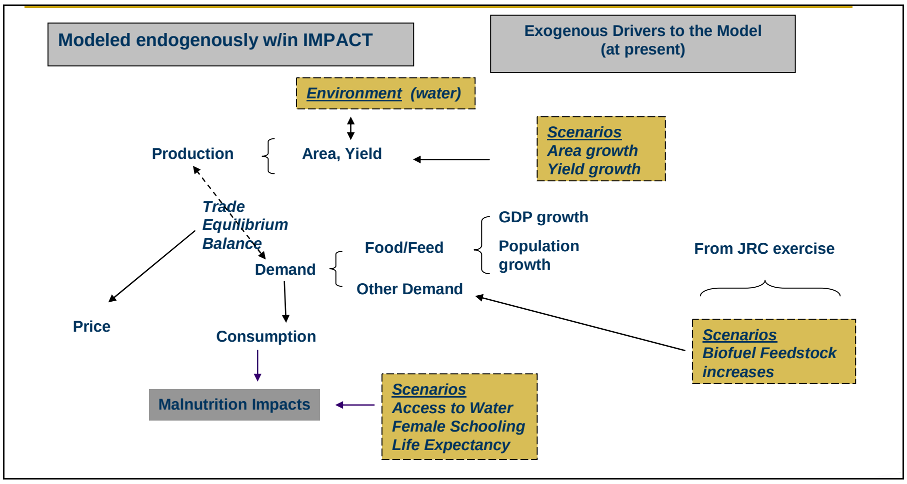


Figure 4 Modelling biofuel feedstock shocks

The model components which matter to the analysis are:

- Disaggregation between irrigated and rainfed area – one can increase yield by expanding more on irrigated versus rainfed
- Sub-national disaggregation of crop area -- gives a better idea of where production changes occur (especially for big regions – US, China, India, Brazil). There are 281 spatial units, but more work needs to be done here.
- Price response for yield as well as for area – allows for yields to increase due to price effects, as well as due to irrigation and technological change (however technological change is not endogenized to price, at the moment)

The increase in production needed to meet demand can come from either additional yield on existing land or achieving a sufficient level of production on new land. In terms of the marginal calculations made in order to determine where new production will come from, the following equation was used:

$\Delta Q^{total} = \Delta y^{old} \cdot A^{old} + y^{new} \cdot \Delta A^{new}$, where

- ΔQ^{total} = change in production,
- A^{old} = area previously cultivated
- Δy^{old} = change in yield on harvested area previously cultivated
- y^{new} = average yield on additional land going into production
- ΔA^{new} = additional land going into production

<u>Introduced shocks to feedstock demands</u>

They focused on the key feedstock crops in which IMPACT has better disaggregation:

- Cereals: maize, wheat, other grains
- Roots & Tubers: cassava
- Sugar crops: sugarcane and sugar beet

The ‘oils’ category is undergoing further disaggregation at present to 6 categories, that better separate temperate seed oils from tropical oil plantation products – with soybean and meal/oil on its own. However, results for this are not very compelling, but will be doing more on this during early 2010.

<u>Disaggregating ‘old’ from ‘new’ land</u>

Given that they do not have a spatially explicit representation of land use in IMPACT, at present land is treated as homogenous in quality (no distinction between good quality and poor quality land) and yield is treated in terms of its average level over all harvested area – with no explicit disaggregation between yields on ‘good’ and ‘poor’ land.

The results of the simulations were disaggregated in an *ex post* fashion to infer the distinction between yields that are achievable on ‘old’ and ‘new’ land. However, a ratio of “1” when calculating ratio of “new” to “old” yield was found.

Summary of results

For the developing regions, which start out with lower yield levels, the increase in yields, due to price change, is likely to be bigger. Yield share is slightly larger on irrigated land, but not always. Russia, Former Soviet Union (FSU), West Asia – North Africa (WANA) respond more strongly in wheat area to additional feedstock demands. Brazil and Sub-Saharan Africa (SS Africa) respond more strongly in maize area to additional feedstock demands. The yield response of sugar crops seems to be quite strong, across regions – but this will need to be looked at further.

Continuing work

Some on-going efforts to improve the way in which biofuels are modelled in IMPACT, particularly:

- Better disaggregation of oil commodities (at least 6), to distinguish between temperate seed oils and tropical tree oils – plus soybean and its products
- Continuing improvement to the modelling of biofuels to account for by-products in a better way, differences between molasses and cane juice-based ethanol production, better data, etc.
- Efforts to build a better land use module will allow us to address the question of indirect effects in a more detailed way, with land heterogeneity.
- Better disaggregation of livestock (e.g. important to distinguish intensive and extensive systems in Africa), including grassland and spatial interaction.

Discussion

Some questions were raised during the presentation, which are summarized here below.

How is the intensity of land use (e.g. multi-cropping, fallow land) treated in the model?

Crop intensity is endogenous. Land-use intensity in the model is based on expert assessment in terms of identifying which systems intensify and which don't.

What is the difference in yields in new land and yields in old land? Which references were used?

The parameters used in the model result in no (significant) difference between yields on new land and on old land.

The changes in both total land area and yield are known. However, it is not distinguishable in the model the specific yield of new and old areas (nor is the quality difference of land). Ratio close to 1 = close to average. It would be very useful to have a very spatially-explicit model.

What treatment does the model give to by-products?

The order of magnitude of the total ILUC effect from the scenario of increasing demand of EU wheat by one tonne was calculated at 0.42 ha/t EU wheat (of both irrigated and rainfed land). In comparing this to the ha/Mtoe of ethanol, one needs to bear in mind that about 3 tonnes of wheat are needed to make 1 toe of ethanol, but about 1/3 of that is recovered by DDGS substituting animal feed (in the US ethanol scenario at least). Thus the figure corresponds roughly to 0.8 ha/toe ethanol.

Are yields exogenous or endogenous?

Table 9 below shows the share of production increase met by yield growth. As there is no explicit production function (related equations are available from author), yield is not linked to the use of inputs (e.g. fertilizer and labour not accounted for). No disaggregation was made between area and yield changes as a response to price changes, only change in total quantity. The total quantity change (implicit aggregated area and yield changes) is elasticity driven. Price elasticity of yield is derived from various studies plus expert judgments.

Furthermore, there is no interaction between different land uses (competition). Yield growth explains 30-40%, sometimes as much as 50% of the total additional production.

Impact of feedstock demand on area

Table 8: Change in Kha per ton of feedstock

	US Maize		US Wheat		EU Wheat		EU Other Grains		EU Sugarbeet		Brazil Sugarcane	
	Irrigated	**Rainfed**	**Irrigated**	**Rainfed**	**Irrigated**	**Rainfed**	**Irrigated**	**Rainfed**	**Irrigated**	**Rainfed**	**Irrigated**	**Rainfed**
USA	0.0015	0.0124	0.0003	0.0080	0.0003	0.0080	0.0001	0.0025	0.0000	0.0001	0.0000	0.0000
Rest of NAFTA	0.0011	0.0014	0.0002	0.0047	0.0002	0.0047	0.0005	0.0072	0.0000	0.0000	0.0000	0.0000
EU 27	0.0008	0.0031	0.0026	0.0089	0.0008	0.0031	0.0026	0.0089	0.0001	0.0002	0.0000	0.0000
Russia	0.0001	0.0003	0.0004	**0.0063**	0.0004	**0.0063**	0.0005	0.0131	0.0000	0.0001		
C. Asia & FSU	0.0002	0.0007	**0.0018**	**0.0044**	**0.0018**	**0.0044**	0.0009	0.0090	0.0000	0.0001		
Brazil		**0.0038**	0.0000	0.0012	0.0000	0.0012		0.0008			0.0001	0.0006
Rest of LAC	0.0006	0.0024	0.0002	0.0031	0.0002	0.0031	0.0008	0.0012	0.0000	0.0000	0.0001	0.0001
WANA	0.0005	0.0003	**0.0036**	**0.0041**	**0.0036**	**0.0041**	0.0035	0.0118	0.0000	0.0000	0.0000	0.0000
SS Africa (All)	0.0004	**0.0097**	0.0002	0.0010	0.0002	0.0010	0.0001	0.0017			0.0000	0.0001
E. SS Africa	0.0001	0.0021	0.0000	0.0008	0.0000	0.0008	0.0000	0.0015			0.0000	0.0000
W & C SSA	0.0000	0.0038	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000	0.0000

Table 9: Share of production increase met by yield growth

	US Maize		US Wheat		EU Wheat		EU Other Grains		EU Sugarbeet		Brazil Sugarcane	
	Irrigated	**Rainfed**	**Irrigated**	**Rainfed**	**Irrigated**	**Rainfed**	**Irrigated**	**Rainfed**	**Irrigated**	**Rainfed**	**Irrigated**	**Rainfed**
USA	0.39	0.39	0.36	0.36	0.36	0.36	0.30	0.30	0.64	0.64	0.65	0.65
Rest of NAFTA	0.51	0.53	0.44	0.36	0.44	0.36	0.31	0.31	0.66	0.66	0.76	0.76
EU 27	0.42	0.43	0.33	0.33	0.33	0.33	0.23	0.24	0.63	0.63	0.65	0.65
Russia	0.39	0.39	0.43	0.43	0.43	0.43	0.33	0.33	0.66	0.66		
C. Asia & FSU	0.41	0.40	0.50	0.47	0.50	0.47	0.36	0.34	0.66	0.67		
Brazil		0.46	0.36	0.36	0.36	0.36		0.28			0.70	0.70
Rest of LAC	0.37	0.34	0.44	0.28	0.44	0.28	0.30	0.23	0.79	0.79	0.77	0.76
WANA	0.41	0.35	0.48	0.48	0.48	0.48	0.29	0.30	0.72	0.72	0.71	0.71
SS Africa (All)	0.48	0.47	0.40	0.46	0.40	0.46	0.34	0.40			0.74	0.76
E. SS Africa	0.52	0.56	0.48	0.49	0.48	0.49	0.36	0.41			0.75	0.75
W & C SSA	0.54	0.41	0.42	0.42	0.42	0.42	0.40	0.40			0.75	0.78

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The effects of increased biofuel feedstock demand on world agricultural markets: Analysis with the IMPACT model

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Workshop on "Effects of increased demand for biofuel feedstocks on world agricultural markets and areas"
10-11 February 2010, JRC, Ispra, Italy

During the course of this presentation….

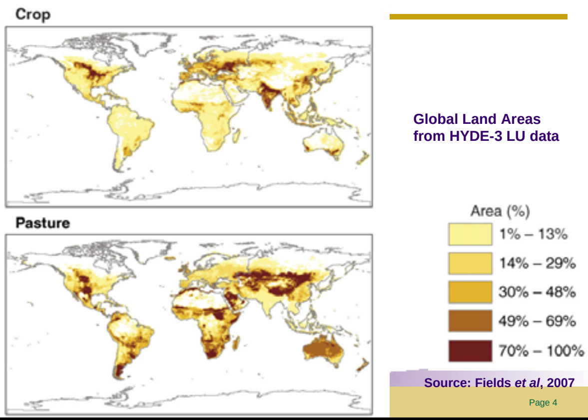
We hope to:

- **Explain the methodology we used for carrying out the calculations of yield changes due to marginal impacts**
- **Summarize results on area and yield change due to biofuel feedstock shocks**
- **Discuss further extensions which are underway on the IMPACT model**
- **Concluding thoughts**

Ag. Growth: Extensification vs. Intensification

- There are two 'margins' along which expansion or substitutions can take place – either more extensive displacement of the agricultural landscape or more intensive use of inputs
- There might be constraints to one of these which means production growth has to rely more the other – such as land availability in Asia vs. Africa
- Either of these options have implications for the environment – loss of natural cover or forested area versus increased load of pesticides, fertilizer and water consumption

Where is the land for agriculture?



Global Land Areas from HYDE-3 LU data

Source: Fields *et al*, 2007

Relevance to the discussion on biofuels

- IFPRI has been looking at these issues with a view to assessing the role of biofuels among other major 'drivers of change' in global food systems and to highlight issues that countries should pay attention to
- Food-vs-fuel tradeoffs – or fuel & food synergies
  - Does biofuels 'crowd out' land needed for food production or can it actually 'crowd in' investments that can make a difference for the whole sector?
- Question of 'indirect impacts' of biofuels
  - The changes that growth of biofuels in US/EU induce in the RoW – mostly in terms of land use
  - Some concern about food security impacts too

Key questions to answer

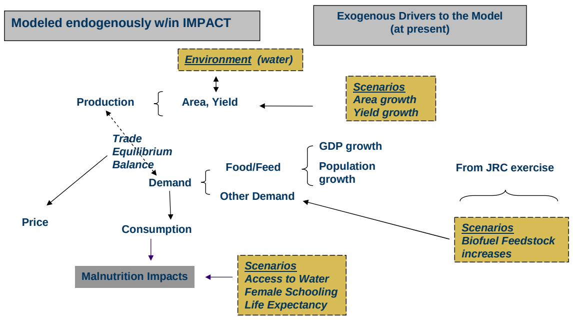
- **What is the extent of crop area changes due to increased biofuel feedstock demand for key commodities?**
- **How much of the additional demand is met by yield change, versus area change?**
- **How much of the yield change is increased yield on (pre-)existing area and how much is due to yields achieved on new area?**

The IMPACT model

Typical IMPACT-driven scenarios

- Looking at the implications of socio-economic growth (income, population) on food/feed demand and other indicators mentioned above
- Looking at the implications of adverse environmental conditions (water scarcity & CC effects) on crop yield – and production
- Fairly simple trade liberalization or protection scenarios (with phased changes over time)
- Looking at implications of improved socio-economic conditions (access to clean water, girls secondary schooling, rural roads) on child malnutrition

Modeling biofuel feedstock shocks



Model components which matter to analysis

- Disaggregation between irrigated and rainfed area – one can increase yield by expanding more on irrigated versus rainfed
- Sub-national disaggregation of crop area -- gives a better idea of where prodn changes occur (esp. for big regions – US, China, India, Brazil,)
- Price response for yield as well as for area – allows for yields to increase due to price effects, as well as due to irrigation and technological change (however technological change is not endogenized to price, at the moment)

Marginal Calculations

Where will new production come from?

The needed increase in production, to meet demand can come from additional yield on existing land or achieving a sufficient level of production on new land

$$\Delta Q^{total} = \Delta y^{old} \cdot A^{old} + y^{new} \cdot \Delta A^{new}$$

ΔQ^{total} **= change in production**

Δy^{old} **= change in yield on harvested area previously cultivated** $\left(A^{old}\right)$

y^{new} **= average yield on additional land going into prod'n** $\left(\Delta A^{new}\right)$

Introduced shocks to feedstock demands

- Focused on the key feedstock crops that IMPACT has better disaggregation
  - Cereals: maize, wheat, other grains
  - Roots & Tubers: cassava
  - Sugar crops: sugarcane and sugarbeet
- The 'oils' category undergoing further disaggregation at presented to 6 categories, that better separate temperate seed oils from tropical oil plantation products – with soybean and meal/oil on its own
  - Results for this are not very compelling, but will be doing more on this during 2010

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Disaggregating 'old' from 'new' land

- Given that we do not have a spatially explicit representation of land use in IMPACT, at present
  - Land is treated as homogenous in quality (no distinction b/w good quality and poor quality land)
  - Yield is treated in terms of its average level over all harvested area – with no explicit disaggregation between yields on 'good' and 'poor' land
- The results of the simulations were disaggregated in an *ex post* fashion to infer the distinction b/w yields that are achievable on 'old' & 'new' land
- **Pretty much ended up getting a ratio of "1" when calculating ratio of "new" to "old" yield**

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Impact of feedstock demand on area

Change in ha per ton of feedstock

	US Maize		US Wheat	
	Irrig	Rainfed	Irrig	rainfed
USA	0.0015	0.0124	0.0003	0.0080
Rest of NAFTA	0.0011	0.0014	0.0002	0.0047
EU 27	0.0008	0.0031	0.0026	0.0089
Russia	0.0001	0.0003	0.0004	0.0063
C. Asia & FSU	0.0002	0.0007	0.0018	0.0044
Brazil		0.0038	0.0000	0.0012
Rest of LAC	0.0006	0.0024	0.0002	0.0031
WANA	0.0005	0.0003	0.0036	0.0041
SS Africa (All)	0.0004	0.0097	0.0002	0.0010
E. SS Africa	0.0001	0.0021	0.0000	0.0008
W & C SSA	0.0000	0.0038	0.0000	0.0000

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Impact of feedstock demand on area

Change in ha per ton of feedstock

	EU Wheat		EU Other Grains	
	Irrig	Rainfed	Irrig	rainfed
USA	0.0003	0.0080	0.0001	0.0025
Rest of NAFTA	0.0002	0.0047	0.0005	0.0072
EU 27	0.0008	0.0031	0.0026	0.0089
Russia	0.0004	0.0063	0.0005	0.0131
C. Asia & FSU	0.0018	0.0044	0.0009	0.0090
Brazil	0.0000	0.0012		0.0008
Rest of LAC	0.0002	0.0031	0.0008	0.0012
WANA	0.0036	0.0041	0.0035	0.0118
SS Africa (All)	0.0002	0.0010	0.0001	0.0017
E. SS Africa	0.0000	0.0008	0.0000	0.0015
W & C SSA	0.0000	0.0000	0.0000	0.0000

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Impact of feedstock demand on area

Change in ha per ton of feedstock

	EU Sugarbeet		Brazil Sugarcane	
	Irrig	Rainfed	Irrig	rainfed
USA	0.0000	0.0001	0.0000	0.0000
Rest of NAFTA	0.0000	0.0000	0.0000	0.0000
EU 27	0.0001	0.0002	0.0000	0.0000
Russia	0.0000	0.0001		
C. Asia & FSU	0.0000	0.0001		
Brazil			0.0001	0.0006
Rest of LAC	0.0000	0.0000	0.0001	0.0001
WANA	0.0000	0.0000	0.0000	0.0000
SS Africa (All)			0.0000	0.0001
E. SS Africa			0.0000	0.0000
W & C SSA			0.0000	0.0000

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Share of prodn increase met by yield growth

	US Maize		US Wheat	
	Irrig	Rainfed	Irrig	rainfed
USA	0.39	0.39	0.36	0.36
Rest of NAFTA	0.51	0.53	0.44	0.36
EU 27	0.42	0.43	0.33	0.33
Russia	0.39	0.39	0.43	0.43
C. Asia & FSU	0.41	0.40	0.50	0.47
Brazil		0.46	0.36	0.36
Rest of LAC	0.37	0.34	0.44	0.28
WANA	0.41	0.35	0.48	0.48
SS Africa (All)	0.48	0.47	0.40	0.46
E. SS Africa	0.52	0.56	0.48	0.49
W & C SSA	0.54	0.41	0.42	0.42

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Share of prodn increase met by yield growth

	EU Wheat		EU Other Grains	
	Irrig	Rainfed	Irrig	rainfed
USA	0.36	0.36	0.30	0.30
Rest of NAFTA	0.44	0.36	0.31	0.31
EU 27	0.33	0.33	0.23	0.24
Russia	0.43	0.43	0.33	0.33
C. Asia & FSU	0.50	0.47	0.36	0.34
Brazil	0.36	0.36		0.28
Rest of LAC	0.44	0.28	0.30	0.23
WANA	0.48	0.48	0.29	0.30
SS Africa (All)	0.40	0.46	0.34	0.40
E. SS Africa	0.48	0.49	0.36	0.41
W & C SSA	0.42	0.42	0.40	0.40

Share of prodn increase met by yield growth

	EU Sugarbeet		Brazil Sugarcane	
	Irrig	Rainfed	Irrig	rainfed
USA	0.64	0.64	0.65	0.65
Rest of NAFTA	0.66	0.66	0.76	0.76
EU 27	0.63	0.63	0.65	0.65
Russia	0.66	0.66		
C. Asia & FSU	0.66	0.67		
Brazil			0.70	0.70
Rest of LAC	0.79	0.79	0.77	0.76
WANA	0.72	0.72	0.71	0.71
SS Africa (All)			0.74	0.76
E. SS Africa			0.75	0.75
W & C SSA			0.75	0.78

Summary of results

- For the developing regions, which start out with lower yield levels, the increase in yields, due to price change, is likely to be bigger
- Yield share is slightly larger on irrigated land, but not always
- Russia, FSU, WANA respond more strongly in wheat area to additional feedstock demands
- Brazil and SS Africa respond more strongly in maize area to additional feedstock demands
- The yield response of sugar crops seems to be quite strong, across regions – but will look at this further….

Continuing work

Some on-going efforts to improve the way in which biofuels is modeled in IMPACT

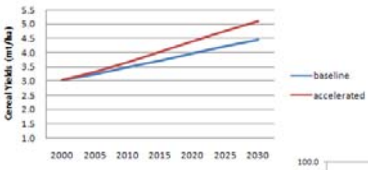
- Better disaggregation of oil commodities, to distinguish between temperate seed oils and tropical tree oils – plus soybean and its products
- Continuing improvement to the modeling of biofuels to account for by-products in a better way, differences b/w molasses and cane juice-based ethanol production, better data, etc.
- Efforts to build a better land use module will allow us to address the question of indirect effects in a more detailed way, with land heterogeneity

Thank You!

Additional Results

Additional yield growth in cereals to offset malnutrition impacts of US biofuels target

Global Cereal Yield Growth



Additional (annual average) yield growth in cereals:

1% in developing world

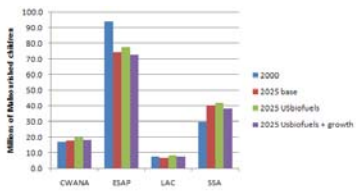
0.5% in developed world

In other words….

Going from: 1.3% → 1.8%

Avg annual yield growth, globally

Malnourished children (0-5)



The Bread & Butter of IMPACT

- Much of the past work of IMPACT has centered around providing a forward-looking perspective on what's needed to meet future food needs, and the implications for key CGIAR mandate commodities
- It was designed to look at the medium-to-long term periods, that aren't covered by short- to medium-term models of USDA, OECD, FAO
- Used for projections and not prediction – which implies that you're more interested in percentage changes from a starting point, or in terms of deviations from a baseline, under alternative scenarios

Typical IMPACT-driven scenarios

- Looking at the implications of expansion in (irrig/rainfed) area and increased yields on key indicators of:
  - Production (area/yield), Demand (total/food/feed/other), Net Trade, Prices (int'l/national)
  - Per capita calorie availability from all foods
  - Implied changes in child (under 5) malnutrition
- Looking at the implications of the growth in irrigated area and yield, mentioned above, on increased investments in agricultural research and rural roads investments

Solving an 'ill-posed' problem

Essentially, we're trying to find the value of two unknowns on the basis of a single datum – avg yield

$$\Delta y^{old} = \left[1 + \sum_s \left(p_s^{old} \cdot z_s^{old}\right)\right] \cdot \Delta y^{avg} \qquad \sum_s p_s^{old} = 1 \qquad \sum_s p_s^{new} = 1$$

$$y^{new} = \left[1 + \sum_s \left(p_s^{new} \cdot z_s^{new}\right)\right] \cdot y^{avg} \qquad z_s^{old,new} = \left[-\gamma, +\gamma\right] \quad \gamma > 0$$

$p_s^{old,new}$ **= calculated weights on plausible deviations from the avg**

$z_s^{old,new}$ **= the maximum deviations (positive/negative) from the avg [cover the interval (-dev,+dev) centered around zero)**

Maximum entropy solution

The maximum entropy solution is designed to give a uniform distribution to the calculated weights in the absence of any information $p_s^{old} = p_s^{new} = ½$

giving the average values of yield and yield change

$$\Delta y^{old} = \left[1 + \underbrace{\sum_s \left(p_s^{old} \cdot z_s^{old}\right)}_{=0}\right] \cdot \Delta y^{avg} = \Delta y^{avg}$$

$$y^{new} = \left[1 + \underbrace{\sum_s \left(p_s^{new} \cdot z_s^{new}\right)}_{=0}\right] \cdot y^{avg} = y^{avg}$$

The full optimization problem

$$\max_{\left\{p_{i,r,c,s}^{old},\, p_{i,r,c,s}^{new}\right\}} \left[\sum_s \sum_r \sum_c \sum_{i=\{irr,rfd\}} p_{i,r,c,s}^{old} \cdot \ln\left(p_{i,r,c,s}^{old}\right) + \sum_s \sum_r \sum_c \sum_{i=\{irr,rfd\}} p_{i,r,c,s}^{new} \cdot \ln\left(p_{i,r,c,s}^{new}\right)\right]$$

$s.t.$

$$\Delta Q_{i,r,c} = \Delta y_{i,r,c}^{old} \cdot A_{i,r,c}^{old} + y_{i,r,c}^{new} \cdot \Delta A_{i,r,c}$$

$$\Delta y_{i,r,c}^{old} = \left[1 + \sum_s \left(p_{i,r,c,s}^{old} \cdot z_s^{old}\right)\right] \cdot \Delta y_{i,r,c}^{avg}$$

$$y_{i,r,c}^{new} = \left[1 + \sum_s \left(p_{i,r,c,s}^{new} \cdot z_s^{new}\right)\right] \cdot y_{i,r,c}^{avg}$$

$$\sum_s p_{i,r,c,s}^{old} = 1 \quad \sum_s p_{i,r,c,s}^{new} = 1$$

$$p_{i,r,c,s}^{old} \in [0,1], \quad p_{i,r,c,s}^{new} \in [0,1] \qquad z_s^{old}, z_s^{new} \in [-\gamma, +\gamma] \quad \gamma \in [0,1]$$

where the subscripts:

i=irrigated/rainfed
r=regions
c=crops
s=support values (1,2)

Growth in cereals consumption

	food consumption		total consumption	
	Growth in Consumption, 2005-2015 (millions mt)	Share of total increase	Growth in Consumption, 2005-2015 (millions mt)	Share of total increase
N America & Europe	-3.5	-10%	178.2	54%
Central W Asia & N Africa	15.3	43%	33.9	10%
E & S Asia & Pacific	11.5	32%	78.4	24%
L America & C	2.1	6%	21.4	7%
SS Africa	10.5	29%	15.9	5%

9. Effects of biofuel on worldwide land use in the LEITAP-model (Geert Woltjer - Agricultural Economics Research Institute (LEI)) [11]

LEITAP is a general equilibrium economic model, based on GTAP. It integrates and extends most aspects of GTAP_Agr, GTAP_E and GTAP_DYN. There are several differences with other GTAP-based models, of which the most important is the land supply method (described below).

To predict LUC, LEITAP2 adds a land supply curve approach using information from land allocation models IMAGE and CLUE. Both of these have a grid-based approach, which is a challenge because GTAP has a "countries" approach.

Marginal vs. average yield

For determining the *marginal yield*, LEITAP uses information from the land allocation module of the IMAGE model (Bouwman et al. 2006).

IMAGE estimates potential rainfed yields on the basis of land suitability etc. for 0.5 degrees grid-cells (56 km^2 at the equator). The allocation of new land in IMAGE follows a suitability approach, taking into account population density, distance to existing agriculture, accessibility, and a random factor. In order to provide marginal yields, i.e. yields on the new land compared to the existing yield average, all grid cells are ordered according to their suitability, and a curve of average yield versus cumulative area is constructed. In most regions, marginal yields are lower than average yields, and are further decreasing with increasing cropland area. However, the fraction of marginal to average is mostly close to 1, except for regions where practically all possibly usable land is already farmed (e.g. North Africa.). This marginal yield is fed back to GTAP, and also used to determine the effect of area expansion on yield, and the resulting area of land use change. There are two reasons why the factor is mostly close to 1, i.e. why the effect of expansion on average yield is rather small:

1) The factor is based on potential rainfed yields, not on actual yields. However, the yield gap (difference between potential and actual yield) tends to be larger in remote areas with low population density (Neumann et al. 2010). This means, that even with identical potential yields, actual yields would tend to be lower on newly converted areas than on average. This effect is still ignored in the IMAGE-LEITAP methodology, as only potential yields are taken into account at the moment.

2) Initially, the allocation approach in IMAGE had put a strong weight on yield potentials in determining the overall suitability for expansion. However, yield potentials often only have a minor impact on agricultural expansion (e.g. Soler et al. 2008), and therefore it had been advised to reduce the weight of yield potential in the allocation procedure. However, this issue is still under discussion, and an improved allocation module for IMAGE is currently under development.

Land supply

This is a distinct procedure from the marginal yield method, although the graphs look similar. LEITAP2 pioneers a new and unique method. The land rental price (Figure 5) is assumed to follow an exponential function of utilized agricultural land, with an asymptote at the limit of available land. The average price is the weighted average for different land uses. Thus land supply elasticity on price rises with the fraction of suitable land which is already occupied by

[11] Detailed report and calculations sheets only are available on CIRCA

agriculture. The default curvature parameter sets price elasticity of land supply at 4, for 50% land use.

The audience questioned the empirical basis of the formula, and pointed out that land conversion costs should be included.

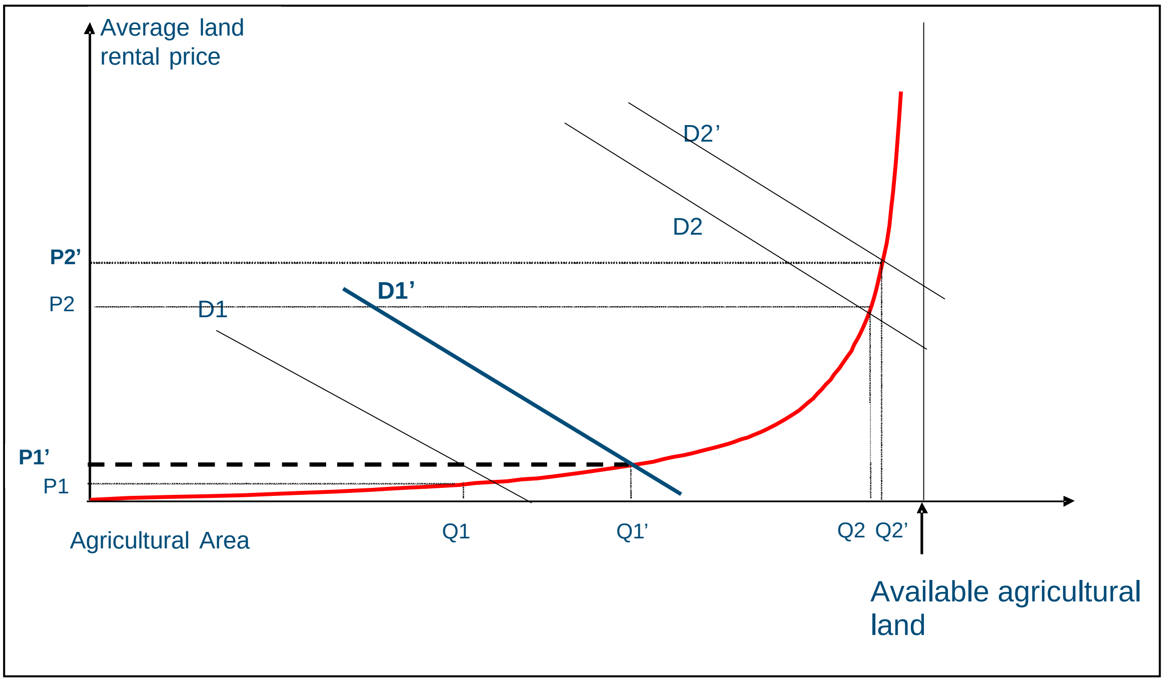


Figure 5 Method for determining elasticity of land supply in LEITAP

Treatment of by-products

By-products are taken into account, but, like all the substitutions between inputs in the GTAP structure (slides 6, 7 and 8), animal feed substitutions are done on the basis of relative price, rather than looking at biophysical attributes such as protein and energy content. Furthermore, since there is no distinction between oilseed meal and oil, DDGS and rapeseed cake substitute vegetable oil as well as animal feed.

Scenarios

The model shocked demand rather than biofuel production, because shocking the production resulted in larger knock-on effects on production outside the target country.

The results presented are for 3 scenarios vs. baseline:

1. 1 Mtoe increase of biodiesel demand in Germany (JRCBiodDeu)
2. 1 Mtoe increase of ethanol demand in France
3. 1 Mtoe increase of ethanol demand in US

In the subsequent report another scenario has been added, which is also reported here:

4. 1 Mtoe extra biodiesel in Germany, made from Indonesian palm oil

The report makes clear that, except for scenario 1, the increase in global biofuel production in the "1Mtoe" biofuels scenarios (compared to baseline) is reduced to about 0.9 Mtoe, by resulting reductions in biofuel production outside the target country.

A production increase of 1 Mtoe of biodiesel in Germany (scenario 1) corresponds to 1.08 million tonnes (Mt) of biodiesel (N.B. These figures differ slightly from JEC-WTW figures possibly due to the difference between Lower Heating Values, LHV, and Higher Heating value, HHV, definitions). However, price changes mean that a little less biodiesel is produced in the rest of the world, so that the net world increase is only 1.06 Mt, whilst world ethanol production falls by 0.11 Mtoe. For some reason, extra ethanol production in France leads to extra ethanol production elsewhere (EU-wide subsidy?).

The following Figure 6 shows the land use changes in different regions of the world, and on the world as a whole, arising from these three scenarios.

It is clear from the graph that the scenario of increased demand for 1Mtoe of German biodiesel (scenario 1) causes more land use change in the world (~14,000 km^2) than the other two scenarios. French demand (~2,500 km^2) (scenario 2) and then the US demand (~820 km^2) (scenario 3) for ethanol follow.

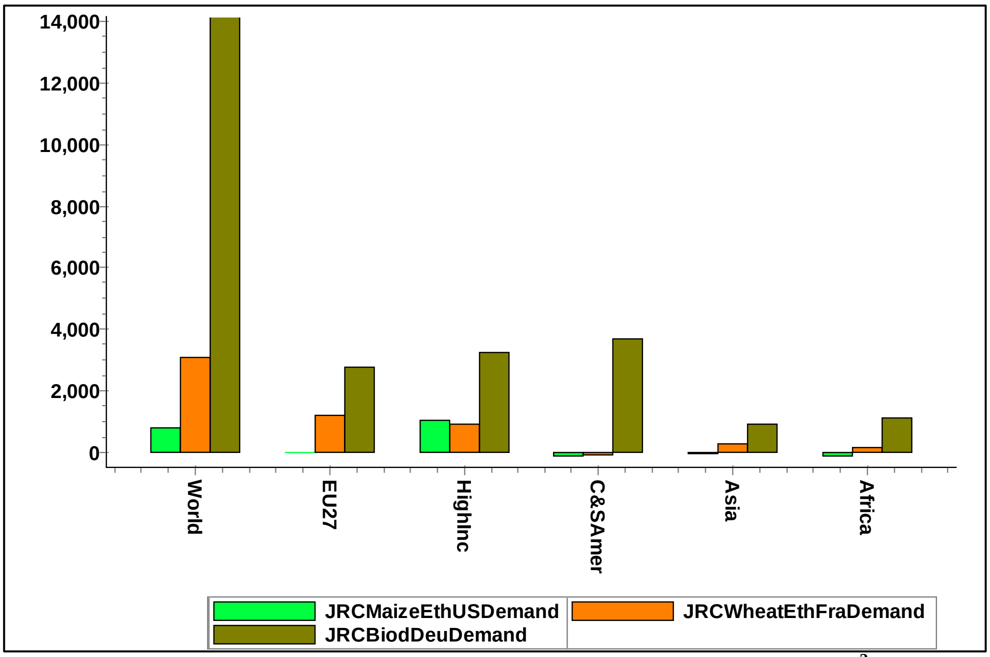


Figure 6 Land use changes (change in area of cropland + grazing land) [km^2]

Counterintuitive results from increased ethanol demand in the US (scenario 3) have also been presented. Land demand and agricultural production slightly decrease in South America, despite increasing in the world by 817 km^2. This may be an artefact caused by the lack of disaggregation in the model between vegetable oil and oilseed meal: DDGS production in US reduces not only soybean meal imports, but (automatically) soybean oil imports from South America. There is also a smaller loss of grazing land in S. America.

There is also a tiny reduction in EU land use in the US corn scenario, which may be the result of lower biofuel production in EU. It was suggested that this could not happen if the biofuel use in EU is modelled as an obligation rather than a subsidy.

(*<u>JRC comment</u>: another reason for the effect in EU may be a spurious substitution of EU rapeseed oil by US DDGS in the model, analogous to the South American explanation).*

The percentage changes in arable area (green) and yield (orange) for different scenarios are shown in the following figures 7, 8 and 9). Generally, roughly twice as much additional production comes from area increase than from yield increase. The exception is US corn-ethanol, where almost all extra production comes from increased area. Most changes happen in the continent where the extra demand is taking place.

Increased ethanol demand/production in the US (scenario 3) actually reduces yield in EU (in line with the strange area reduction mentioned previously).

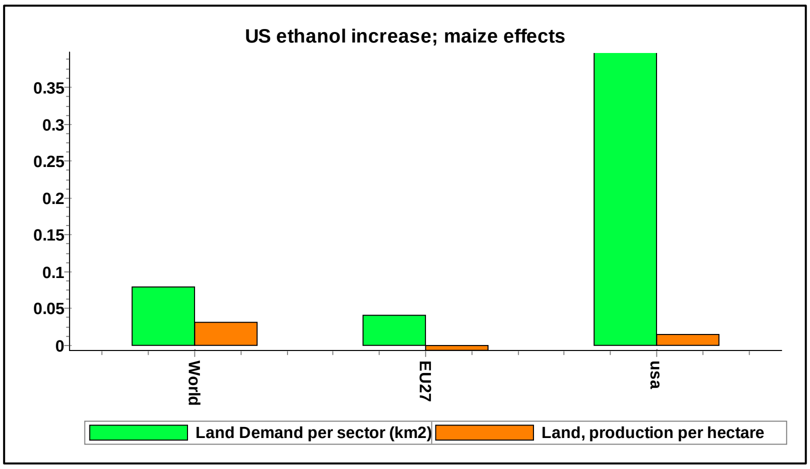


Figure 7 Land demand versus land productivity: maize

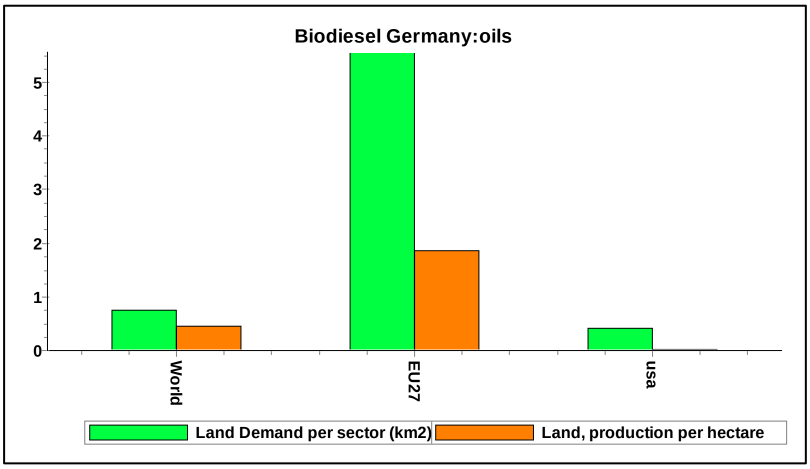


Figure 8 Land demand versus land productivity: Biodiesel Germany

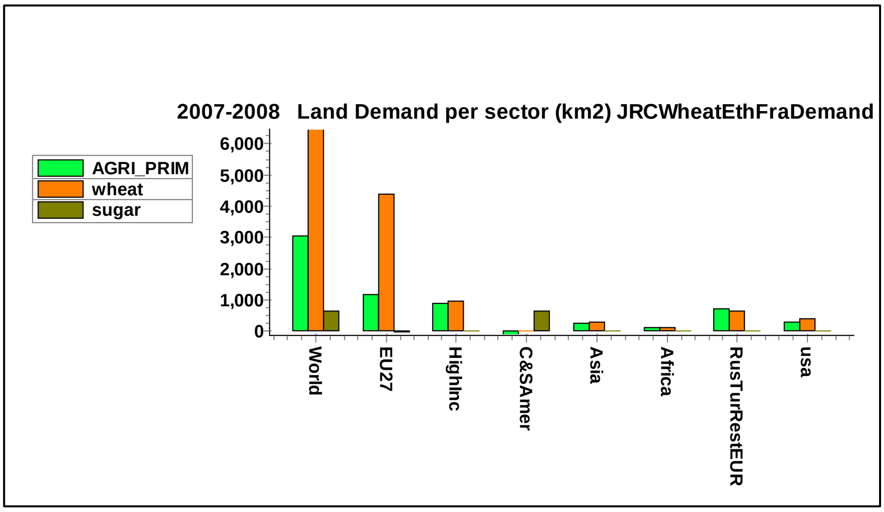


Figure 9 Land demand change wheat Ethanol in France

Price effects

Land prices generally increase under all scenarios, but the effect is ten times greater in the EU, where each Mtoe increase-demand-for-biodiesel-in-Germany increases arable land price by 1.4%. (n.b. EU 10% biofuel target is ~30 Mtoe). Feed prices are not significantly affected in any scenario.

Contrary to FAPRI-CARD model results, livestock production decreases in both EU and USA in the German biodiesel scenario (slide 27). This is because LEITAP takes into account the effect of land price on livestock production. However the *value* of net livestock exports increases slightly due to higher prices, especially in EU.

In the US corn-ethanol scenario, the effect of DDGS on decreasing feed price dominates over increased land price, and that increases US livestock production and decreases US livestock price. All biofuels scenarios slightly reduce food consumption in EU and US compared to baseline, (except for the US maize ethanol scenario in US).

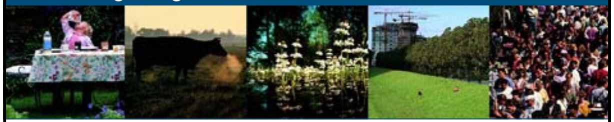
Conclusions

- The qualitative results can be explained with some plausible mechanisms
- Especially the uncertainties with respect to land use decrease in South America and the EU27 have been solved
- General equilibrium effects seem to be important through
  - Land supply curves
  - Feed-land and feed substitution
  - Crude oil prices
- Size of the effects depends on data
  - We are working to get a better controlled database of land use
  - Nevertheless, for specific products like palm oil, a correction factor must be included
- Needed: Correct CES and Armington for energy and quantity balances
- Needed: explicit modelling of animal feed from oils; oils and oil cake are not split now.
- We are starting to digest check the results and assumptions

Effects of biofuels on worldwide land use in the LEITAP-model

Prepared for ISPRA Workshop on ILUC modeling, 10/11 February 2010

Geert Woltjer
LEI-Wageningen UR



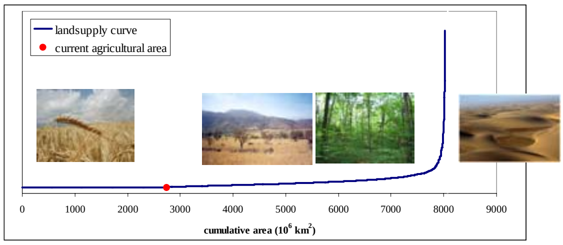
General equilibrium effects

- Focus will be on general equilibrium effects of ethanol production or demand
- Sketch of LEITAP
- Some preliminary results, with a focus on general equilibrium effects and some results presented before me

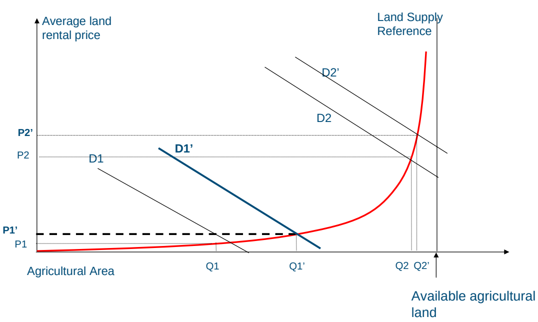
LEITAP

- LEITAP is a general equilibrium economic model, based on GTAP
- Integrates and extends most aspects of GTAP_Agr, GTAP_E and GTAP_DYN
- Land supply curve approach using information from land allocation models IMAGE and CLUE
- IMAGE and CLUE have a grid based approach

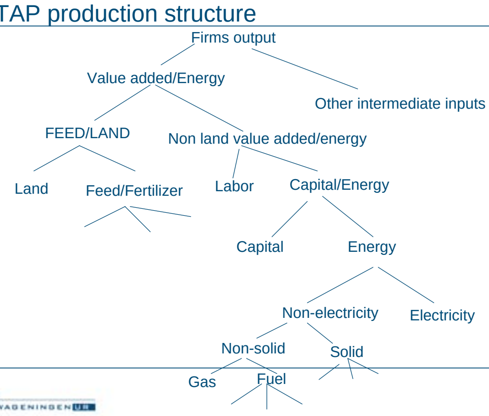
Land supply curve



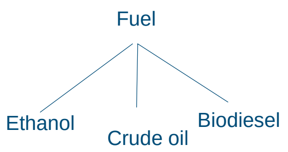
Modeling Land Use Changes in LEITAP



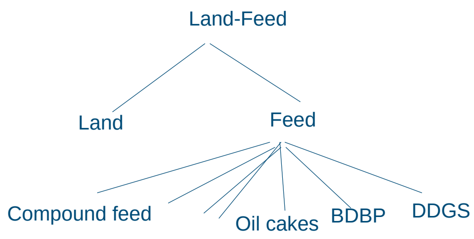
LEITAP production structure



The fuel nest in petroleum production



The land-feed nest in livestock



Byproducts

- DDGS for ethanol from maize and wheat
- Biodiesel Byproducts (BDBP) for biodiesel
- Reduces feed cost and land use for feed

Dynamic labor and capital mobility

- Outflow of capital and labor from agricultural sectors to non-agricultural sectors depends on relative value added per worker
- This is estimated by a long term an error correction model
- Medium term effects of policy and other changes on agricultural income depends very much on this equation
- In this application not used, but if used may show the importance of timing

Dynamic international capital flows

- Decision to invest in domestic firms or internationally
- Decision where to invest internationally
- Dynamic equation, with important effects for exchange rates, current account balance
- Not completely implemented yet
- May be important to analyze for example the effects of increased crude oil production in Brazil on exchange rate and therefore competition in the world with respect to biofuels
- Not used in these experiments

Three scenarios

- 1 Mtoe increase of ethanol production/demand in US
- 1 Mtoe increase of ethanol production/demand in France
- 1 Mtoe increase of biodiesel production/demand in Germany

Biofuel production change

Quantity change in Mln kg

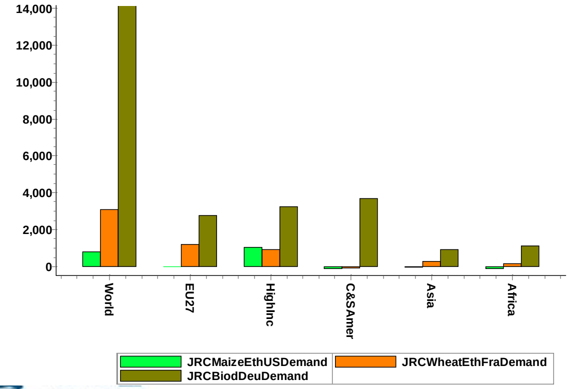
	World biodiesel	World ethanol	German biodiesel
JRCBiodDeu	1.06	-0.11	1.08
JRCBiodDeuDemand	1.06	-0.11	1.06

	World biodiesel	World ethanol	French ethanol
JRCWheatEthFrk	-0.06	2.07	1.56
JRCWheatEthFraDemand	-0.04	1.43	0.97

	World biodiesel	World ethanol	USA ethanol
JRCMaizeEthUS	-0.05	1.55	1.56
JRCMaizeEthUSDemand	-0.05	1.50	1.50

- Demand shock in ethanol production or demand in France generates 35% respectively 47 % more ethanol production in rest of world
- Biodiesel production increase in Germany reduces ethanol production in the world with 10% of biodiesel production increase

Land use changes



Surprising results for ethanol demand increase in US

		World	EU27	South America
Land demand	Total	817.00	(38.00)	(111.00)
Land demand	Arable	1207.00	(74.00)	(83.00)
Land demand	Grass	(390.00)	36.00	(28.00)
Production	Total	35	(17)	(3)
Production	Arable	28	(12)	(1)
Production	Grass	8	(6)	(2)

- Reduction of agricultural production and land use in South America
- Reduction of agricultural production and arable land use in EU27

South America paradox I

Land demand change in South and Central America

Total	oils
-121	-198

- Oil seed land demand causes decreases in land demand in South and Central America

South America paradox II

Exports and production of South and Central America (constant 2001 dollars)

	vegetable oils	animal feed
Exports	-6.37	-2.83
Production	-6.04	-3.50

- DDGS byproducts of ethanol production in the US reduces vegetable oil imports

South America paradox III (US)

Change in feed expenditures in 2001 dollars

Total	DDGS	maize	ımpound fe	oils	wheat
16.6	544.1	-214.8	-225.8	-51.3	-10.8

Percentage change in feed prices

DDGS	grain	compound	oils	wheat
-1.060	0.010	0.001	0.000	-0.004

- Maize, oils and compound feed substituted for DDGS

South America paradox solution

- DDGS substitute for oils in US
- Less oil imports
- Less oil exports South America
- Less land use in South America
- Only partly compensated by other land uses

Byproduct effects in US

1 Mtoe increase ethanol demand in US

Land Demand per sector (km2) (abs change) (2007-2008) (usa)

	Total	Arable	Grass	wheat	maize+	oils
Current byproducts	1120	1187	-67	-844	3110	-938
Half of current byproducts	3935	4245	-310	-745	5797	-690

Production volume (abs change in constant dollars) (2007-2008) (usa)

	AGRI_PRI	ARABLE	AGRI_GRA	wheat	maize+	oils
Current byproducts	58	36	22	-13	105	-22
Half of current byproducts	113	135	-23	-11	196	-16

Byproducts of US effect on Brazil

Production volume (abs change) (2007-2008) (bra)

	Total	Arable	Grass	wheat	maize+	oils
Current byproducts	-4.247	-2.829	-1.418	-0.012	-0.048	-5.692
Half of current byproducts	-2.304	-1.766	-0.538	-0.003	0.043	-4.959

Land Demand per sector (km2) (abs change) (2007-2008) (bra)

	Total	Arable	Grass	wheat	maize+	oils
Current byproducts	-186.5	-114.5	-72	-1.1	-4.2	-187
Half of current byproducts	-113.5	-82.8	-30.7	-0.3	3.1	-162.7

Europe paradox for ethanol demand increase in US

		World	EU27	South America
Land demand	Total	817.00	(38.00)	(111.00)
Land demand	Arable	1207.00	(74.00)	(83.00)
Land demand	Grass	(390.00)	36.00	(28.00)
Production	Total	35	(17)	(3)
Production	Arable	28	(12)	(1)
Production	Grass	8	(6)	(2)

- Why does more ethanol demand in US generate a decrease in land use in EU27?

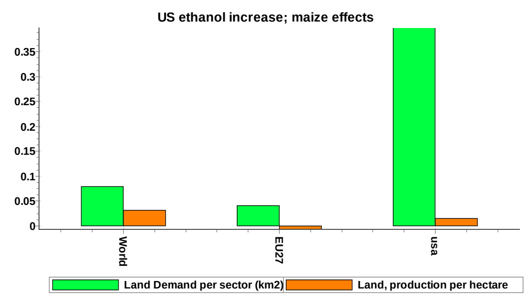
Effect ethanol in US on EU27

Market price and input substition in petroleum production

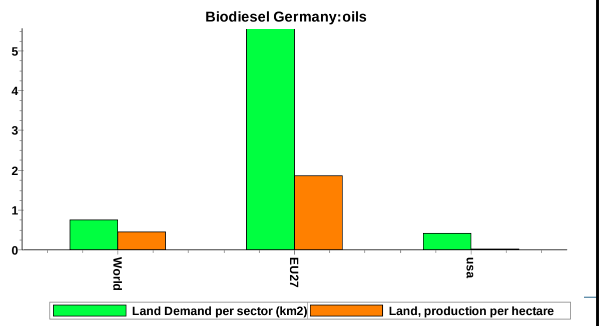
	Petro	c_oil	biod	eth
Volume of inputs	0.033	0.043	-0.77	-0.51
Market price	-0.0627	-0.08	-0.02	-0.04

- Lower crude oil price
- Generating substitution away from biodiesel and ethanol in EU27
- Increase in demand of petroleum as consequence of lower price doesn't compensate this

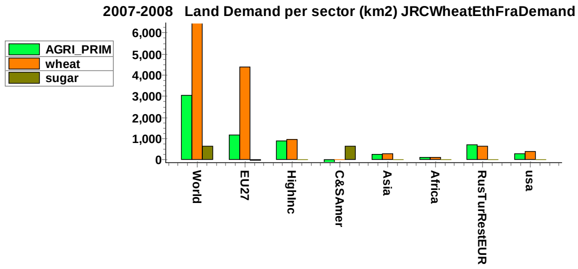
Land demand versus land productivity: maize



Land demand versus land productivity: Biodiesel Germany



Land demand change wheat Ethanol in



Land prices

		Land prices (% change)		
		Total	Grass	Arable
JRCMaizeEthUSDemand	usa	0.06	0.01	0.04
JRCWheatEthFraDemand	EU27	0.46	0.39	0.44
JRCBiodDeuDemand	EU27	1.28	0.63	1.42

- Effect on land prices is at least 10 times as high as in the US

Feed prices

	Land prices EU (% change)		Feed prices (% change)	
	ARABLE	AGRI_GRASS	EU27	USA
JRCMaizeEthUSDemand	-0.05	-0.03	-0.002	-0.004
JRCWheatEthFraDemand	0.44	0.39	0.008	-0.001
JRCBiodDeuDemand	1.42	0.63	0.018	0.001

- Feed prices reduced for US biofuels
- Increase for EU biofuels

Livestock decrease in EU as consequence of biodiesel production (effect of land prices; contrast with FAPRI)

Production volume (abs change) (2007-2008) (JRCBiodDe

	Livestock	Arable
EU27	-9.4	461.6
usa	-7.8	43.6

Export-import (value at world prices) (abs change) (World)

	Livestock	Arable
EU27	1	-309.3
usa	2.6	58.3

Consumption effects

Private consumption volume ((% change)) (2007-2008)

	EU27	usa
	AGRI	AGRI
JRCMaizeEthUSDemand	-0.0010	0.0003
JRCWheatEthFraDemand	-0.0027	-0.0007
JRCBiodDeuDemand	-0.0047	-0.0018
JRCMaizeEthUSDemandL	-0.0011	-0.0022

Europe versus US

- In Europe land price effect is higher than effect on animal feed
- In EU cost of animals increases, in USA it decreases as a consequence of biofuel production
- In USA livestock production increases despite a reduction in land use

LEI WAGENINGEN UR

Conclusion

- The qualitative results can be explained
- Especially the puzzles with respect to land use decrease in South America and the EU27 have been solved
- General equilibrium effects seem to be important through
  - Land supply curves
  - Feed-land and feed substitution
  - Crude oil prices
- Size of the effects depends on data
  - We are working to get a better controlled database of land use
  - Nevertheless, for specific products like palm oil, a correction factor must be included
- Needed: Correct CES and Armington for energy and quantity balances
- Needed: explicit modeling of animal feed from oils; oils and oil cake are not split now.
- We are starting to digest check the results and assumptions

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10. Calculation of the effects of increased demand for biofuel feedstock on the world agricultural markets: Intermediate Results and Characteristics of the GTAP model (Alla Golub - Purdue University (USA))[12]

The marginal calculations were made with a modified version of the GTAP general equilibrium model (Hertel, T. W., W. E. Tyner and D. K. Birur (forthcoming). "Global Impacts of Biofuels." Energy Journal 31(1): 75-100). Some elements of the model and the data base used in the analysis reported here differ from the data and model used for the California Air Resources Board. With respect to data base, the differences include representation of oilseeds biodiesel production in all regions and EU wheat ethanol sector. Important model structure modifications include more nested structure of animal feed producing sectors.

The baseline represents the world economy in 2001, with 87 GTAP regions aggregated into 19. Within each region, land endowment is divided into Agro-Ecological Zones (AEZ)[13]. There may be as many as 18 AEZs in a region. The reason why GTAP v6 was used instead of GTAPv7 (representing world economy in 2004) is because land use data consistent with global economic data are only available for 2001.

Additional model specifications, such as land use change mechanism, production structure, substitution among livestock feeds etc., may be found in the slides.

In the GTAP model, crop replacement depends on trading patterns. The Armington approach is used here, instead of an integrated-world-market assumption. With this approach, the composition of trade (that determines land use change patterns) is not fixed, but it tends to be concentrated on the country where the demand occurs and its major trade partners. The stickiness of (1) the composition of trade and (2) the mix of imported and domestic goods depends on the elasticities of substitution among imports from different sources (regions in the model), and elasticities between imported and domestic goods, respectively.[14] Whether the Armington structure increases or decreases net global land requirement relative to the integrated world market assumption depends on relative yields. As an example, the case of US coarse grains can be considered: US coarse grains yields are the highest in the world. When one hectare of corn grown for food is displaced by one hectare of corn for fuel in US, more than one hectare in the rest of the world will be needed to cover the shortage of corn for food. In the integrated world market assumption, the shock originated in US is more easily transmitted through the global economy than it is using the Armington approach. Because US corn yields are higher than corn yields in other regions of the world, the net global land requirement under integrated world market will be higher than under Armington assumption. The situation is opposite with EU biodiesel.

<u>Scenarios assumptions</u>

The shock introduced in the model (1 Million toe shock) to the baseline assumptions is relatively small to guarantee the linearity (see discussion points in par. 4), but still large enough to allow the assessment of the effects of increased production of biofuels feedstocks.

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[12] Report and supporting calculation sheets may be found on CIRCA.
[13] Definition of AEZ used in GTAP may be found at https://www.gtap.agecon.purdue.edu/resources/download/3671.pdf
[14] See Hertel et al (2007)

The following scenarios were considered:

Scenario A: marginal extra ethanol demand in EU (1 Mtoe = 0.53 billion gallons increase of ethanol production from wheat). EU uses of ethanol from sugar cane and biodiesel, as well as EU imports of biodiesel are fixed at the baseline levels.

Scenario B: marginal extra biodiesel demand in EU (1 Mtonne = 0.314 billion gallons increase of biodiesel from oilseeds). EU uses of ethanol from wheat and ethanol from sugar cane and biodiesel, as well as EU imports of biodiesel are fixed at the baseline levels.

Scenario C: marginal extra ethanol demand in US (1 Mtoe increase in production of ethanol from coarse grains in US). Total biofuel use in EU is fixed at the baseline level.

Scenario D: marginal extra palm oil demand in EU for biodiesel (1 Mtonne increase in biodiesel use in EU). Domestic biodiesel production in EU is fixed at baseline level, increased biodiesel demand being supplied with imports from Malaysia/Indonesia.

By-Products

Two types of by-products were considered in the model:

- Dried distillers grains with soluble (DDGS), by-product of corn and wheat ethanol (produced only in the regions where ethanol is produced, i.e. 7 out of 19 regions in the database)
- Oilseeds meal, by-product of crude vegetable oil (VOBP) was split out of the standard GTAP sector "vegetable oils and fats". In contrast to DDGS, oilseeds meal reported here covers all types of meal produced across the world. Because of a lack of quantitative data, not explicit quantities, but indirect observations were used to introduce this by-product into the GTAP database.

Although protein and energy are complementary, a small value for the elasticity of substitution between these two groups was chosen, since DDGS could displace a portion of meals in some feed rations.

The effects on land use reduction derived from the use of by-products on net land are significant:

- 30% recovery of net cropland for EU wheat ethanol (scenario A)
- 52% recovery of net cropland of EU oilseeds biodiesel (scenario B)
- 46% recovery of net cropland for US corn ethanol (scenario C)
- 22% recovery of net cropland for palm oil biodiesel (scenario D)

The effect is smaller in scenario D, since the proportion of palm kernel meal coming from palm oil biodiesel is much smaller than the by-products from other oilseeds. Even this effect is perhaps overestimated because GTAP assumes palm kernel meal replaces soybean meal 1:1 whereas in practice it is a much poorer quality of feed.

Changes in crop prices

The following Figure 10 gives changes in crop prices per Mtoe of biofuel, due to increased biofuels demand for the four different scenarios.

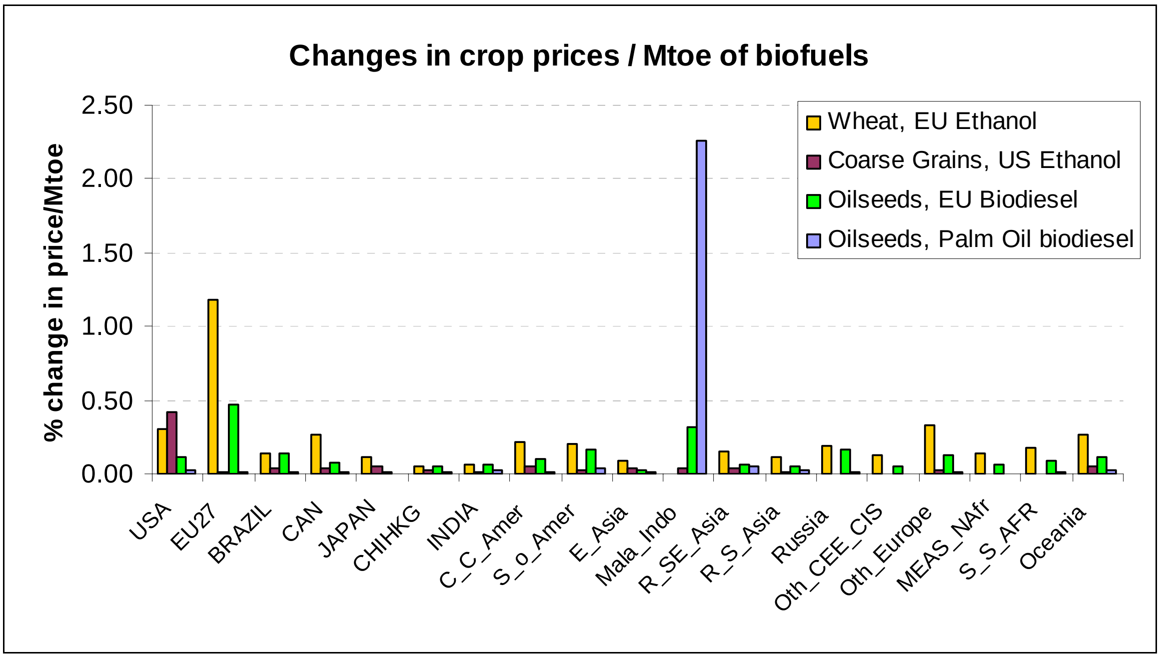


Figure 10 Changes in crop prices per Mtoe of biofuels

Since roughly 30 Mtoe of extra- biodiesel in EU are needed to reach the 10%-share mandate the **total** effect on prices is much higher than shown in the graph, which is for 1 Mtoe.

Changes in feedstock yields.

Two important assumptions of the model are related to changes in crop yields:

1. Intensification is modelled considering a price crop elasticity of 0.25: a permanent increase of 10% in crop price, relative to variable input prices, would result in roughly a 2.5% rise in yields.
2. Ratio of the yield on the new cropland (marginal yield) to the average yield of existing cropland of the same crop within the region is 2/3 (0.66).

The following Figure 11 shows an example of yield changes for different crops in the 19 regions of the model, resulting from increased EU ethanol consumption (scenario A)

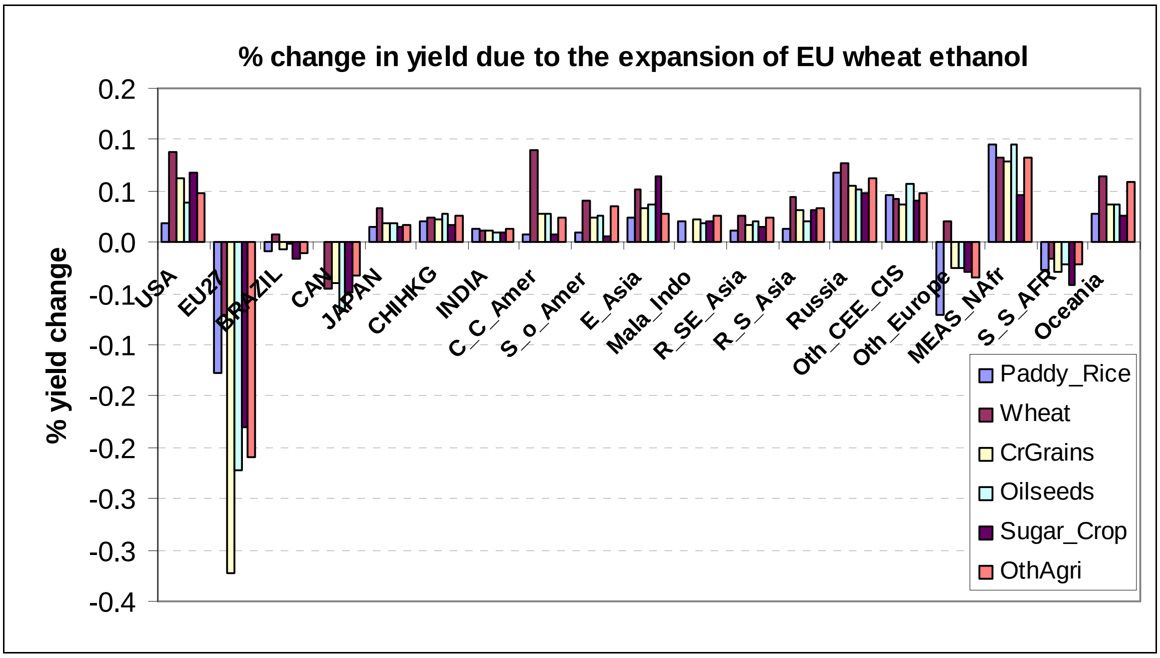


Figure 11 Percentage change in yield

A static model like G-TAP can model three types of yield changes:

a. Yields changes due to producers' responsiveness to price.

As feedstock prices rise, producers increase the use of capital, fertilizers and other inputs to boost yields. This change in yield is endogenous to the increases in demand for biofuels and modelled as an endogenous response in the GTAP model. The response is introduced through non-zero substitution among various intermediate inputs and value added. Accordingly, the production function is not Leontief. The elasticity of substitution for each crop in each region is calibrated such that a permanent increase of 10% in crop price, relative to variable input prices, would result in roughly a 2.5% rise in yields.

b. Yields increase due to past R&D.

As time passes yields may go up. These changes in yields have nothing to do with the increased demand for biofuels modelled in GTAP, and are exogenous to the model. The analysis submitted to the JRC is based on v.6 GTAP data base, representing the world economy in 2001. One may argue that yields have changed between 2001 and 2010. How to reflect this? Assume that the model based on 2001 data predicts that the net global cropland expansion due to higher demand for US corn ethanol is increased by 10 units of land. Assume that historical US corn yield change from 2001 to 2010 is 10%. Then, to adjust for higher yields, it is sufficient to deflate by 1.1 such that net global cropland expansion is 10/1.1 = 9.09. This calculation assumes that everything in the world economy grows at 10%, including non-ethanol demand, yields in US and yields outside US. The issue of changes in ROW yields relative to changes in US yields is critical for the validity of this adjustment. If in the ROW yields had grown slower than in US over 2001-2010, then we underestimate the net global cropland requirement.

c. Yield changes due to R&D triggered by biofuels.

Important issue here is how long it takes for these investments to boost feedstock yields. Would we grow corn for fuel by the time the yields go up because of specific R&D?

If answer is yes, then one way to reflect this would be to apply adjustment as in (b). Another more complex way to model this would be to introduce endogenous technical change mechanism in the model.

Breakdown of net feedstock demand

The model provides an estimate of how much of the net feedstock demand for biofuels is met by reduction in food consumption, how much by yield intensification and how much by area expansion. The decomposed changes (in percentage) are shown in the following

Table 8 (more details on the numbers may be found in the slides presented during the workshop).

Table 8 Percentage changes in feedstock demand

	EU wheat ethanol	US corn ethanol	EU oilseeds biodiesel	Palm Oil biodiesel
Additional feedstock required (Mton)	**5.25**	**4.67**	**2.12**	**4.25**
Yield Intensification	9%	7%	8%	11%
Yield extensification	-6%	-1%	5%	15%
Harvested area	87%	42%	54%	43%
Reduction in non-fuel consumption	10%	52%	32%	26%
Reduction in Mala-Indo domestic biodiesel use[15]				5%

Concerning yield extensification, there might be two different effects, for example:

- cropland converted to another type of cropland (i.e. soybean to corn); in this case the value can be positive or negative, depending on the relative land productivity measured by land rents.

- pasture/forest converted to crop. In this case the value is always negative, and the factor of 0.66 mentioned above for the ratio between new yield and previous yield applies.

[15] This reduction is due to the fact that Mala_Indo increased their biodiesel exports to the EU

Land Cover Changes

The changes in land cover and use (e.g. from pasture to crop and from forest to crop) due to 1 Mtoe expansion of biofuels is shown in the following Figure 12.

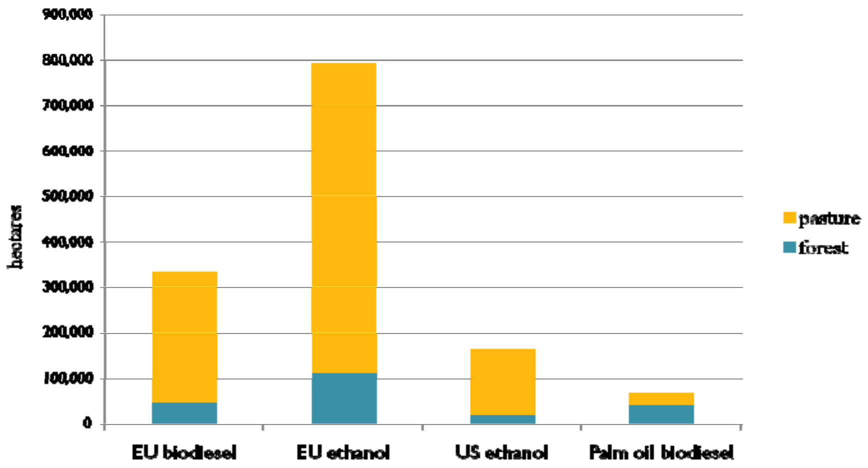


Figure 12 Land cover changes due to 1 Mtoe expansion of biofuels

Concerns were raised against the very low value for scenario D, palm oil biodiesel. In particular for this scenario results strongly depend on the model and scenario set-up. This scenario was built considering all palm oil biodiesel produced in Malaysia/Indonesia and then exported to the EU. However, if considering alternative scenarios, where for example the EU produces biodiesel but imports palm oil from Malaysia and Indonesia, then global land cover changes go from about 68.000 ha to more than 400.000 Ha (see slide 21). However, because of the high carbon release from (peat) forest conversion in Malaysia/Indonesia, even the lowest of these LUC scenarios might give very high GHG emissions.

Calculation of the Effects of Increased Demand for Biofuel Feedstock on the World Agricultural Markets: Intermediate Results and Characteristics of the GTAP model

Alla Golub (Purdue University)

Objectives

- Using a version of GTAP model, calculate the effects of marginal increase in demand for biofuel feedstocks on
  - Prices
  - Yields
  - Harvested area and land cover
  - Consumption
  - Changes in fertilizer use ascribed to yield intensification
- Provide characteristics of the model
  - Ratio of yield on the new cropland to the average yield of existing crop land
  - Effect of biofuel co-products on land use change
  - Relations used to determine market substitutions between animal feeds
  - Decomposition of net feedstock demand
  - Price-induced yield changes
  - Effect of trade assumptions on land use change

Overview of the presentation

- Modeling framework
- Description of the experiments
- Results

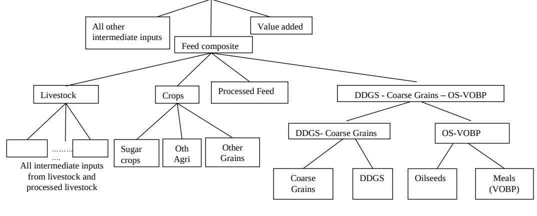
Model and data

- Static computable general equilibrium model of global economy
  - Modified version of GTAP-BIO model (Hertel et. al, 2010)
- GTAP v.6 data base representing world economy in 2001
  - 18 Agro-Ecological Zones
  - 19 regions and 31 industries
  - Modified to include biofuels and their by-products (by Farzad Taheripour)

Modified Data

- Split up the standard GTAP sectors
  - "Other food" (ofd) sector into grain based ethanol, DDGS, processed food, processed feed
  - "Vegetable oils and fats" (vol) into crude and refined veg. oil, VOBP, biodiesel
  - Sugar cane ethanol is split from "Chemical, rubber, plastic products" (crp)
- Ethanol from corn (1.68 bill gall), wheat (0.133 bill gall) and sugar cane (3.6 bill gall)
- Biodiesel is produced from crude vegetable oil (US 0.005 bill gall, EU 0.208 bill gall)
- Crude vegetable oil from oilseeds (all together)
- Two types of by-products
  - Dried distillers grains with soluble (DDGS), by-product of corn ethanol and wheat ethanol
  - Oilseeds meal, by-product of crude vegetable oil (VOBP)

New element in production structure



- With CES functions, substitution among various inputs depends on changes in relative prices, shares in cost of production and substitution parameter

Substitution among livestock feeds

- Price of a biofuel by-product should not fall on the historical 2001-2006 experiment with the model, as it had been observed historically
- Different magnitudes are assigned to the parameters within DDGS-Coarse Grains composite in ruminants, non ruminants and dairy to reflect different substitution possibilities in these sectors
- Oilseeds and oilseed meals are assumed to be close to perfect substitutes => high elasticity of substitution between these two feed materials

Substitution among livestock feeds (cont.)

- Substitution parameter between DDGS-Coarse Grains composite and Oilseeds – Meals composite
  - Protein and energy are complements => zero elasticity, however
  - Small value for the elasticity of substitution between these two groups of feedstuffs was chosen because DDGS could displace a portion of meals in some feed rations, as shown in Arora, Wu, and Wang (2008)

Biofuel by-products

- Dried distillers grains with soluble (DDGS)
  - By-product of corn ethanol and wheat ethanol
  - Represented only as ethanol by-product
  - In the data base, DDGS is produced only in regions where ethanol is produced (7 regions of 19)
  - Available quantities data were use to split DDGS from "other food"
  - Other types of distillers grains are not included in DDGS, but in "processed feed" sector that covers other types of distiller grains
- Oilseeds meal
  - By-product of crude vegetable oil
  - In contrast to DDGS, oilseeds meal in the data covers all types of meal produced across the world
  - Indirect observations were used in splitting VOBP from "vegetables oils and fats"
  - Consistent with available data (EU and US)

Assumptions about changes in crop yields

- Own price crop yield elasticity is 0.25 for all crops and regions (based on literature review for corn in US)
  - A permanent increase of 10% in crop price, *relative to variable input prices*, would result in roughly a 2.5% rise in yields. If the long run price of crop were to double, from $2/bu to $4/bu, and the price of land substituting inputs increased by 50%, then the output-input price ratio would rise by 33% and the expected yield increase would be 0.25 * 33% = 8.33%.
- Ratio of the yield on the new cropland to the average yield of existing cropland of the same crop within the region is 2/3 = 0.66. The same value is assumed for all regions and crops.
  - It takes 3 additional hectares of pasture or forest to produce what 2 hectares of average current cropland produce (globally)

Land use change mechanism

- 18 Agro-Ecological Zones
  - 6 growing period (6 categories x 60 day intervals)
  - 3 climatic zones (tropical, temperate and boreal)
- The competition for land within a given AEZ across uses is constrained to include activities that have been observed to take place in that AEZ
- 3 broad types of economic use of land: cropland, pasture and forestry
- Within AEZ, land supply is constrained via a nested CET frontier
  - First, allocation of land among three land cover types, i.e. forest, pasture, cropland
  - Then, allocation of land between various crops
- AEZs are inputs into a single national production function for each commodity

Trade as it relates to land use change

- Armington approach
  - Agents first decide on the sourcing of their imports
  - Then, based on the resulting composite import price, they determine the optimal mix of imported and domestic goods
- With this approach, the composition of trade is not fixed, but sticky
  - For example, in the case of increased production of biodiesel in EU, most crop land conversion arises within the EU, followed by its dominant export competitors and trading partners
- The stickiness of the composition of trade depends on the elasticities of substitution among imports from different sources
  - Econometric estimates based on Hertel, Hummels, Ivanic, Keeney in Economic Modeling , 2007

Experiments

- In general, the result per unit of energy is sensitive to the size of the shock
- However, this nonlinearity is small for smaller shocks
- This report is based on 1 million metric TOE shock
  - 0.53 billion gallons for ethanol
  - 0.314 billion gallons of biodiesel
  - Small enough to allow the assumption that the effects per metric TOE would be roughly the same for smaller shocks
  - Large enough to allow the assessment of the effect of expanded production of biofuel feedstock

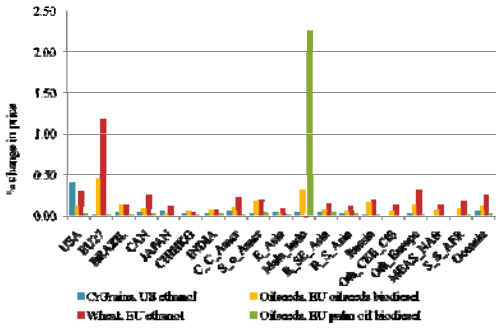
Scenarios A and B

- A. Marginal extra ethanol demand in EU
  - 0.53 billion gallons (1 million TOE) increase in EU production of ethanol from wheat
  - EU uses of ethanol from sugar cane and biodiesel are fixed at the baseline levels
  - EU imports of biodiesel are fixed at the baseline level
- B. Marginal extra biodiesel demand in EU
  - 0.314 billion gallons (1 million TOE) increase in EU production of biodiesel from oilseeds
  - Oilseeds includes oil seeds and oleaginous fruit, soy beans and copra, both domestic and imported by EU from other regions
  - EU uses of ethanol from wheat and ethanol from sugar cane are fixed at the baseline levels
  - EU imports of biodiesel are fixed at the baseline level

Scenarios C and D

- C: marginal extra ethanol demand in US
  - 0.53 billion gallons (1 million TOE) increase in production of ethanol from coarse grains in US
  - Coarse grains GTAP category includes mostly maize, but also barley, rye, oats, other cereals
  - Total biofuel use in EU is fixed at the baseline level
- D: marginal extra palm oil demand in EU for biodiesel
  - 0.314 billion gallons (1 million TOE) increase in biodiesel use in EU
  - Domestic production of biodiesel is fixed at the baseline level
  - Increase in biodiesel use in EU is satisfied vi increased imports from Mala_Indo region (includes Malaysia and Indonesia)
  - In Mala_Indo region, extra biodiesel production uses domestically produced vegetable oil only
  - In Mala_indo region, extra vegetable oil is produced from domestically grown oilseeds only (oil palm)

Changes in crop prices

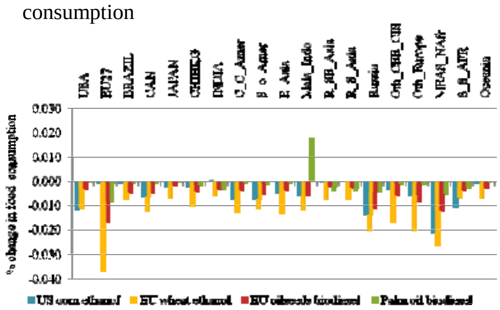


Effect of by-product on net land requirement

- Comparison of the net land requirements in “with by-products” and “without by-products” situations (“without by-products” is when quantity of by-products produced is fixed at the baseline level)
  - 30% for DDGS, by-product of EU wheat ethanol
  - 52% for oilseeds meal, by-product of EU oilseeds biodiesel
  - 46% for DDGS, by-product of US corn ethanol
  - 22% for oilseeds meal, by-product of palm oil biodiesel

Food consumption

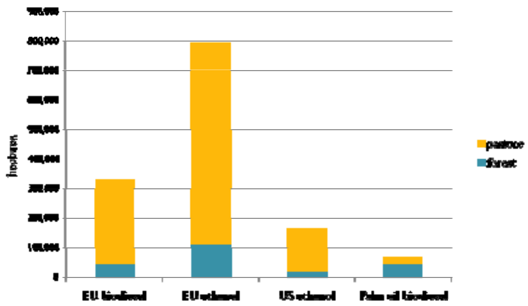
- Food expenditure share weighted percent change in food consumption



Decomposition of net feedstock demand needed to produce 1 mill TOE of biofuel

	EU wheat ethanol	US corn ethanol	EU oilseeds biodiesel	Palm oil biodiesel
Extra fuel produced, bill gallons	0.53	0.53	0.314	0.314
Feedstock measurement unit	mill bu	mill bu	mill bu	mill t
Additional feedstock	193	184	78	4.25
Change in production due to change in				
Yield intensification	17 (0.09)	13 (0.07)	6 (0.08)	0.47 (0.11)
Yield extensification	-11 (-0.06)	-1 (-0.01)	4 (0.05)	0.63 (0.15)
Harvested area	167 (0.87)	77 (0.42)	42 (0.54)	1.83 (0.43)
Reduction in consumption	19 (0.1)	95 (0.52)	25 (0.32)	1.11 (0.26)
Reduction in Mala_Indo domestic biodiesel use				0.21 (0.05)

Land cover changes due to 1 mill TOE expansion of biofuel



Proportion of global land use by land cover type and region

	EU wheat ethanol		EU biodiesel		US corn ethanol		Palm oil biodiesel	
Region	Forests	Pasture	Forests	Pasture	Forests	Pasture	Forests	Pasture
USA	0.02	0.06	-0.02	0.05	0.14	0.28	0.01	0.03
EU27	0.34	0.10	0.31	0.10	0.05	0.03	0.04	0.04
BRAZIL	-0.02	0.07	0.02	0.09	0.02	0.05	0.02	0.04
CAN	0.07	0.05	0.05	0.04	0.06	0.05	0.04	0.03
JAPAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHIHKG	-0.05	0.04	-0.05	0.04	-0.02	0.03	0.01	0.01
INDIA	0.01	0.01	0.01	0.02	0.01	0.01	0.04	0.03
C_C_Amer	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.01
S_o_Amer	-0.08	0.11	-0.07	0.11	-0.03	0.07	0.00	0.04
E_Asia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mala_Indo	-0.01	0.00	0.00	0.00	-0.01	0.00	0.42	0.00
R_SE_Asia	-0.01	0.00	-0.01	0.00	0.00	0.00	0.01	0.00
R_S_Asia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Russia	-0.12	0.10	-0.12	0.10	-0.12	0.10	-0.05	0.05
Oth_CEE_CIS	-0.01	0.07	-0.02	0.06	0.00	0.04	0.00	0.02
Oth_Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MEAS_NAfr	0.00	0.03	0.00	0.03	0.00	0.02	0.00	0.01
S_S_AFR	0.00	0.18	0.01	0.20	0.02	0.17	0.05	0.07
Oceania	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.02
Global	0.14	0.86	0.13	0.87	0.11	0.89	0.59	0.41

Effect of Armington trade specification on land trade pattern

- The composition of trade is sticky
- The stickiness depends on trade elasticities
- Make elasticities very high to mimic situation when goods coming from different sources, including domestic, are perfect substitutes
- Whether the Armington structure increases or decreases net global land requirement relative to the integrated world market assumption depends on relative yields
- Net global land requirement under Armington relative to global market assumption for agricultural land based goods
  - EU wheat ethanol: 4% less
  - EU oilseeds biodiesel: 3.82% more
  - US corn ethanol: 20% less
  - Palm oil biodiesel: 10% less

Limitations

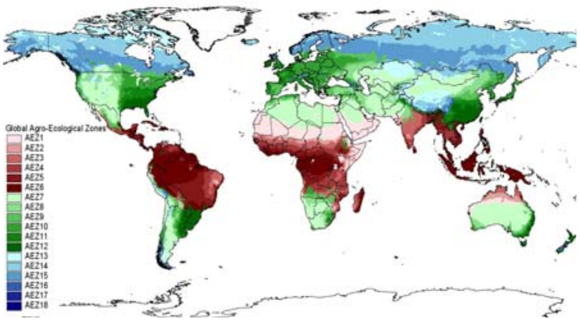
- No unmanaged land (only land that generates rents)
- Constant elasticity of transformation function allows only to look at net changes in land cover => move to full transition matrices
- Uncertainty regarding the ratio of the yield on the new cropland to the average yield of existing cropland
  - One for all regions

Thank you!

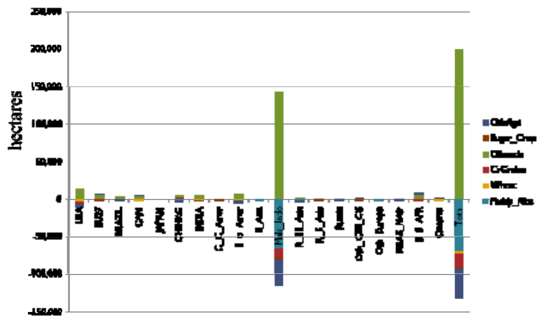
Questions
Comments

golub@purdue.edu

Global Distribution of AEZs

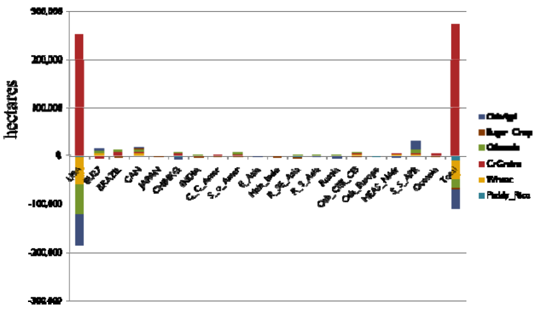


Changes in harvested area due to extra palm oil biodiesel



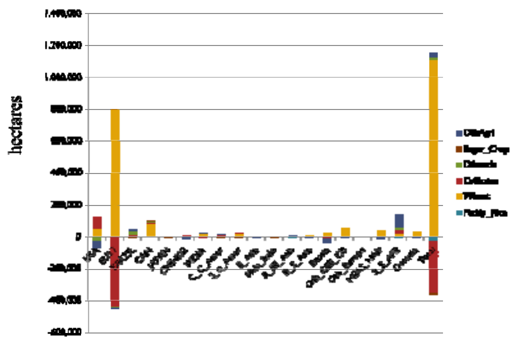
Net change in global cropland 68,480 ha

Changes in harvested area due to extra US ethanol



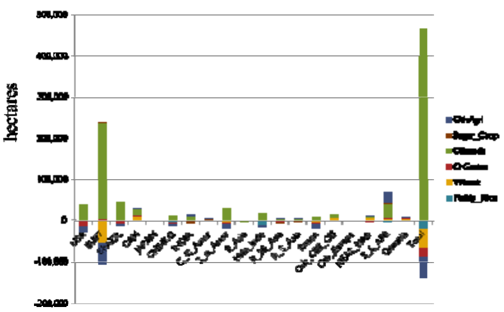
Net change in global cropland 164,680 ha

Changes in harvested area due to extra EU wheat ethanol



Net change in global cropland 794,454 ha

Changes in harvested area due to extra EU biodiesel



Net change in global cropland 330,880 ha

Emission Factors (EFs)

- Constructed by colleagues at Energy Resource Group at Berkeley; documented in California's Low Carbon Fuel Standard and forthcoming Hertel et al. (2010) in BioScience
- EF for each type transition predicted
  - forest-to-crop, pasture-to-crop, and pasture-to-forest for each region
- Account for changes in above- and below-ground carbon stocks as well as changes in 30 year carbon sequestration
- Most of the emissions occur in the first few years after land conversion due to aboveground biomass loss, while oxidation of soil carbon and avoided sequestration can continue for decades

Emission Factors (EFs)

- The GTAP model estimates changes in the economic use of land (i.e. among forestry, cropland and pasture uses)
- In general, there are many ecosystems (specific types of forest, grassland, savannah, or wetland) within a given region, each with unique profile of carbon stocks and sequestration rates
- To estimate which ecosystems are likely to be converted, the model developed by Searchinger et al. (which relies on data compiled by the Woods Hole Research Institute) was adapted with the following modifications:
  - Include carbon stocks in replacement crops
  - 10% of forest biomass is sequestered in timber products, and 90% is oxidized

11. Preliminary Analysis of Indirect Land Use Change for the EU using the GTAP Model (Stefan Unnasch – Life Cycle Associates)[16]

Stefan Unnasch of Life Cycle Associates (LLC) presented the preliminary analysis of evaluating the effects on crop prices, crop production per region, iLUC and iLUC emissions for major biofuel feedstocks in the EU. This analysis was undertaken using the GTAP model that was developed and configured for iLUC analysis for the California Air Resources Board (ARB). The general approach taken to evaluating iLUC was to calculate land selection (modelled in GTAP), and carbon release (using ARB carbon factors) over a 30 year time scale. The general equilibrium GTAP model tracks factors of production, different industrial sectors, taxes etc to provide outputs of value added, tax revenue and employment. Of interest to this analysis is the GTAP inventory of land within the equilibrium model that shows the shifts of agricultural commodities. GTAP has been run for ARB initially using the GTAP 2001 database (for ethanol), and more recently biodiesel using the 2004 database. The ARB setup was applied to EU scenarios.

The results presented here focus on corn (maize) in the EU. The GTAP runs were undertaken for corn ethanol using the GTAP7[17] database and data for 2004, and demand shocks applied. The GTAP results for land cover change were then multiplied by the ARB carbon emission factors and divided by the 30 year time horizon. The response to production volume was solved using the linear Johansen method and a variation of the non-linear Euler's method.

Results.

The first exercise was to use the GTAP model to replicate the Californian Low Carbon Fuel Standard (LCFS) scenario case for corn ethanol in the US. The GTAP model was then run with a shock for EU ethanol from corn and a shock for EU ethanol additional to US corn. The results show that there is a significant response to ethanol production volume. If the EU demand is added to the US demand then that has a significant impact on iLUC emissions per MJ.

Global changes in land area show that converted land for the EU comes from either converted pasture or forest. The biodiesel and ethanol scenarios in the EU both produced greater changes in land use from converted forest than in the US, which may reflect the lack of available land in the EU. For the scenario of EU corn ethanol much of the corn comes from the US. A significant fraction of the land change also comes from other grains (wheat) which could represent a long term substitution effect (see Figure 13)

[16] Detailed report is available on CIRCA
[17] Alla Golub queried if it was actually the GTAP 6 database that was used.

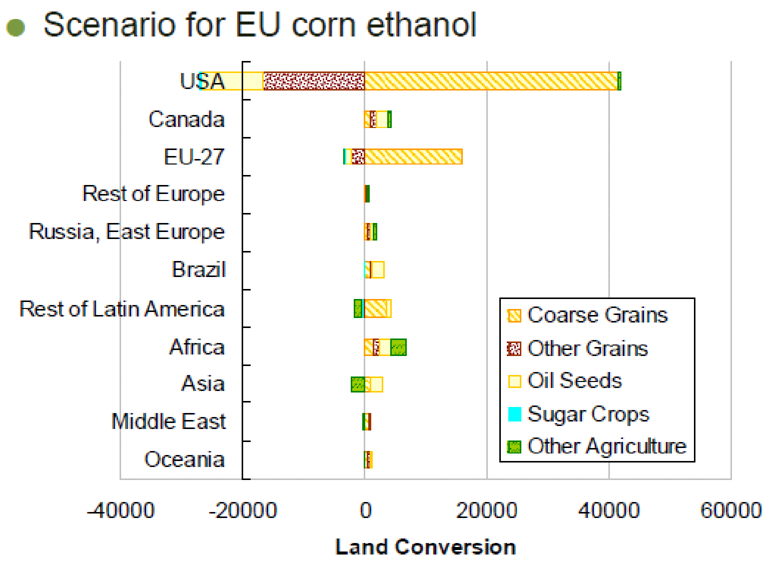


Figure 13 Global changes in land

Validation and modelling issues.

Process parameters need to be related to monetary parameters (GTAP inputs) to make better comparisons. GTAP does not explicitly model explicitly fertiliser production, which should be considered as part of the indirect effect. There are many other indirect effects linked to biofuel production that need to be considered such as increased fertiliser, type of process fuels used in biofuel production, transportation logistics, crop effects (*e.g.* price rationing, expand use of co-products) and forestry. One thing that is really missing is the estimate of above ground carbon.

Conclusions

It was found that GTAP predicts well the land cover changes for various crop types. For the EU corn ethanol scenario the GHG factor was in the range of ARB LCFS runs. There is a lot of variation in the carbon stock parameters and the effect of 2001 vs. 2004 economy needs to be addressed. There were significant differences in forestry conversion compared to U.S.

Preliminary Analysis of Indirect Land Use Change for the EU using the GTAP Model

Stefan Unnasch
Life Cycle Associates, LLC
10 February 2010

Outline

- GTAP Runs for EU
  - Marginal iLUC
  - Biofuel sectors
  - GTAP results
- Other Indirect Effects
- Conclusions

General Approach to iLUC

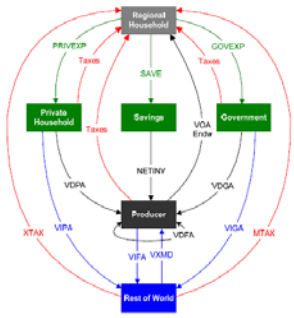
Land Selection → Carbon Release → GHG Inventory & Time Horizon → **iLUC CI**

Inputs to this study

GTAP | **ARB Carbon Factors** | **30 years**

General Equilibrium

- Economic impacts
- Modeling outputs
  - Value added
  - Tax revenue
  - Employment
- Shifts of agricultural commodities



ARB LCFS GTAP Models

Fuel	Biofuel Sector
Corn Ethanol	Ethanol1
Sugar Cane Ethanol	Ethanol2
Soy Biodiesel	Biodieself

Scenarios of Interest

Ethanol Feedstocks	Biodiesel Feedstocks
Wheat	Rapeseed oil
Corn	Palm oil

Life Cycle Associates GTAP Model

Economic Sectors

- Sectoral representation for factors of production
- Monetary data for producers, consumers, etc.
- New fuels are not represented in the model
- Develop new sector and adjust all other sectors

VDFA	7 EthanolC	9 Biodiesel	15 Oil
1 CrGrains	96.4	0	0.4
2 OthGrains	0	0	0.2
3 Oilseeds	0	347.2	0.1
4 Sugarcane	0	0	0.1
5 Livestock	0	0.1	2.7
6 Forestry	0	0	0.9
7 Ethanol2	0	0	0
8 OthFoodPdts	0.3	16.6	20.5
9 ProcLivestoc	0.1	0.2	19.1
10 OthAgri	0.2	0.1	15.6
11 OthPrimSect	0	0	10.3
12 Coal	0	0	0
13 Oil	0	0	6.2
14 Gas	0	0	396.7
15 Oil_Pcts	0	0	7
16 Electricity	30.4	25.6	137.3
17 En_Int_Ind	19.4	91.9	118.8
18 Oth_Ind_Se	7	9.6	4433.5

VDFA = Intermediates - Firms' Domestic Purchases at Agents' Prices

7

Life Cycle Associates Scenarios

GTAP Runs

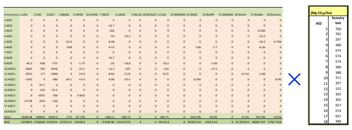
Parameter	Values
Fuels	Corn ethanol
Database	GTAP 7 2004 data
Regions	U.S., EU
Demand shocks	100% to 1500% 757% U.S. + 100% EU

- Replicate ARB analysis
- Examine marginal EU Cases

Life Cycle Associates GTAP Analysis

GHG Emissions from Land Cover Change

$$CI\ ILUC = \Sigma(F \times EF_F + P \times EF_P - FG \times EF_{FG})_{AEZ} \div \tau$$



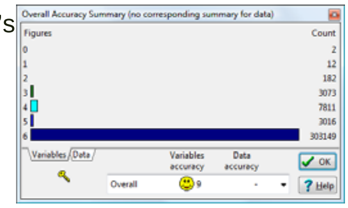
× ÷ 30

- Replicate ARB analysis
- Examine marginal EU Cases
- External to GTAP

Life Cycle Associates GTAP Analysis

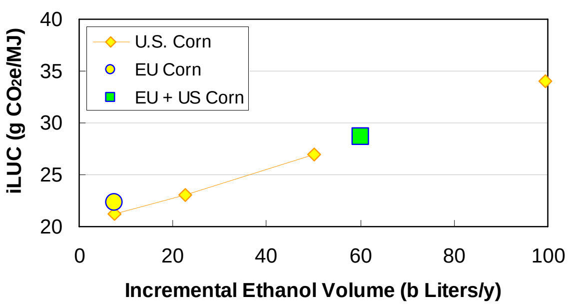
Response to Volume

- Linear Solution
  - Johansen method
- Non-Linear Solution
  - Gragg method
  - Variation on Euler's method



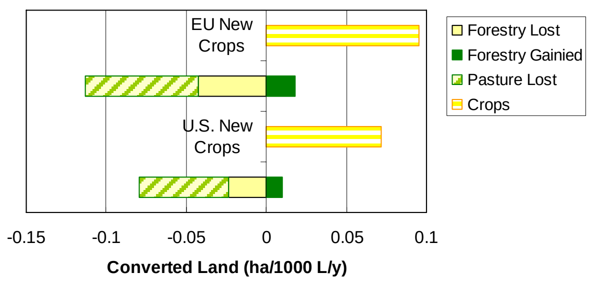
Life Cycle Associates Results

iLUC Results



Life Cycle Associates Results

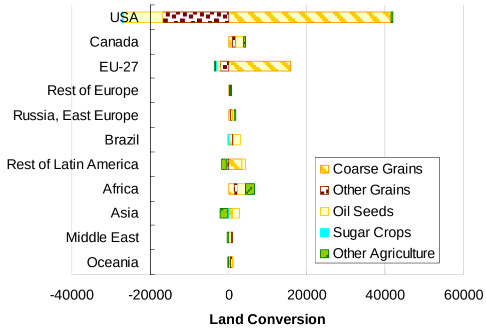
Global Changes in Land



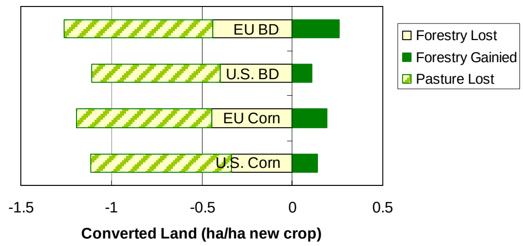
12

Global Changes in Crops

- Scenario for EU corn ethanol



Changes in Land Type



Validation Checks

- GTAP inputs are monetary based
- Compare process inputs to model parameters
  - e.g. natural gas use, DGS yield
- Examine crop iLUC
  - Partial equilibrium approach
  - Disaggregates biofuel from co-products
  - Disaggregate biorefinery and crop effects

Modeling Issues

- Biorefinery operating parameters
  - Process fuels
  - Co-products
  - Fertilizer
  - Reporting and translation of process inputs to economic parameters
- Price induced yield
- Non equilibrium prices

Soil Carbon

- Factors based on Woods Hole analysis
- From ARB LCFS
- 25% of below ground

Emission factors (Mg CO_2e/ha)

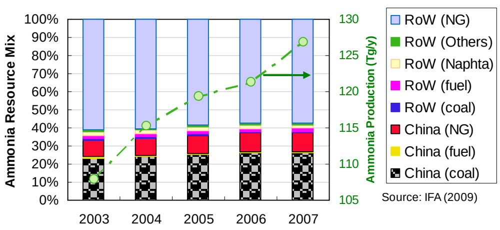
Region	forestry lost	forestry gained	unmanaged land	crops	livestock
1 USA	760	219	0	18	106
2 CAN	705	434	0	18	196
3 EU27	297	362	0	18	156
4 BRAZIL	388	164	0	18	72
5 JAPAN	574	223	0	18	85
6 CHIHKG	574	223	0	18	196
7 INDIA	574	223	0	18	196
8 LAEEX	388	164	0	18	72
9 RoLAC	388	164	0	18	72
10 EEFSUEX	311	392	0	18	156
11 RoE	297	362	0	18	156
12 MEASTNAEX	152	59	0	18	82
13 SSAEX	305	129	0	18	43
14 RoAFR	305	129	0	18	43
15 SASIAEEX	937	337	0	18	85
16 RoHIA	574	223	0	18	85
17 RoASIA	937	337	0	18	85
18 Oceania	388	198	0	18	98

Other Biofuel Indirect Effects

- Biofuel production
  - Fertilizer
    - Coal based fertilizer
  - Process fuels
    - Limited natural gas resources
      - Impacts on power sector, home heating
      - New natural gas resources
        - LNG and Fractured shale
  - Transport logistics
    - Reduced crude oil transport
    - Changes in agricultural goods movement
- Crop effects
  - Price rationing
  - "New" economy
  - Expanded use of co-products
- Forestry
  - Avoided wildfire risk
  - Lumber products
  - Methanogenic activity
- Avoided petroleum indirect effects

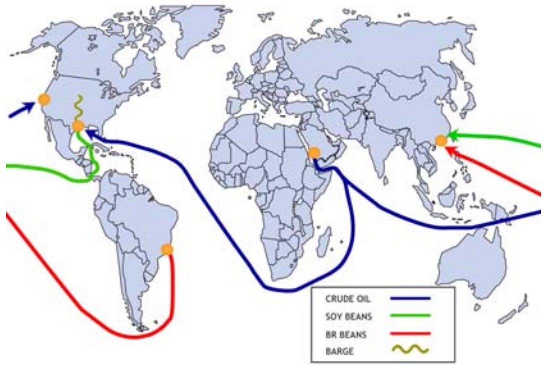
Fertilizer Production

- Growth in Coal Based Fertilizer



Source: IFA (2009)

Transport Logistics



Conclusions

- GTAP predicts land cover changes for various crop types
- Results similar to ARB LCFS runs
  - 25 to 35 g CO_2e/MJ range for corn ethanol
  - Variation in carbon stock parameters
  - Effect of 2001 vs 2004 economy?
- Differences in forestry conversion compared to U.S.
- Marginal results should reflect cumulative feedstock demand
  - Consider global demand for biofuels

Recommendations

- Biorefinery configuration
  - Relate process parameters to economic parameters
- Disaggregation
  - Examine intermediate values
    - Ha/1000 L
    - Relate process inputs to monetary units
    - Other intensity metrics
  - Biorefinery independent LUC calculations
  - Compare model results on a consistent basis
- Uncertainty
  - Recognize model limitations
  - Consider GTAP model years as surrogates for different economic situations

12. Biofuels, Crop Yield, and Land Use: How Can We Learn From Data? (Steve Berry - Yale University, Department of Economics)

In order to analyze bio-fuels, we need to know the empirical magnitude of elasticities of supply, yield and land-use. For iLUC it is important to know how yield and land use respond to price changes, caused by changes in demand.

Elasticities

All of the economic models are trying to model the fact that price, quantity, yield and land use are jointly and simultaneously determined in equilibrium. However, it is not only in the model that these factors should be jointly and simultaneously determined but also in the actual data that is observed. Traditional regression analysis will not reveal any information with regards to a large change in exogenous demand. The instrumental variables (IV) solution to this problem says that to study supply what is needed in the data is a plausible exogenous source of change in demand that is not determined within the system. It is the change in demand that traces out production relationships, whilst changes in supply might be used to trace out changes in demand relationships. When there is no distinction between supply and demand, neither production nor supply is traced out.

Different empirical approaches will identify short-run elasticities versus long-run elasticities. For biofuel policies, that are expected to be maintained in place in the long term, it is important to have long run elasticities. However, most recent studies ignore simultaneity and many just focus on short-run elasticities.

In every sub field of empirical micro economics the use of IV methods to solve the endogeneity problem are at the heart of the endeavour. We need to know:

- What is the instrument?
- Why is it exogenous?
- Why does this mimic the policy under concern?

Any serious empirical work should start with the question of what is the exogenous change in demand that tells us we are getting production instead of demand.

CARD-FAPRI.

The FAPRI-CARD model makes a distinction between long and short run elasticities. They have current but also a long lag in price cost margins. The model can be used to answer economic concepts such as how does area affect yield. The difficulty in characterizing the FAPRI-CARD model is that all the variables including area are endogenous. Area should not be treated as being pre determined with respect to yield.

Conclusions

Any reasonable study that is being used to obtain elasticity has to address the problem of endogeneity and simultaneity upfront. Lagging price is not the solution. Studies that do not address this problem do not provide any evidence about causation. Instead they only provide evidence about within sample correlation, which is only useful as long as the mix of supply and demand factors is not going to change. However, for iLUC we do need to address the question of a big change in demand factors. What is needed is an IV method that shifts demand while not being correlated with measured supply factors. Perfect instruments are difficult or impossible to find, but fairly rapid progress could be made toward better practices.

In the bio-fuels context, long-run elasticities are essential. If time-series data is to be used then either use a model of partial adjustment of land-use or consider how to use the very rich cross-sectional variation in land-use (using the experience of the modellers here) to draw out the responsiveness of land use to different conditions (*e.g.* if policies or transportation induce exogenous price differences.)

IV methods are not difficult, although finding good instruments and interpreting IV results requires care. To deal with long-run elasticities, there are long-term land-use studies completed and in-progress, which need to be modified for the question.

JRC Comment*: interpretation of the above could be:*

Steve Berry's intention was to focus on the reliability of the parameters that are embedded in the typical simulation model. Thus, it related to an issue that lies 'outside' any particular simulation model or the use of any particular model for simulation, and instead discussed one of the steps underlying the construction of simulation models generally.

His underlying assumptions were:

1. *In simulation models, the response parameters (e.g. supply and demand elasticities) are (usually) estimated econometrically from time series data.*
2. *Econometric estimation of these parameters is usually performed using simple econometric models in which there is simultaneity (i.e. causality runs not only from right to left in the equation, but also from left to right). Of course, it is well known that in these circumstances basic multiple regression techniques provide biased estimates.*
3. *Agricultural economists/CGE modellers are unaware of this, and they are still deriving their estimates (which are then transferred into simulation models) using these biased techniques.*
4. *Consequently, their models incorporate biased and hence unreliable parameters.*
5. *Econometric techniques (based on the principle of Instrumental Variables) exist for overcoming this problem.*

In the discussion, it was argued that point 1 and point 3 misrepresent the real situation, in that (a) many response parameters in these models are not even econometrically estimated but (worse?) are simply guesstimates or are obtained empirically by other means, and (b) agricultural economists have been aware – and have responded to – the simultaneity issue for as long as any other kind of economist (i.e. > 40 years). Nonetheless, point 4 may still be generally true, as parameterization of large-scale models is often quite crude, and there are many reasons why parameters may be unreliable. His general message – that modellers must continue to critically assess and try to improve the parameterization of their models - is a very good one.

Biofuels, Crop Yield, and Land Use: How Can We Learn From Data?

Steven T. Berry
James Burrows Moffatt Professor of Economics
Yale University and NBER

February 11, 2010

Idea

To analyze bio-fuels, we need to know the empirical magnitude of elasticities of supply, yield and land-use. What does standard micro-econometric theory & practice tell us about how to do this?

- Review the most basic econometric principles for the empirical analysis of production and demand,
- Ask whether recent policy oriented empirical work respects these principles,
- Make suggestions for further progress.

Key points

1. Price, quantity, yield & land-use are jointly and *simultaneously* determined in equilibrium.
   - Therefore, correlations or traditional regression analysis of, e.g., price and yield reveal correlation, *but nothing about causation.*
   - Classic "instrumental variables" solutions to this problem say to study supply via plausibly *exogenous* changes in demand that can trace-out causal supply relationships.
2. Different empirical approaches will identify short vs. long-run elasticities. For bio-fuels, want the long-run elasticity.
3. Most recent studies ignore simultaneity and many focus only on short-run elasticities

Figure: Biofuels Increase Demand for Crops

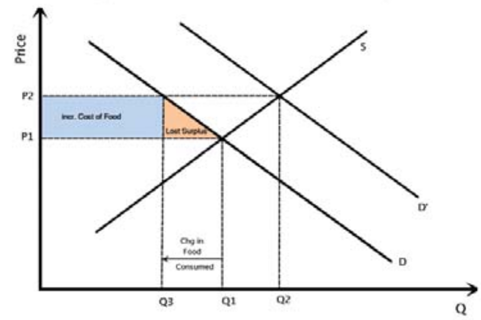


Figure: Elasticities Matter

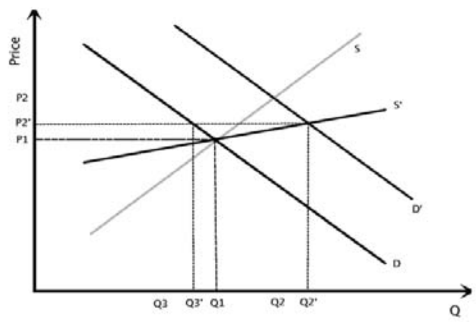
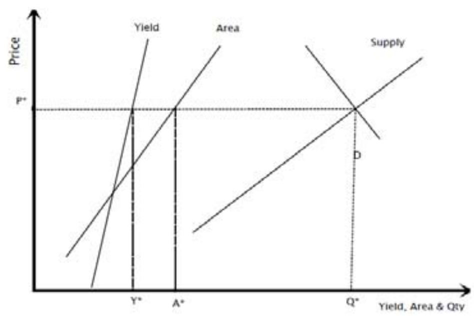


Figure: $Q_S = AY = Q_D$



S & D: from Theory to Data

H. Moore (1914) [4] estimated agricultural demand curves by regressing Q on P. Yield curves by OLS regression of Y on (lagged) P.

Finding:

- Ag demand curves slope down
- Manufacturing goods demand curves slope up! A "new kind of demand curve!"
- Yield Curves slope down (not robust to choice of lags?)

Explaining Moore

P.G. Wright (1915):

Crops:

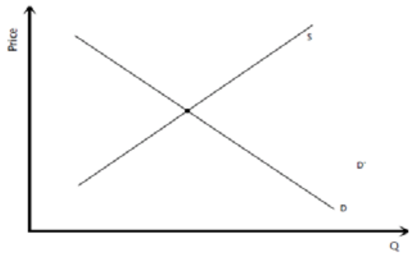
- large amount of variation is in supply (weather),
- S is changing greatly while D changes a little.
- Data traces out a demand-like curve

Manufactured Goods:

- large amount of variation is in demand (bus. cycle),
- D is changing greatly while S changes a little.
- Data traces out a supply-like curve

"What do Statistical Demand Curves Show"

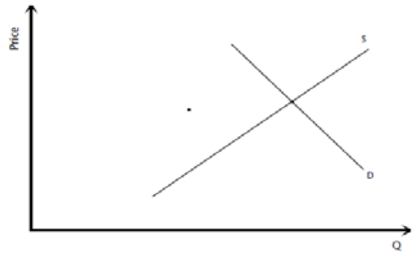
Working (1927)



What does best-fit line through S & D data show?

"What do Statistical Demand Curves Show"

Working (1927)



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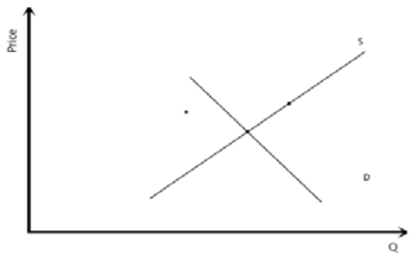

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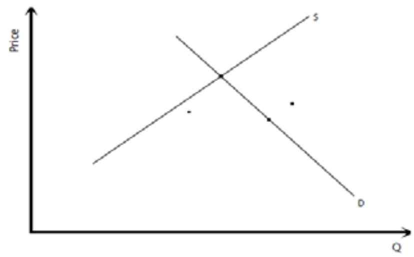

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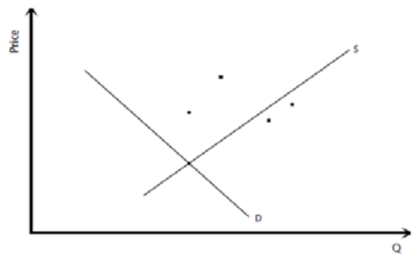
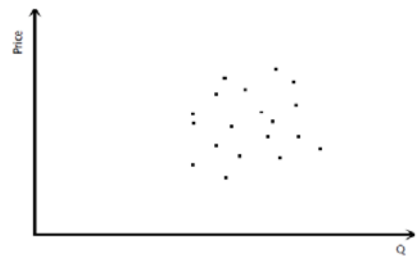


What does best-fit line through S & D data show?

"What do Statistical Demand Curves Show"

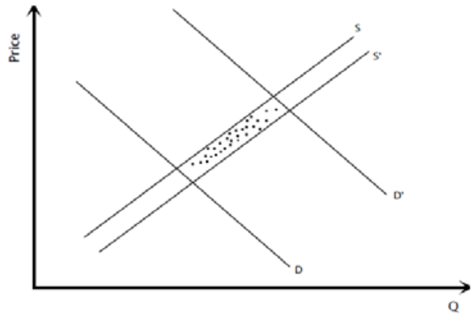
Working (1927)



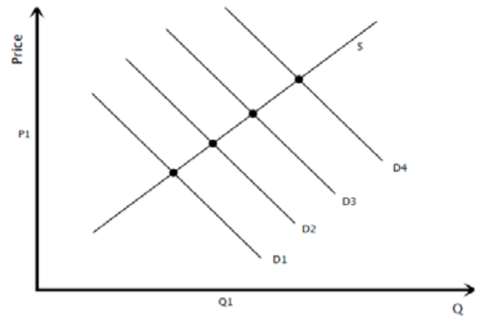
What does best-fit line through S & D data show? *Nothing*

S changes little: almost get *S*

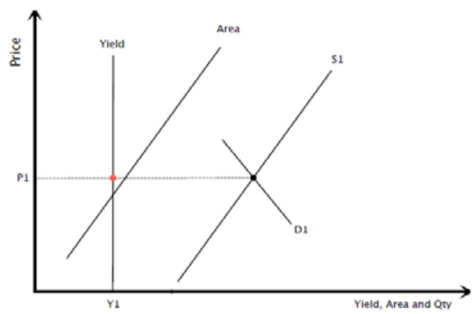
Figure: *D* Changes More Than *S*



Unlikely Case: Only *D* Changes to Reveal *S*

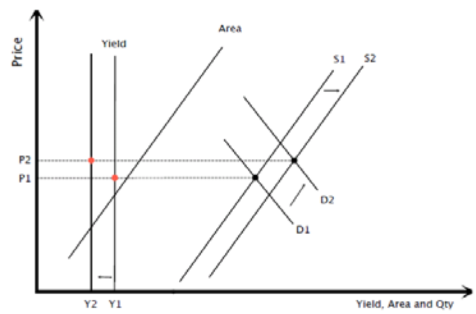


Data from Equilibrium Yield and Price



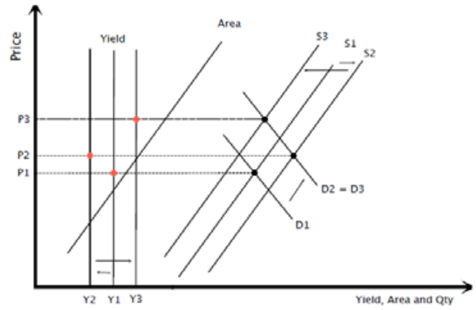
First Data Point

Data from Equilibrium Yield and Price



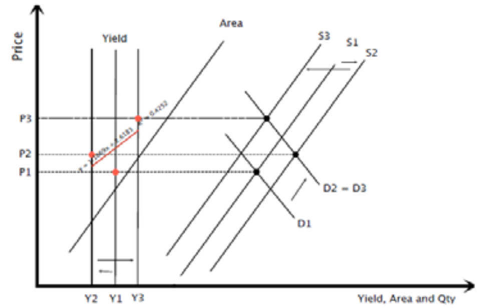
D increases, *Y* decreases

Data from Equilibrium Yield and Price



Y increases

Data from Equilibrium Yield and Price



Add Regression Line: Incorrect Slope

OLS on the Yield Curve

Estimating a constant-elasticity yield curve:

$$ln(q_t) = \beta_0 + \beta_z z_t + \beta_t t + \beta_p ln(p_t) + \epsilon_t.$$

We want the true "structural" supply curve, that stays constant as D shifts to get the correct counter-factual effect of bio-fuels.

Condition for OLS to be correct:

RHS variables have to be uncorrelated with ϵ_t, which captures the unmeasured supply shifters

But price is determined in part by ϵ_t: *Simultaneity* problem.

Lagged Price

Does using lagged price, p_{t-1} solve the problem? After all, supply today does not *cause* last year's price.

The correlation of p_t with p_{t-1} means that incorrect inferences using p_t may be repeated when using p_{t-1}.

Once again, we need a theory of why p_{t-1} matters: because it predicts p_t. If it predicts p_t, that is because some elements of S and D from period $(t-1)$ will persist into period t.

BUT: are these persistent elements from S or D?

Example

Suppose for some sub-periods of time there is a rapidly diffusing new technology (new resistant seed.) In these periods output grows fast and p_{t-1} and p_t are falling faster than average trend, while yield y_t and land-use a_t are growing above trend. At other times, slower tech growth. This creates a negative correlation between p_{t-1} and a_t that is similar to the simultaneous correlation.

This is a general problem that lagged prices will be *endogenous* in the sense that they are correlated with unobserved factors at time t. (And if they are not, then they should not predict time t outcomes.)

Instrumental Variables

P. G. Wright (1928): to estimate production, need a variable that shifts demand on average, while not affecting supply. (True for p_t and for p_{t-1} and for $t-1$ futures prices.)

An instrumental variable
for price in the supply equation is a demand shifter that

1. is not also a supply shifter (i.e. is "excludable" from supply),
2. is not correlated with the supply side unobservables (i.e. is "exogenous"), and
3. is correlated with price (because it is shifting demand and therefore equilibrium p.)

Wright's 1928 Instruments

- To learn S, need an exogenous demand-side shifter that is excluded from S.
- To learn D, need an exogenous supply-side shifter that is excluded from D.

To estimate the S and D for crops, Wright used as "instruments"

- "Weather" (actually, yield) as supply-shifter to learn D, and
- Price of a substitute crops as a demand-shifter to learn S.

Critique

Actual weather would be better than yield, which may be endogenous, and weather affecting the substitute crop would be better than price of the substitute

IV as "Natural Experiments"

One interpretation of instrumental variables (IV) is that we are looking for "natural experiments" as instruments. In this case, we want the natural experiment to mimic, as much as possible, the effect of greatly increased bio-fuels use. See Angrist and Krueger (2001) [1] and (for a plea to keep IV reasoning close to economic logic) Rosenzweig and Wolpin (2000) [8].

IV in Modern Econometrics

Instrumental Variable methods have been at the core of modern micro-econometrics since the work of the Cowles Commission in the 1940-50s. But for some time in the 1960s-1980s, solutions to the problem of endogenous variables were "honored in the breach" by some sub-fields, which concentrated on various other problems.

Recently, the problem of endogenous variables is at the forefront of almost all fields of micro-econometrics, with the use of IV methods, panel data methods and (more recently) field experiments as the usual solutions.

Some part of applied empirical agricultural economics seems to have missed these developments.

Exogenous Changes in D

Any serious empirical work

on the question of estimating production relationships has to begin with the question of how to deal with the problem of endogeneity. What is the exogenous change in D that traces out supply?

Or at least: what other method and set of assumptions justifies some other approach?

Example: Schlenker & Roberts, 2009

Schlenker & Roberts ([11], [9]) develop an IV method for the S & D of crops, with

- Current weather as supply shifter,
- Past weather effects as demand shifter – past weather creates current inventories and so is claimed as a current demand shifter.

Problem in current version: yield is proxy for weather. Supported by large cross-sectional variance in yield, indicating yield is not *primarily* function of common world price. But yield could still be partly responsive to price and therefore endogenous.

Better suggestion: same authors [10] show large effect of # very hot days on yield, this would make better instrument and is also used in work-in-progress.

Instrumenting changes the magnitude of the supply elasticity by a **factor of 4**. Still very inelastic S: very bad news for consumer price effects.

Other Possible Instruments

In a time-series or cross-section:

- Changes in Farm Policy? (Plantinga (1996) [7] uses changes in diary price supports in a land-use study)
- Transportation costs? (Pfaff (1999) [6] looks at cross-sectional variation in Brazil.)
- Changes in Tariffs / Trade?
- Changes in bio-fuel demand? (maybe not yet)

Additional Concern: Long vs. Short Run Elasticities

Particularly for land-use elasticities, looking for long-run effect of an expected long-run change in price that comes from a long-run increase in bio-fuels.

Annual time-series studies, at best, get short-run effects, likely to greatly understate long-run change in land use.

In the ag literature: Nerlove (1956) [5] suggests a partial adjustment model of slow adjustment to long-run equilibrium. Many "modern" improvements, e.g. Eckstein (1985) [2].

Long-run studies of cross-sectional land-use may be better than time-series (Stavins & Jaffe (1990) [12], Pfaff (1999), etc.)

Long-run vs. Short-run and Choice of Data

Cross-Sectional Data
(or a combination of cross-section and time-series) may be best for the study of long-run land use. Time-series models at least have to take account of slow adjustment.

Additional Issues for Another Day

These include:

- Substitution across crops rather than to / from agricultural use.
- Time Series Analysis and Co-trending Unobservables
- Heterogeneity in Production vs. the "Representative Farmer"
- Aggregation across Regions
- Broader General Equilibrium effects when using world or national level data.
- Risk Aversion and Expected Profits.

Application to Lywood, Pinkney and Cockerill (2009.)

LPC (2009) [3] use

- time-series data on yield, land-use, price,
- bivariate least-squares analysis,
- *no* shifters of D or S (t shifts price, but not technology)
- no discussion of casuation vs. correlation,
- no instrumental variables or discussion of S vs. D,
- no discussion of long-run land use,
- focus on yield and acreage elasticity (warming effects) not total supply = yield*acreage (consumer price effects)

In method, LPC (2009) is very close to Moore (1914). Moore regressed yield on averaged-over-time lagged price, without knowing about IV methods.

OLS on the Yield Curve

Compare LPC to a classic constant-elasticity yield curve:

$$ln(y_t) = \gamma_0 + \gamma_z z_t + \gamma_t t + \gamma_p ln(p_{t-1}) + \nu_t.$$

OLS is not correct if p_{t-1} correlated with ν_t The residual includes: input prices, government ag policies, diffusing technologies. LPC have no supply shifters and no technology trend (although price is detrended.) Also, y_t and p_{t-1} are replaced with 4-year average changes.

Averaging y and p over time

LPC's regression contains changes in y and p averaged over time, perhaps to reduce dependence on single-year measures and/or to "control for" auto-correlation (which is not a big problem in the *absence* of endogeneity problems.)

LPC use 4-year average percentage changes, with the price construct lagged by one period. This means that $y_{t-1}, y_{t-2}, y_{t-3}$ (plus y_t) are used on the left-hand side of the equation while $p_{t-1}, p_{t-2}, p_{t-3}$ (plus p_{t-4}) are used on the right-hand-side of the equation, *reproducing much of the same-year simultaneity problem.*

We have already seen that unaveraged y_t on p_{t-1} is not right, either.

Region-Specific Yield-Area Equations.

At the region level, LPC regress yield on area, rather than yield and area regression on price. Obviously, yield and area are completely co-determined and now an IV strategy is even harder to imagine.

Why yield on area and not area on yield?? Indeed, the regression only makes sense if area is exogenous to any omitted shock to yield (including price!). This undermines the very purpose of the analysis.

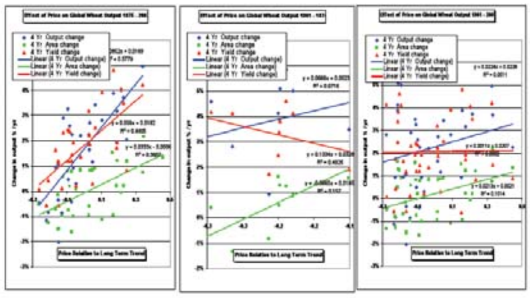
Implicit argument (?): both are driven by price. But also by much else!

LPC try to get back to the question at hand via the accounting identity

$$Y = Q/A$$

but this reinforces the joint determination of the two.

Trends in yield and area vs. price before and after 1974, and whole data series 1961-2007



Other Studies: CARD -FAPRI

OLS regression of yield on trend, current and past (10-yr ave) price/cost margins, own-crop area, total-crop area.

All the RHS variables other than trend are endogenous in models, but for OLS have to be exogenous (uncorrelated with unobserved residual in yield equation.)

Should the regression be yield on price & area *or* price on yield & area *or* area on price & yield?

Not estimating the "structural" yield function, just partial correlations.

Suggestions for Further Progress

- Any reasonable study has to address the problem of endogeneity / simultaneity. Lagging price is not a solution.
- Studies that do not address this problem do not provide *any evidence* about causation, as opposed to correlation.
- What is likely needed is an "instrumental variable" that shifts demand while not being correlation with measured supply factors.
- "Perfect" instruments are difficult or impossible, but fairly rapid progress could be made toward better practices.
- In the bio-fuels context, long-run elasticities are needed.
- With time-series data, we need a model of the slow adjustment of land-use. Else, consider the use of study cross-sectional land-use (if policies or transportation induce exogenous price differences.)

Can We Wait for Better Research?

IV methods are not difficult, although finding good instruments and interpreting IV results requires care. To deal with long-run elasticities, there are long-term land-use studies completed and in-progress, which need to be modified for the question.

Moving forward on the basis of results that may be wrong in sign and/or order of magnitude will result in expensive and hard-to-reverse investments. The irreversibility of investment creates an option value to waiting for the inclusion of further existing research into the policy analysis. There is also an option value to waiting for the conclusion of new, perhaps in-progress, studies.

This option value obviously has to be weigh against the on-going march of climate change.

Waiting for Research?

Since the *sign* of the effect on climate change is in serious dispute and since many existing estimates indicate inelastic overall supply (and therefore large price increases), the argument for state-of-the art empirical research is especially strong.

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unpublished, Columbia University.

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Wolfram Schlenker and Michael J. Roberts.
World supply and demand of food commodity calories.
American Journal of Agricultural Economics, 91(5):1235–1242, 2009.

Robert N. Stavins and Adam B. Jaffe.
Unintended impacts of public investments on private decisions: The depletion of forested wetlands.
The American Economic Review, 80(3):337–352, 1990.

13. Additionality, Land use change and dealing with uncertainties (Timothy D Searchinger, Princeton University)

This presentation focused on the following questions:

- What are we doing when we look at indirect land use change?
- Why do biofuels have the potential to reduce greenhouse gas emissions?

Additionality

Biofuel production does not automatically bring GHG gains from the energy or transportation sectors. The potential GHG gains from biofuel production and use come from offsetting the CO_2 emissions, via additional plant uptake or reduced decomposition. If you grow biofuels crops on uncultivated land, you will cause direct land use change. If you use crops grown on existing arable land for biofuels instead of food, this will cause indirect land use change because of the necessity to replace the food. This workshop is about the second case.

> "*if you are not using existing crops you have direct land use change, our conference is about indirect land use change which is when you use existing crops*"

Reduced Consumption:

One form of indirect GHG gain is where the crop is not replaced. Carbon sequestered by a crop grown for food is emitted back into the atmosphere via respiration from livestock and humans. If less of the crop is consumed a physical GHG gain is achieved from less carbon being emitted because people (and livestock) are eating less.

> *"if we eat less food, the physical gain comes from reduced respiration, the actual physical source of the gain is less carbon is going out of the mouths of people and livestock"*

If a price increase leads to lower food consumption then in theory this may result in a GHG gain. It should be noted that this gain does not take into account the amount of energy used for mining and refining oil to produce fossil based fuel.

Results from the GTAP run for corn in the US indicated that 52% of the change in emissions was due to reduced food demand. This result indicates that GHG reductions from corn will come mainly from reduced food demand. This is a really important fact to communicate to policy makers. However, when modelling such an effect it should be noted that simply closing a single function in the model (*e.g.* food demand) may not reflect the real situation.

Intensification

Another GHG gain could take place under intensification (e.g. increased prices causing farmers to improve yield). The physical GHG gain is that more carbon is being absorbed from the atmosphere on existing land, due to improved yields. However, to achieve the improved yields, inputs of N fertiliser inputs may increase which could in turn lead to higher N_2O emissions. The increase in N_2O emissions is important as these emissions could potentially exceed CO_2 emissions from land use change. It essential that the additional GHG emissions related to increasing the yield are taken into account in calculating the GHG balance of biofuels.

It has been suggested that the intensification effect is likely to be greater in developing countries than in developed countries because the yield is lower in developing countries and therefore the potential for intensification is greater. However, yields are mainly lower because there is more land availability. Area expansion is occurring where yields are lower, because that is where land is also available. Therefore there is no reason to believe that the potential for intensification is greater where yields are lower.

It is forecast that yields are not being increased sufficiently to meet increased food demands by 2020, so any increase in biofuel demand requires an additional intensification (more than double the rate of intensification is needed to keep up with biofuel demand).

Lessons to learn

1. There are no GHG benefits from biofuel production when only direct effects are accounted for.

2. All the uncertainties of calculating iLUC are the same uncertainties used to calculate the indirect benefits because the yield, demand and land use responses are all aggregate functions of each other.

3. The fundamental error in estimating the gains from biofuels was the assumption that the carbon is free in the feedstock. In the iLUC process it is additionality in the feedstock that counts.

Additionality from co products

When land use change occurs on existing agricultural land (e.g. corn to switch grass) there is additionality because of the additional carbon uptake from the higher yielding biomass crop. A large part of additionality comes from harvesting the whole crop, and not leaving a large part of the crop as residue which subsequently decomposes on the ground. For example, when sugarcane is harvested part of the crop can be turned into bagasse which provides an additional energy source. The GHG calculations should include a carbon credit for the bagasse as well as for the sugar content. It is important to note that it is the co product, in this case the bagasse produced from the crop residue, which provides the additional GHG gain.

Variation in modelled results.

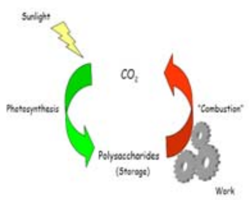
There are differences between the PURDUE analysis and the FAPRI-CARD analysis, where only 10% of the land use change comes from pasture. That is a direct result of the FAPRI function for area expansion that is a function of a constant elasticity of transformation. This function is derived from US data using correlation analysis[18] as applied to every region of the world and is a function of the amount of returns to pasture and forest in those areas. In contrast, PURDUE did not estimate area intensification economically but identified the sources of cropland in the 80s and 90s, and making the assumption that the future situation would be the same. This methodology has obvious limitations. The best way to deal with these uncertainties is to look at the different models and to see what they have to say about each of these different effects.

[18] Refer to Steven Berry's presentation on limitations of correlation

Biofuels & Greenhouse Gases

Conventional approach

Combustion of biomass provides carbon neutral energy



But . . .

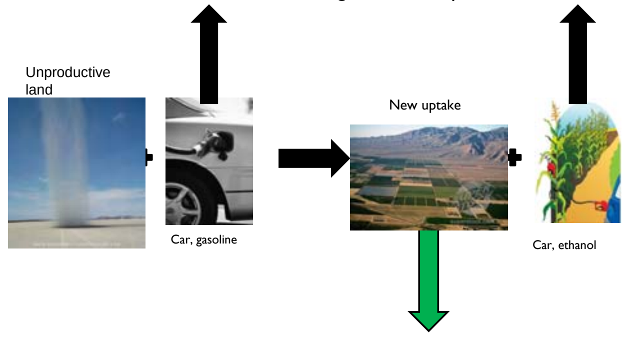
Land grows plants (carbon) anyway

* forest
* food

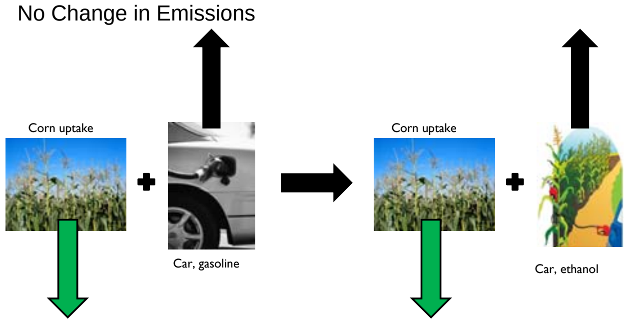
Only ADDITIONAL carbon counts

* more plant uptake
* less decomposition

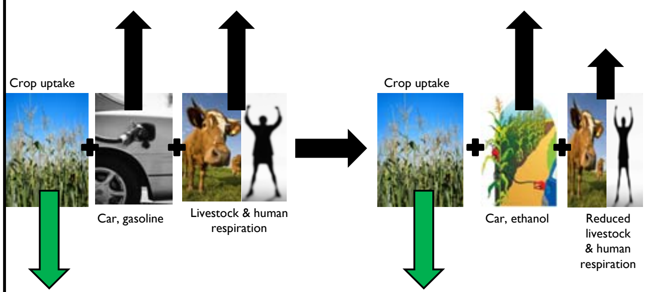
Growing Biofuels on Otherwise Unproductive Land – Reduced emissions through carbon uptake



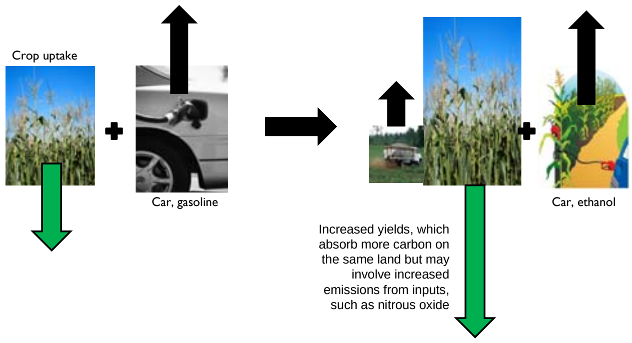
Direct Effects of Diverting Crops to Biofuels – No Change in Emissions



Indirect Scenario 1 – Ethanol Leads to Less Crop Consumption for Food, which Reduces CO2



Indirect Scenario 2 – Ethanol Leads to Yield Growth on Existing Farmland to Replace Diverted Crops, which Absorb More Atmospheric Carbon and Reduces CO2



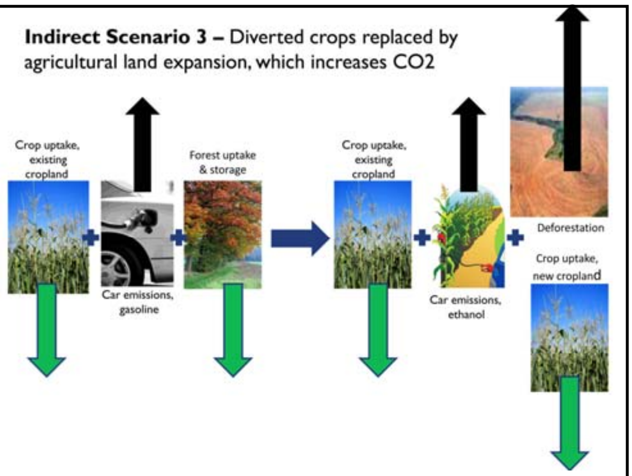
GHGs from Nitrous Oxide For Yield Gains

Through Fertilizer (assuming 7 extra additional lbs of fertilizer/bushel of corn)

N_2O Formation Rate	Greenhouse gases (CO_2 eq.)/km
2%	401
3%	603

Compare 316 g/km from land use

Indirect Scenario 3 – Diverted crops replaced by agricultural land expansion, which increases CO2



Lessons

- When there is no direct land use change because existing crops are used:
  - There are no greenhouse gas benefits if you don't count indirect effects.
  - Uncertainties with ILUC apply equally and symmetrically to analysis of GHG benefits.

Error is assuming feedstock carbon is free (neutral).

ILUC is the way you determine additionality of feedstock.

Potential GHG Reductions When Existing Crops Are Used

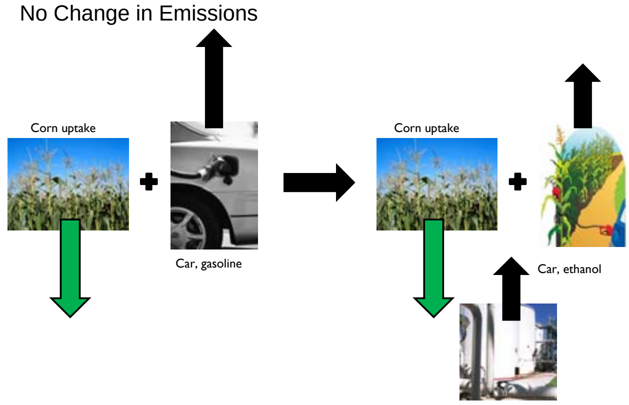
- Reduced crop consumption (or less polluting livestock)
  - Less land, fewer inputs, less methane
- Price-induced yield gains
  -- Greater carbon absorption
  but increased N_20 energy
- Net positive indirect land use change
  -- Increased productivity on land expansion (mainly theoretical)
  -- Reduced land through higher value DDG replacement (high protein meal)
  but probably negative as a whole

Additional Possible Benefits When New Crops are Grown on Existing Cropland

E.g., switchgrass, sugarcane

- Possible higher yields/NPP
- Utilization of entire crop (not just grain) and reduced decomposition emissions

Direct Effects of Diverting Crops to Biofuels –
No Change in Emissions



Different questions:
(1) What are consequences of biofuel increase? v.
(2) What are consequences if we hold X (e.g. food demand) constant?

(1) Effect	Reduced Food Demand	Intensification	Improved Livestock Feeding Efficiency	Extensification
Elasticity % Change in Output	.3	.3	.1	.3
Real % Effect	30%	30%	10%	30%

(2) Effect	Reduced Food Demand	Intensification	Improved Livestock Feeding Efficiency	Extensification
Elasticity	0	.3	.1	.3
Calculated % Effect	**0%**	43%	14%	43% (+13%)
Attributed % Effect	**13%**	-	-	**30%**

Alternative

- Reduced in feed & food consumption
- Reductions in hectares & emissions reductions because of reduced feed & food
- Quantify total hectares "saved" by price-induced yield increases

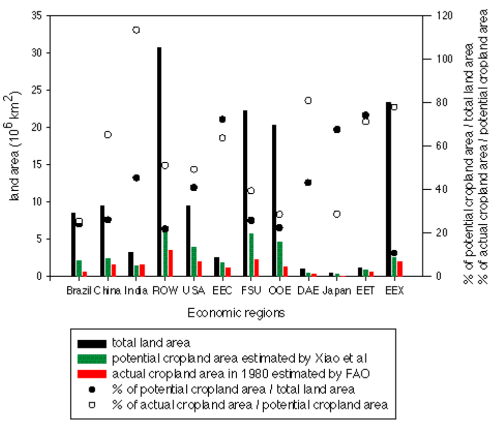
Etc.

Key Factors

- DDG effects
- Reduced crop demand
  (+ any estimated changes in methane)
- Intensification
  (separate out marginal land effect if estimated separately)
- Extensification
- Types and location of land & explanation
  - Tropical forest (perhaps dry & wet)
  - Tropical grassland
  - Temperate forest
  - Temperate grassland
  - Peatlands
  - Foregone sequestration?

Implied Yield Growth by 2020 Scenario 10.2% Transport Fuel(Etech 4)

Crop	Biofuels, adjusted for by products	Non Biofuel food demand	Biofuel and Non Biofuel	1996-2006 Trend
Cereals (corn,wheat	0.8%	1.8%	2.6%	1.3%
Oilseeds (soy, rape)	0.9%	2.2%	3.2%	1.5%
Sugar (cane)	5.0%	0.6%	5.5%	0.8%
Palm	3.0%	3.9%	6.9%	1.9%



14. Biofuels Policy, Land Use Change, Uncertainty, and Time (Michael O'Hare, University of California)

The presentation by Michael O'Hare focused on how policy can cope with the irreducible uncertainty in ILUC measurements, and recognize differential climate effects of changing emissions trajectories over time, even with the same total emissions.

The main points were:

- Uncertainty, time and how they relate to biofuel policy.
- Biofuel policy making is separate from the modelling exercise of estimating an iLUC number from increased biofuel use.

Indirect land use change.

To meet a biofuels target, for example 15 billion gallons of US Corn Ethanol, the gross feedstock land requirement would be approximately 15 million ha (see Figure 14). However, this land area can be reduced by resource constraints such as land, labour and capital, co-products replacing crops, prices reducing demand or higher prices increasing yields. In contrast the land area can be increased because of the lower productivity of converted land. In the example shown the World net land conversion from forest and pasture to meet the biofuel target would be approximately 4 M ha.

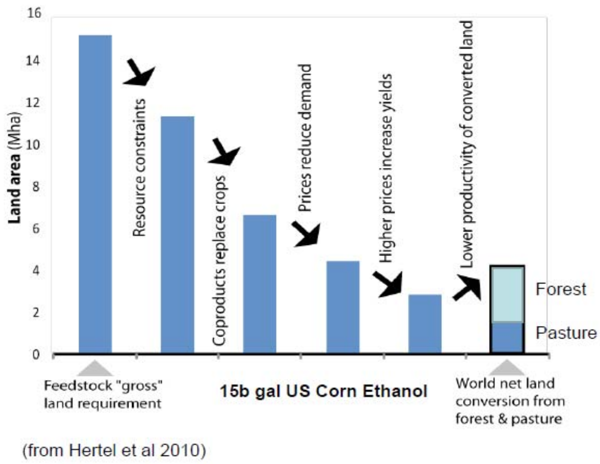


Figure 14 Land requirement and constraints

Estimates of indirect emissions (g per MJ) can be too low because of underestimates of production time or because of atmospheric residence time and reduction of food consumption.

The estimates of ILUC can vary depending on many factors including:

- Higher yields of all crops
- Different allocations of area changes to different natural lands
- Different C stock & land use data

- Accounting for co-products
- Counting C recapture after production
- Changes in the Albedo effect (*e.g.* snow on former boreal/temperate forest land)
- Nitrogen cycle (where yield is increased from N fertilizer application)
- Time and warming effect
- How forests and unmanaged land are modelled
- Other greenhouse gases (e.g. cattle, rice methane)
- Production period (e.g. short rotation forestry or continued rotation)
- More conversion from lower-C land types (pasture) and not peatlands.
- Increased cattle intensity/better practice

The total area land supply is reduced by inefficient agriculture, urban land cover, infrastructure, unsuitability or protected areas.

Key concepts and cautions

Ceteris paribus principle: Models estimate GHG in atmosphere because of biofuel use that is additional to GHG from everything else happening. The implication is that exogenous yield increase does not account for all iLUC (but does reduce it).

ILUC cannot be observed or controlled in any particular place because iLUC is diffuse and averaged over varying effects. This statement was presented on the slide under Key concepts and cautions.

Policies and practices in producing and consuming jurisdictions for the most part cannot reduce iLUC. The exception is yield.

Major Issues for iLUC emission.

The four big issues for iLUC emissions are:

1. How big will iLUC emissions be?

- In particular will iLUC emissions exceed the GWI (petroleum) minus GWI (direct biofuel)?
- Can iLUC emissions be reduced at the point of production or consumption?
- Yields are critical (cellulosic), non-food-competitive feedstock.

2. Policymaking where iLUC estimates are uncertain

3. Time and fuel GHG comparisons

[note that this issue is also important for:

- Anything whose discharges are not constant over time
- Hydro and nuclear (GHG/capital intensive)]

4. [note that ILUC matters for anything that competes with food for land such as housing and sprawl, highways, or parks]

Time Issues.

It is important to understand a realistic production period for each fuel and when substitutes will become more attractive to the market. In an example it was shown that for corn ethanol production over 25 years with extra CO_2e emissions (g per MJ annual production capacity) of 60g from direct emissions and 776 g from LUC it would take 30 years to recover 50% of the emissions due to LUC.

The potential global warming index (GWI) should be calculated for each type of biofuel along with the residence time of emissions. Economic quantities should be discounted not physical ones. It will take until 2060 before biofuels gain an advantage over fossil fuels.

Uncertainty in iLUC

The aim is for iLUC, induced by biofuel policies, to be as low as possible but it cannot be zero. There is a balance to be sought between setting too high a biofuel level or too low. Setting a level too high may result in increased GHG emissions while setting a level too low will result in reduced energy security. No study estimates iLUC as zero with the exception of non-land feedstocks such as algae.

There are many uncertainties in the methods used to estimate land use change and these can produce a large range in the parameters such as fuel yield or land displacement. The example shown for the variance of the land net displacement factor (NDF) was from 25% (low) to 80% (high). It is important to focus on the parameters that return the most variance reduction for the capital invested in research.

Nutrition Consequences.

In the UC/GTAP model with the food consumption level of corn constant the iLUC is 50% higher. This can be viewed as “the nutrition cost of biofuels in GHG units”. The price effects will not be uniform across populations, or from different fuels. For example, the price of cereals will increase under global biofuel policies, while the price of oil seeds increases significantly under EU biofuel policies.

Non-iLUC biofuels.

Non-iLUC biofuels such as algae, cellulose from forest on steep slopes, intercropping, or the use of marginal waste land are very limited and/or prohibitively expensive.

What is the best use of land? Is it for financial gain or offsetting GHG emissions?

Can food crops be double cropped with bioenergy crops to reduce iLUC?

What are the opportunities for marginal land?

Analytic context

Asking the “policy question” at different stages of the biofuel process can greatly change the answer. Consider:

- How can we enrich farmers and ADM?

- How should we reduce the GW index of liquid transportation fuel?
- What's the best use of biomass?
- What's the best use of biomass for energy?
- What's the best use of a hectare of land?

If biofuels policies had been proposed in response to any but the second of these (the first is arguably the tacit motivation) it's not clear that we would be advocating or considering making liquid biofuels for vehicles.

Biofuels Policy, Land Use Change, Uncertainty, and Time

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and does not necessarily represent the view of either organization

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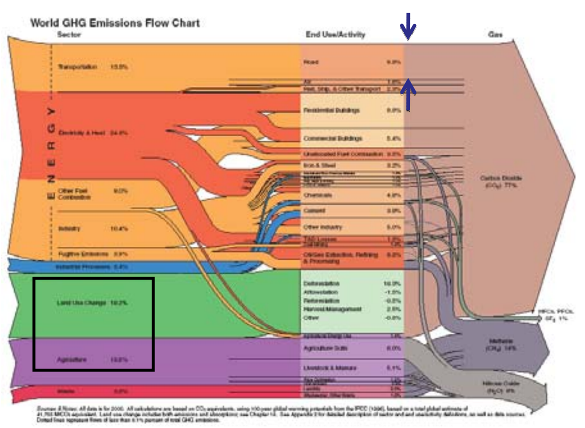
Overview

- Discharge time profiles
- Uncertainty and its discontents
- Food
- Emerging issues

Policy Context

- Agricultural subsidies and tariffs
- EISA/EPA (statute)
  - Volume mandate
  - Biofuels in categories (advanced, etc.) on the basis of GW index
  - LUC in statute, may be overridden by W-M bill
- California LCFS/ARB (exec. order)
  - Average carbon intensity limit
  - All fuels assigned a GWI
  - LUC included



Policy options

- **Mechanisms**
  - Tax
  - Subsidy
  - Information
  - Obligation/prohibition
- (applied to) **Practice**
  - **Quantity** of specific fuels (EU, USA) mandates
  - **Intensity** (average) of all fuel (CA, others)
- ***What is the [operational definition of] the GWI of a given fuel?***

GWI in the LCFS

- For producer *j* in year *t* who blends Q_i units of fuel with GHI index G_i, the fine (or sale of credits) when the standard is S_t will be:

$$AFCI_{jt} = G_p Q_p + G_b Q_b$$
$$C_{jt} = (S_t - AFCI_{jt}) PQ_t$$

p = petroleum, *b* = biofuel

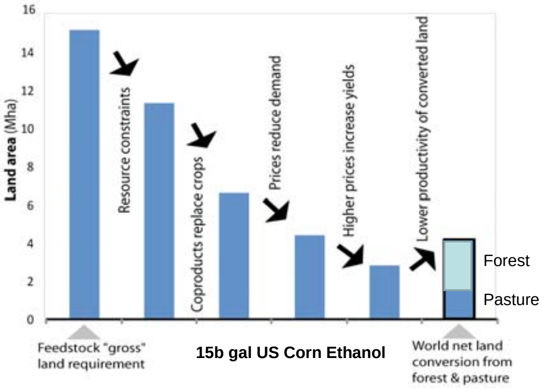
P = price of credits (+/- sold or bought) (or fine)

LCFS Example

Reduction required (Gasoline 96 -> 86)	10%
Blend limit for ethanol	20%
GWI_b required	**45**

Can there be a consequential LCA of a product/substance, or only of a policy?

The indirect land use change issue



(from Hertel et al 2010)

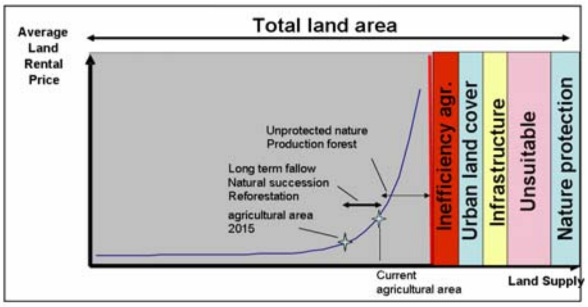
Fuel	Direct	Indirect	Total [constant food]
Gasoline	96	0-3	96 [96]
US corn ethanol	60 (Liska/Plevin 09)	30* ** (CARB 09)	90 [114]
Sugarcane ethanol	27	46** (CARB 09)	73
Soybean diesel	27	62** (CARB 09)	89
Electricity	105	(efficiency)	39 [39]

*too low, because of production time
** too low, because of atmospheric residence time (and food?)

How might these LUC results be too high/low?

- Higher yields of all crops
- Different allocations of “makeup” to different natural lands
- Better C stock & land use data
- Coproduct accounting
- Counting C recapture after production
- Albedo changes (eg, snow on former boreal/temperate forest land)
- Nitrogen cycle (yield increase from fertilizer)
- Time and warming effect
- Better modeling of forests and unmanaged land
- Other greenhouse gases (eg, cattle, rice methane)
- Production period
- More conversion from lower-C land types (pasture)
- Increased cattle intensity/better practice

Unmanaged land

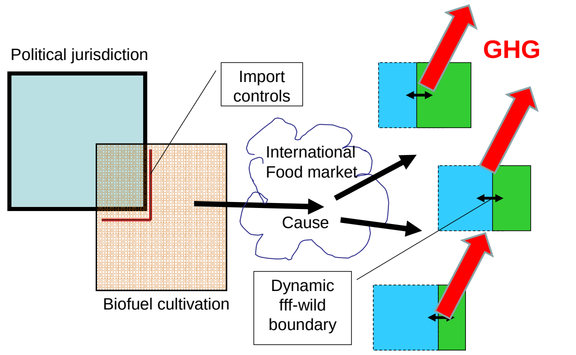


From Banse NEI 2009

Key concepts and cautions

Ceteris paribus principle: Models estimate GHG in atmosphere because of biofuel use that is **additional to GHG from everything else happening**.
Implication: exogenous yield increase does not “make up for” iLUC (but does reduce it)

iLUC **cannot be observed or controlled in any particular place**: it is diffuse and averaged over varying effects.



What policies and practices *in producing and consuming jurisdictions* can reduce iLUC?

Almost nothing except yield.

Four big issues for iLUC (indirect land use change emissions)

- How big is it
  - especially, is it bigger than [GWI(petroleum) - GWI(direct biofuel)?
  - Can it be reduced at the point of production or consumption?

  Yields are critical (cellulosic), non-food-competitive feedstocks
- Policymaking and uncertainty in LUC estimates
- Time and fuel GHG comparisons
  - Anything whose discharges are not constant over time
  - Hydro and nuclear (GHG/capital intensive)
- Anything that competes with food for land
  - Housing and sprawl
  - Highways
  - FFF
  - Parks

Time and discharge profiles

Time issues

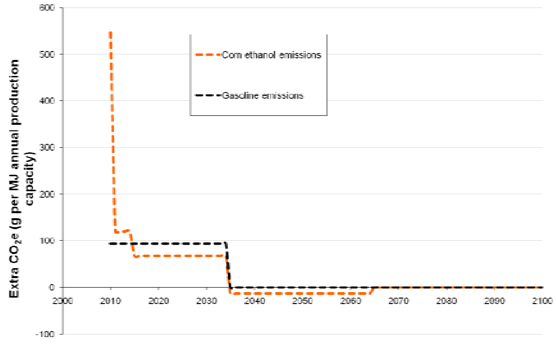
- Realistic production period
  - For each fuel
  - Until substitutes are more attractive in the market
- Calculate warming, not just emissions
  - Residence time of emissions
- Discount economic quantities, not physical ones

What is the present value in January of a bucket of water for use in…

June

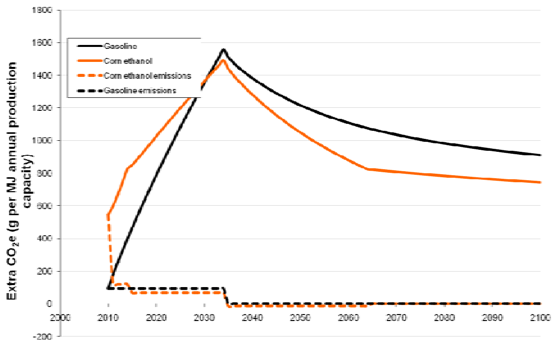
Jan

Corn ethanol: 25 yrs production, 60g direct emissions, 776 g LUC, 30 yrs recovery of 50% of LUC



http://rael.berkeley.edu/BTIME

Corn ethanol: 25 yrs production, 60g direct emissions, 776 g LUC, 30 yrs recovery of 50% of LUC



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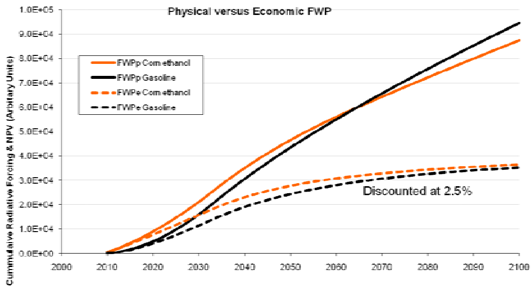
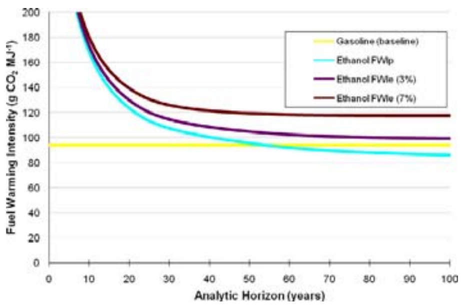


FWP(t) is total warming up to time t



Uncertainty

Decision Theory

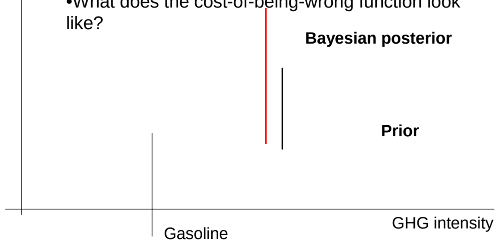
- Act: 'Implement' a vector of values $\{G_i\}$ for fuels *i*.
- State of world: $[\{G^*_i\}, R\{G_i\}]$, where
  - *G** is actual value,
  - *R* is response of system.
- Max $E(V(\{G_i\}, [\{G^*_i\}, R\{G_i\}]))$, where
  - *V* is net benefit
  - *G*, R* have probability distributions

How should we think about uncertainty?

•Is the GHG intensity of a biofuel an RV with a PDF?

•If so, what statistic should be used for its GHG index in a regulatory context?

•What does the cost-of-being-wrong function look like?



Theory-practice gaps

- No unitary decisionmaker, varying data reference sets, so conflicting pdf's
- *V* function varies across experts, stakeholders: politics
- Three grounds of legitimacy:
  - Process
  - Scientific
  - Political

Heuristics

- Let individuals choose, with information
- Choose on the "safe side" (~precautionary principle) considering shape of *V*
- Choose central estimator and let the chips fall where they may
- "Ignore" ILUC …
- **Which means, choose ILUC = 0**

Heuristics

- Let individuals choose, with information
  - Implies a universal carbon tax –but we still need to know marginal damage, which is uncertain
- Choose on the "safe side" (~precautionary principle) considering shape of *V*
  - Need to know marginal cost of compliance function
- Choose central estimator and let the chips fall where they may
  - Abandons benefit maximization duty
- "Ignore" ILUC …
  - No study estimates ILUC as 0 or close except for algae, etc. (non-land feedstocks)

Component	Stochastic uncertainty	Epistemic uncertainty
Economic modeling	Elasticities Crop yields	Type of model (partial or general equilibrium) Model resolution (number of regions and industrial sectors) Baseline year and analysis year Choice of land classes to include Exogenous parameters (e.g. oil price)
Mapping to land cover classes	Satellite data resolution and classification error rates	Number and regional specificity of land cover classes Predictive power of historical patterns of LUC
Estimating emissions by land cover class	Variability in carbon stocks above- and below-ground Variability in fraction of carbon emitted upon conversion Variability in annual foregone sequestration Non-CO_2 emissions Global warming potentials for non-CO_2 emissions	Use of average carbon stocks to estimate C stock of economically-induced LUC Years of foregone sequestration assumed Which climate active phenomena to include Method of aggregating climate effects, e.g. combining regional and global phenomena
Estimating total fuel production	Temporal and spatial variability in biofuels feedstock yield Variability in feedstock conversion yield	Projected changes in crop yield over the production horizon Changes in crop and/or conversion technology over time Affects of climate change on crop productivity Assumed years of biofuels production following initial planting
Treatment of time	Whether to apply discounting, at what rate, and to what (i.e. emission flows, radiative forcing, temperature change, or economic damages?)	Analytic horizon over which to aggregate climate effects

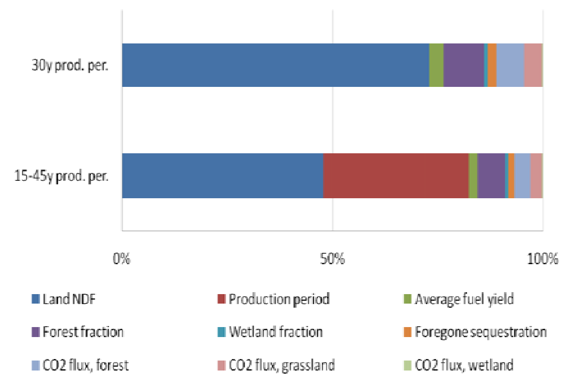
Extreme values

Flat distributions of parameters between "straight-face" or theoretical limits is close to maximizing plausible uncertainty in result.

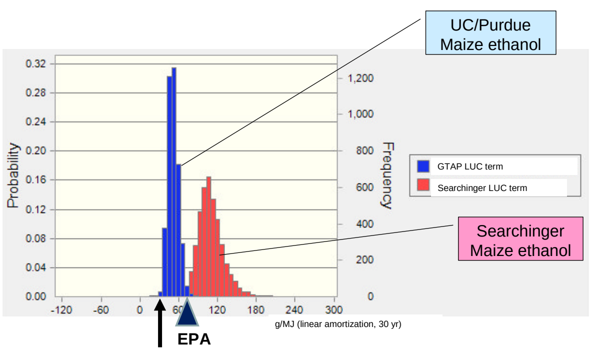
Parameter	Units	Low	High
Fuel yield	MJ ha^{-1} y^{-1}	3500	4500
Net displacement factor	%	25%	80%
CO_2Flux: forest	Mg CO_2 ha^{-1}	350	650
CO_2Flux: grass	Mg CO_2 ha^{-1}	75	200
CO_2Flux: wetland	Mg CO_2 ha^{-1}	1000	3000
Fraction: forest	%	15%	50%
Fraction: grassland	%	1 – (grassland + wetland fractions)	
Fraction: wetland	%	0%	2%
Production period	y	15	45

Strategic research focus: gnat-camel discrimination

What parameters return the most variance reduction per dollar invested in research?



Model Uncertainty and Parameter Uncertainty



Gasoline – direct ethanol EPA

Key issues

- PDF of G* is asymmetric, with long right tail
- V is concave (up), with irreversible catastrophic outcomes at higher absolute values
- V is symmetric: same cost for "too much GHG" from over- or underuse of biofuel

Compare:

EPA must determine[the probability that] a fuel's GWI is in a given range and issue a binary "yes/no" answer

ARB must assign a GWI with infinite precision

Should these decisions be made with reference to the an asymmetric cost of being wrong "too high" compared to "too low (irreversibilities, non-GW costs like biodiversity, etc.) ?

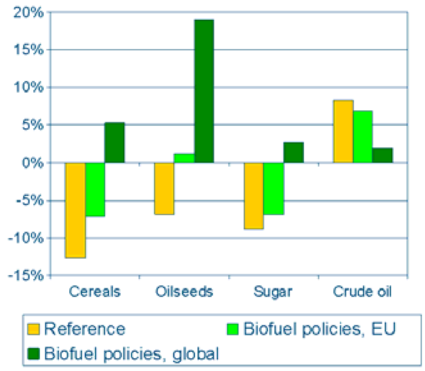
…or just use a central estimator?

If so, should they "average" different models' results?

Food effects

Nutrition consequences

- UC/GTAP: With food constant, ILUC is 50% higher for corn alone
- EPA: Food consumption reduced 1% and population is ~9% higher for all RFS (2022)
- Effects will not be uniform across populations, nor from different fuels



From Banse NEI 2009

Emerging issues

Non-ILUC biofuels

- Algae in desert or water bodies
  - ~€2000/l
- Cellulose from forest on steep slope
- Intercrops (where only non-food crop could be grown
- Marginal waste land (where only biofuel could ever grow)

  …a discouraging list!
- MSW

Should LCA look to the past or the future?

- Consider a kg of hydrocarbon. If it's burned for fuel, its C goes into the air. If not, it will sit underground indefinitely. What is its GWI?

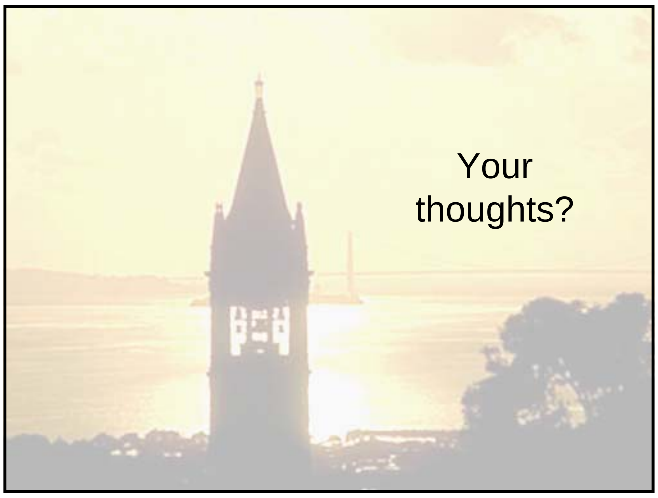
Does it matter whether it is biogenic or fossil originally?

Source only matters if future has a causal link back to creation.

Asking the right question

- How can we enrich farmers and ADM?
- How should we reduce the GW index of liquid transportation fuel?
- What's the best use of biomass?
- What's the best use of biomass for energy?
- What's the best use of a hectare of land?

Policy context dictates the question, and the answers are not usually the same



15. Meta modelling of ILUC analyses – A decomposition approach as a starting point (Peter Witzke, EuroCARE GmbH, Bonn)

There is a benefit to have different model results for estimating ILUC as no-one model type is optimal. However, because the models have differences in parameters (elasticities) comparison of the results is difficult. Moreover, differences in model structure mean that is it is difficult to identify which parameters or combination of parameters are causing the differing results. There are also differences in the scope of the analyses (e.g. Market effect analysis in the CAPRI model applied to LUC in Europe. Not all analyses reach the same level of detail). There are also problems to make the link from GE applications that give results in monetary units to the physical units that are of interest to this study of ILUC. Some models report LUC and emissions but not all of the models.

Critical issues

One of the key issues is the order of magnitude of yield changes because of biofuel policies. It is important to identify whether:

- Yield changes are related to intensification on existing land or expansion onto unused land
- The model includes forest, pasture and cropland or only cropland and how is this estimated?
- The model accounts for by-products? *e.g.* DDGS
- Is there an exogenous demand shock or change in policy/oil price?

<u>Approaches</u>

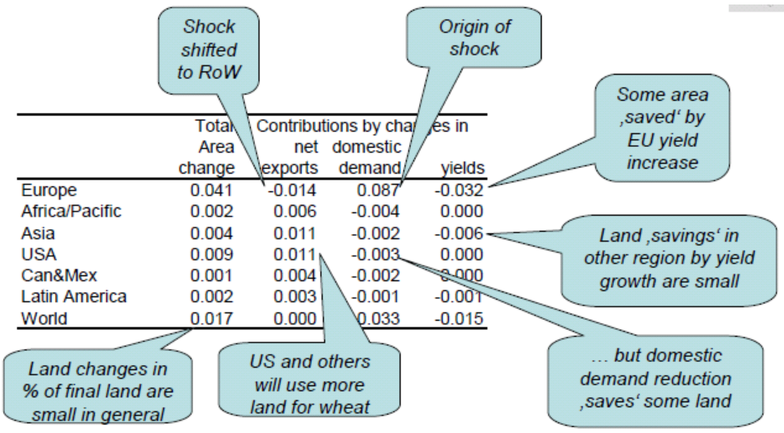
The comparison approach starts with the market balance that includes supply and demand components by region and crops. Further analysis breaks down the supply side to yield and area effects. Demand side components (not yet addressed) can be broken down into feedstock use, food use and other uses. There are many different approaches to splitting change in overall yield to intensification or area expansion.

1. By looking at an extended results file,
2. by using results and prior assumptions
3. by looking into formulae

In this approach it is assumed that first areas are changing, then yields which gives us total change in production.

Results.

An example of the analysis using the FAPRI scenario 1 =+ 1 m toe of wheat ethanol in EU is shown in Figure 15.



	Total\ Area change	Contributions by cha/ es in net exports	domestic demand	yields
Europe	0.041	-0.014	0.087	-0.032
Africa/Pacific	0.002	0.006	-0.004	0.000
Asia	0.004	0.011	-0.002	-0.006
USA	0.009	0.011	-0.003	0.000
Can&Mex	0.001	0.004	-0.002	0.000
Latin America	0.002	0.003	-0.001	-0.001
World	0.017	0.000	0.033	-0.015

Figure 15 Example of results analysis

In this example the FAPRI results have been rearranged to show the relative change in total area use. This total area is then split into contributions from exports, demand or yields. The demand is large in the EU as that is the origin of the shock. Part of that demand is met by increased yields, and another part is met by other countries. The US will use more land for wheat and increased exports will meet part of the EU demand. The aim is to breakdown the different model results into components that can be compared.

Work in Progress:

Further checking of preliminary results is required, in particular the FAPRI – IFPRI comparison and a check of controls pointed to mapping problems. More complete processing of existing model results will be undertaken from the all models.

Further work.

Further breakdown of results to identify Demand (food, feed, other?) and land recovery through by-products. It would be good to also identify the type of by-product treatment is interesting (e.g. DDGS). There is a long way to go before emissions can be compared. To achieve this requires: collecting emission coefficients, including fertiliser needs for increased yields and repercussions on the animal sector. Future work will include moving from an instructive indicator system to drivers that might be varied to get new estimates.

Meta modelling of ILUC analyses – A decomposition approach as a starting point

Peter Witzke
Bonn

11 February 2010,
Eurocare, Bonn

Outline

- Background: heterogeneity of approaches and results
- Approach: decompose LUC into meaningful components based on standard model outputs
- First results
- Outlook and options for further work

Heterogeneity of approaches and results

- Well represented in this workshop
- Model types
  - PE: FAPRI, IMPACT, CAPRI, AGLINK, GLOBIOM...
  - GE: GTAP, LEITAP, DART...
- Parameter differences: Elasticities...
- Scope differences: market results, physical units, LUC, emissions
- Critical issues: Many

Critical issues

- Yield changes
  - On land with unchanged use (intensive margin)
  - Due to expansion (or reduction) of area use (extensive margin)
- Full land use coverage or only cropland
- Treatment of by-products
- Drivers
  - Exogenous demand shock or policy/oil price
- Others

Approach (1): Starting with market balance

- Start with market balance identity (region r, product i)

$$\Delta net_{ri} = \Delta sup_{ri} - \Delta dem_{ri}$$

- Further analysis decomposes these:
  - Supply side components are at the focus here: yields and area changes
  - Demand side components not yet addressed: feedstock use, food use, other use (feed...)

Approach (2): Decompose supply changes

- Several options to decompose supply change into changes in land use and yields:

$$\Delta sup_{ri} = yld^1_{ri} land^1_{ri} - yld^0_{ri} land^0_{ri}$$
$$= yld^0_{ri} \Delta land_{ri} + land^1_{ri} \Delta yld_{ri}$$
$$= yld^1_{ri} \Delta land_{ri} + land^0_{ri} \Delta yld_{ri}$$

- Options:
  - First areas change, then yields (adopted here)
  - First yields change, then areas
  - If difference is large: possibly use GTAP approach to decompose policy packages (small steps)

Approach (3): Key components

- Use decomposition of supply in market balance identity:

$$\Delta net_{ri} = \left(cyld_{ri}^{0} \Delta land_{ri} + land_{ri}^{1} \Delta cyld_{ri}\right) - \Delta dem_{ri}$$

- Rearrange for contributions to relative land use change:

$$\frac{\Delta land_{ri}}{land_{ri}^{1}} = \frac{\Delta net_{ri}}{land_{ri}^{1} cyld_{ri}^{0}} + \frac{\Delta dem_{ri}}{land_{ri}^{1} cyld_{ri}^{0}} - \frac{\Delta cyld_{ri}}{cyld_{ri}^{0}}$$

Relative land use change	…for additional net exports	…for add. domestic demand	…avoided by yield gains

Approach (4): Aggregable with area weights

- Land is the common denominator to aggregate over products:

$$\frac{\Delta land_{r}}{land_{r}^{1}} = \sum_{i} \frac{\Delta land_{ri}}{land_{ri}^{1}} \cdot \frac{land_{ri}^{1}}{land_{r}^{1}}$$

- … and larger regions (like the world):

$$\frac{\Delta land}{land^{1}} = \sum_{r} \frac{\Delta land_{r}}{land_{r}^{1}} \cdot \frac{land_{r}^{1}}{land^{1}}$$

Results (1): FAPRI *scenario 1 = + 1 m toe of wheat ethanol in EU*

Shock shifted to RoW

Origin of shock

Some area ‚saved' by EU yield increase

	Total Area change	Contributions by changes in net exports	domestic demand	yields
Europe	0.041	-0.014	0.087	-0.032
Africa/Pacific	0.002	0.006	-0.004	0.000
Asia	0.004	0.011	-0.002	-0.006
USA	0.009	0.011	-0.003	0.000
Can&Mex	0.001	0.004	-0.002	0.000
Latin America	0.002	0.003	-0.001	-0.001
World	0.017	0.000	0.033	-0.015

Land ‚savings' in other region by yield growth are small

Land changes in % of final land are small in general

US and others will use more land for wheat

… but domestic demand reduction ‚saves' some land

Results (2): IFPRI *scenario D = + 1 m t of wheat feedstock demand in EU*

Shock shifted to RoW

Origin of shock

Some area ‚saved' by EU yield increase

	Total Area change	Contributions by changes in net exports	domestic demand	yields
Europe	0.035	-0.323	0.382	-0.025
Africa/Pacific	0.032	0.235	-0.173	-0.030
Asia	0.028	0.158	-0.101	-0.029
USA	0.040	0.112	-0.049	-0.022
Can&Mex	0.046	0.109	-0.037	-0.026
Latin America	0.048	0.141	-0.072	-0.021
World	0.033	0.000	0.060	-0.026

- Standardised decomposition should work for all models
- But how to compare if shocks are different?

Results (3): LUC contributions divided by size of increased feedstock demand (in billion GJ)

- Larger shock in FAPRI (1 mtoe eth) than IFPRI (1 m t wheat)
- Normalisation gives similar LUC in Europe in IFPRI or FAPRI
- But single contributions are responding stronger in IFPRI compared to FAPRI
  - Due to error in processing model outputs?
  - Due to which model differences?
  - => Further analysis is needed, then feed back to modellers

	Total Area change	Contributions by changes in net exports	domestic demand	yields	Total Area change	Contributions by changes in net exports	domestic demand	yields
		FAPRI				IFPRI		
Europe	5.20	-1.07	6.15	-0.18	6.14	-70.97	84.93	-7.72
Africa/Pacific	-0.14	-0.01	-0.36	0.23	0.31	18.44	-13.98	-4.16
Asia	0.17	0.93	-0.16	-0.60	2.06	16.53	-8.78	-5.72
USA	-0.29	-0.26	-0.08	0.05	3.80	11.21	-2.16	-5.23
Can&Mex	0.18	0.24	-0.05	0.01	6.93	21.15	-7.06	-7.19
Latin America	-0.09	-0.09	0.02	-0.02	-0.15	8.90	-5.91	-3.31
World	1.04	0.00	1.83	-0.87	2.44	-0.02	7.98	-5.54

To do: Disentangling yield changes (1)

- Some models have 'market regions' r composed of small 'supply regions' (e.g. GLOBIOM) :

$$sup_{ri} = \sum_{s \in S_r} sup_{rsi}$$

- Such that total yield change in market region is built up from land and yield changes in 'supply' regions:

$$Total\ Yld\ Effect_{ri} = \frac{\sum_{s \in S_r} cyld_{rsi}^{1} land_{rsi}^{1}}{\sum_{s \in S_r} land_{rsi}^{1}} - \frac{\sum_{s \in S_r} cyld_{rsi}^{0} land_{rsi}^{0}}{\sum_{s \in S_r} land_{rsi}^{0}}$$

- Information is useful to decompose yield changes:

To do: Disentangling yield changes (2)

- Contribution from area changes (expansion, reductions) at given yield gives 'aggregation effect':

$$AggregationYldEffect_{ri} = \frac{\sum_{s\in S_r} cyld^0_{rsi} land^1_{rsi}}{\sum_{s\in S_r} land^1_{rsi}} - \frac{\sum_{s\in S_r} cyld^0_{rsi} land^0_{rsi}}{\sum_{s\in S_r} land^0_{rsi}}$$

- Pure yield effect, given new area allocation:

$$PureYldEffect_{ri} = \frac{\sum_{s\in S_r} cyld^1_{rsi} land^1_{rsi}}{\sum_{s\in S_r} land^1_{rsi}} - \frac{\sum_{s\in S_r} cyld^0_{rsi} land^1_{rsi}}{\sum_{s\in S_r} land^1_{rsi}}$$

- Disentangles yield changes directly from model results

Disentangling yield changes (3)

Alternative solutions for yield growth decomposition

- Post model disaggregation according to some prior assumptions (IFPRI solution)
- Use model results with explicit prior assumptions. Example: GTAP analysis by Alla Gollup ('0.66 rule')
- Sometimes model parameters directly identify yield effects of area expansion (FAPRI)

Other unfinished business:

- Further checking peliminary results
  - FAPRI – IFPRI comparison
  - Check of controls pointed to mapping problems
- More complete processing of existing model results:
  - PE (FAPRI, IFPRI, AGLINK (?), GLOBIOM) and
  - GE (GTAP, DART…)

Options for further work:

- More decompositions
  - Demand (food, feed, other?)
  - Problem to identify land recovery through by-products
    - Auxiliary simulations are quite hypothetical.
    - But kind of by-product treatment is interesting (DDGS)
  - Other interesting decompositions?
- Moving to emissions is a long way to go:
  - Collecting emission coefficients
  - Including fertiliser needs for increased yields
  - Including repercussions on animal sector
- Moving from instructive indicator system to drivers … that might be varied to get new estimates

16. Comparison of model characteristics and results & GHG effects of biofuel directives from LEITAP-IMAGE analysis (Elke Stehfest, PBL)

PBL compared land use effects across a selection of partial equilibrium models, general equilibrium models and non-economic models using existing scenarios and comparable data received from modelling groups and where necessary data from publications (PBL 2010a). Results of the LEITAP-IMAGE analysis of the effects EU and OECD biofuel mandates on land use change and GHG emissions were also presented

Effective additional area and GHG emissions.

The different models presented in this workshop report a large variance in the effective additional area needed to produce one TJ of biofuel. It was shown that models that reported the largest increase in area did not include co-products.

Models that included CO_2 emissions (gCO_2/MJ over a 30 year horizon) from land conversion, estimated these emissions either within the model or coupled to external emission models. For the models that did not include CO_2 emissions a fixed conversion emission rate of 95 tC/ha was applied. This methodology produces a direct relation with area whilst the results from the models that included CO_2 emissions sometimes showed an inversion of the relative effect. In the LEITAP-IMAGE calculations run without co products the **BioEU** and **BioOECD** scenarios produced an inversion of the effect because of the different areas (See Slide 10). Land use conversion emissions are significantly affected by where the conversion takes place within a country. It is especially important to identify if the conversion will occur on peat or non-peat land soils. Relatively few of the models presented in this workshop estimate additional N_2O emissions from increased fertiliser application.

Comparison of model charateristics.

Direct land use (biofuel yield in MJ/ha) differs a lot between the models mainly because of differences in the biofuel crop mix and region of origin. The substantial differences in the crop mix would not be expected if all the models used the same dataset e.g. 2005 or 2007 data. Moreover, the scenarios are implemented very differently. To resolve this variance in results, standardized experiments are needed and the iLUC figure should be reported per crop and per region. In fact, a sound comparison of models is only possible with standardized, crop-specific experiments as coordinated in JRC's marginal calculations.It was highlighted that models used to calculate iLUC should contain all of the four components: co-products, endogenous land use expansion, intensification/yield increase and consumption change. However, it is also important to understand how these components were implemented within the models, especially for co products.

Expansion, Intensification, Consumption

The emissions from intensification (increasing yield in response to higher price) depends on how the yield increase is achieved (PBL 2010b). If the yield increase is obtained entirely by increasing N fertilizer, the extra N_2O emission from N fertiliser can easily exceed fossil fuel reference emissions. However, there are alternative ways to increase yields, such as better farm management and selecting different crop types. These latter methods may also increase the fertiliser use efficiency. In reality a mixture of both processes is likely to take place.

Comparison of historical data (1970 to 2000) on the relation between yields and N input shows that in Europe there has recently been an increase in yield but a reduction in average fertiliser application. Time series data can be used to plot yield against fertilizer rate for different regions and time periods. The time-trend for most of the world is towards higher fertilizer rates and higher yields, and developed countries generally have higher yields and higher fertilizer use than developing ones. One can fit a slope of yield-per kg N though the data points.

Applying the historical relation, the indirect N_2O emissions would amount to 1-8 gCO2 eq. per MJ fuel. However, if crop prices increase, the fast response of farmers might rely more on increased N input in order to boost yields, than was the case historically. (*see also discussion below on short and long term response of yields to prices*). The true emissions from intensification lie between the values found by the two methods.

If intensification should lead to a reduction in indirect land conversion due biofuels, additionality compared to baseline development needs to be proven and it should be ensured that fertilizer use efficiency is maintained.

LEITAP-IMAGE model

The LEITAP-IMAGE modelling work analysed the effect of biofuel mandates in the EU and other OECD countries on land use change and GHG emissions. The model was run using biofuel data from 2007 and subsequently endogenously driven by crude oil prices, and biofuels blending targets. For the BioEU scenario the change in cropland area was reported to be **31** M ha, spread across the world, with soya bean and wheat being the most important feedstock sources for increased biofuel. Under the BioOECD scenario there was increase in cropland area to **51** M ha, with the greatest increase in area occurring in North America and Brazil, accompanied by a slight increase in Europe.

The GHG savings from implementing biofuel policies can be affected by the rebound effect, whereby increased biofuel use leads to a relative decrease in the crude oil price, which in turn increases the consumption of crude oil in other areas. In the LEITAP-IMAGE analysis the reduction in theoretical savings was approximately 50%.

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= RIVM, = MNP, = PBL

PBL work on Biofuels and iLUC

Elke Stehfest

PBL: Jan Ros, Anne Gerdien Prins, Koen Overmaas..., and LEI: Geert Woltjer, Hans vanMeijl, Andrzej Tabeau...

PBL work on biofuels and iLUC

- "Exploring bioenergy's indirect effects – economic modelling approaches". *Report on* ***model features*** *prepared for PBL by J.de Vries*
- Series of briefs report on selected issue of iLUC (overview, co-products, **model comparison**, **intensification**, biodiversity, monitoring)
- **Modelling work together with LEITAP**

2 and 3: (still ongoing work)

Report "Exploring bioenergy's indirect effects – economic modelling approaches

- Prepared by Jan de Vries for PBL (supervised by Anne Gerdien Prins)
- Description of available models to assess the indirect Land Use change effects of biofuels
- To be published in the next few weeks, final draft available.
- Probably already outdated to some extent
- (and there's certainy some errors in the report …)

Models descriptions in the report

Model comparison

Aim:

- Comparison of land use effects across availabel models
- Try to explain the differences

Approach

- Using existing scenarios
- Uniform data request to model teams
- Data received from some model groups, otherwise relied on publication

Obviously, results are much harder to compare than with the marginal runs commissioned by JRC …

Work still onging …

Together with Anne Gerien Prins

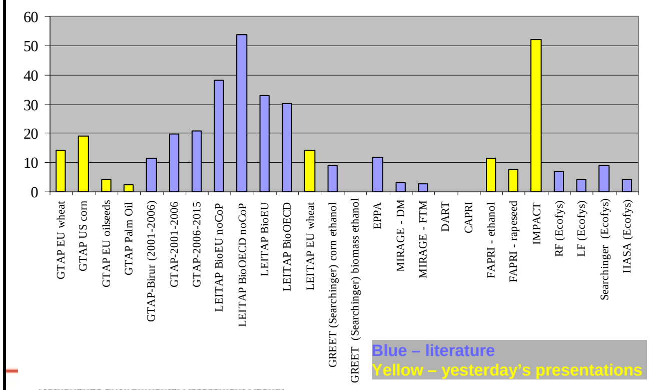
model features - overview

Model	General features			bio-energy chain		Endogenous ...		
Name	Type	Economic background	Sectors	Types of biofuel crops	Co-products	Expansion	intensification	consumption change
GTAP	GE	market clearing	All	sugar cane, corn, wheat	yes	yes	yes	yes
LEITAP	GE	market clearing	All	veg. Oils, wheat, maize, sugar cane, sugar beet, 2nd generation	yes	yes	yes	yes
GTAPGREET	GE			corn ethanol	yes	yes	no	estimati
EPPA	GE	market clearing	All	not specified, 2nd generation	no	no	no	yes
MIRAGE	GE	market clearing	All	bioethanol and biodiesel	no	yes	yes	yes
DART	GE	market clearing	All	Wheat, corn, oil seeds, veg.oil, sugar cane, sugar beet	no	no	yes	yes
GTEM	GE	market clearing	All	2nd generation	n.a.	no	no	yes
AGLINK /COSIMO	PE	market clearing	Agriculture	veg. Oils, wheat, maize, sugar cane, sugar beet, 2nd generation	yes	yes	?	world prices/c
CAPRI	PE	market clearing/profit maximization (supply)	Agriculture	cereals, sugar,veg. oil	yes	no 1)	yes corridor	yes within
FAPRI	PE	market clearing/profit maximization	Agriculture	bioethanol, biodiesel	yes	yes	yes	yes, depends
IMPACT	PE	market clearing	Agriculture	sugar cane, sugar beet, corn, wheat, other grains	no	yes	yes	yes
GLOBIOM	PE	Market clearing/profit maximization	Agriculture, forestry	1st generation, 2nd generation	no	yes	in the form of	yes
G4M	allocation	coupled to GLOBIOM	n.a.	not explicit	n.a.	yes	n.a.	n.a.
IMAGE	IAM	coupled to any economic model (mostly LEITAP)	n.a.	oilcrops, wheat, maize, sugar cane, 2nd generation	n.a.	yes	n.a.	n.a.
GCAM	IAM & PE			2nd generation	no?	yes	no	yes

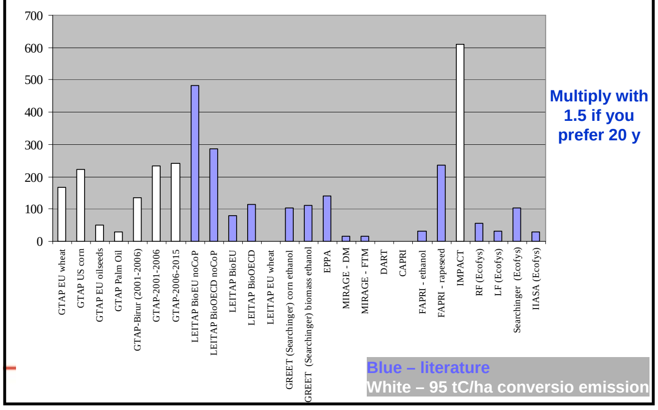
Model feature - emissions

Model	energy c	Endogenous ...				Emissions from ILUC	
Name	Co-products	Expansion	intensification	consumption change		Emissions from fertilizer use	CO2 land conversion
GTAP	yes	yes	yes	yes		yes	-forestry practices, no soil carbon
LEITAP	yes	yes	yes	yes	es	no (but yes via IMAGE)	no (but yes via IMAGE)
GTAPGREET	yes	yes	no	estimati		no	yes, based on historical shares of
EPPA	no	no	no	yes		no	no
MIRAGE	no	yes	yes	yes		no	yes, only CO2 emissions from forest
DART	no	no	yes	yes		no	no
GTEM	n.a.	no	no	yes		no	no
AGLINK /COSIMO	yes	yes	?	world prices/c		included in SAPIM[1]	?
CAPRI	yes	no 1)	yes corridor	yes within		?	?
FAPRI	yes	yes	yes	yes, depends		?	yes, GreenAgsim. Direct GHG emissions from livestock manure,
IMPACT	no	yes	yes	yes		no	no
GLOBIOM	no	yes	in the	yes		yes	yes
G4M	n.a.	yes	n.a.	n.a.		no	yes
IMAGE	n.a.	yes	n.a.	n.a.		yes	yes
GCAM	no?	yes	no	yes		no	yes

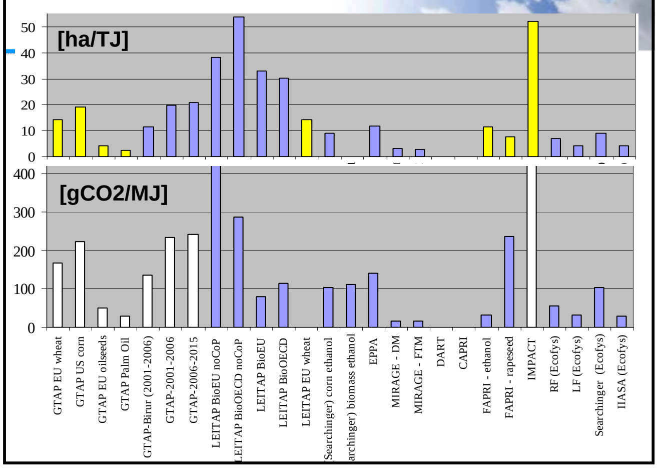
Effective additional area needed [ha/TJ]



GHG emissions [gCO_2/MJ] (30 year horizon)



Multiply with 1.5 if you prefer 20 y



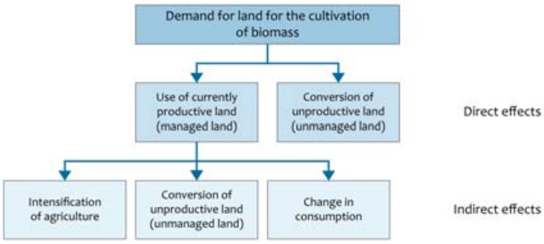
Model Comparison – Conclusions

- Direct land use (biofuel yield in MJ/ha) differs a lot between models due to crop mix and region of origin
- Indirect land use strongly depens on accounting for co-products
- Very difficult to explain difference in outcome, as scenarios set-up so different
  - ➔ Stylized experiments needed for useful model comparison
- iLUC factor should be per crop type and region
- Models used to calculate iLUC should at least contain co-products, land use explasion and endogenous yield increase (and consumption)
- Reliability of the implementation for these features
- Conversion emissions differ a lot, and not included in all model -> uniform translation from area in emissions?

Expansion, Intensification, Consumption – Numbers presented here

Model	energy c	Endogenous ...			Endogenous ...		
Name	Co-products	Expansion	intensification	consumption change	Expansion	intensification	consumption change
GTAP	yes	yes	yes	yes	?	?	0.5
LEITAP	yes	yes	yes	yes	0.7	0.3	small
GTAPGREET	yes	yes	no	estimati	0.3	0.3	0.3
EPPA	no	no	no	yes			
MIRAGE	no	yes	yes	yes			
DART	no	no	yes	yes		high	low
GTEM	n.a.	no	no	yes			
AGLINK /COSIMO	yes	yes	?	world prices/c			
CAPRI	yes	no 1)	yes corridor	yes within		high	low
FAPRI	yes	yes	yes	yes, depends	0.6-0.95	0.05-0.4	low ?
IMPACT	no	yes	yes	yes	0.5-0.7	0.3-0.5	low ?
GLOBIOM	no	yes	in the	yes			
G4M	n.a.	yes	n.a.	n.a.			
IMAGE	n.a.	yes	n.a.	n.a.			
GCAM	no?	yes	no	yes			

Intensification



- Not only land use conversion, but also intensification can cause emissions -> indirect emissions of intensification
  - Agricultural energy use for machinery and production of inputs
  - N2O emissions due to fertilizer application

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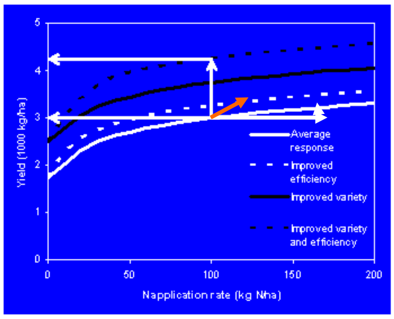
Stehfest, Ros, Bouwman

Relation between yields and N input



Yield / N input = fertilizer use efficiency

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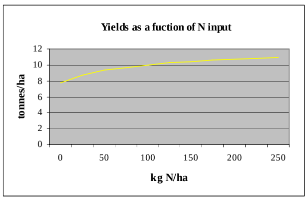
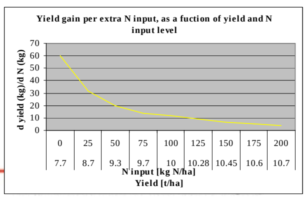
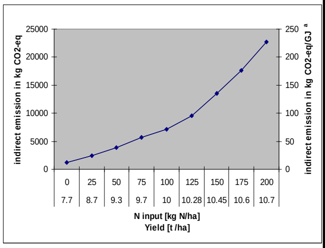
Increase only N input to increase yields …

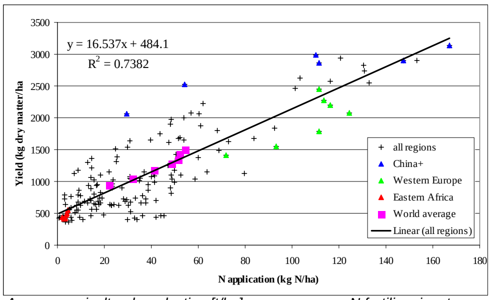






IPCC emission factor applied. Would be even stronger if exponential N2O emissions were applied

Historical relation yields and N input



Average agricultural production [t/ha] versus average N fertiliser input [kg/ha], in 5 year time steps between 1970 and 2000.

Resulting indirect emissions would be 2-8 g CO2-eq / MJ
Emissions might be higher if exponential emission used (not calculated yet…)

Intensification – Conclusions

- Depending on the process of intensification, N2O emission can exceed fossil fuel reference emissions
- If historical relations are applied, additional emissions are in the range of 2-8% CO2-eq/GJ
- If intensification is somehow included in policy-making / labelling:
  - Additionality needs to be proven!!!
  - Fertilizer use efficiency must not decrease

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Modelling work together with LEITAP

- Effect of EU and OECD biofuel mandates on Land use change and GHG emissions
- Baseline: Biofuels in 2007 based on data, after that endogenously driven by crude oil prices
- BioEU: 10% biofuels in Petrol Sector in EU
- BioOECD: 10% biofuels in Petrol Sector in EU. US, Canada, Japan, Australia
- Method: LEITAP – IMAGE (www.pbl.nl\image)

Just a few results …

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Stehfest, Woltjer, Prins, van Meijl, et al. in prep.

Land use change & yield increase

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Table 3. Change in Cropland Area due to European and OCED Biofuel mandates, compared to the baseline in 2020 [%].

	BioEU	BioOECD
NAM	3%	8%
Brazil	5%	6%
RLA	2%	3%
Europe	7%	8%
SSA	0%	1%
FSU	2%	3%
Turkey, Middle East, Northern Africa	1%	1%
India, Indonesia, South East Asia	0%	0%
China, Korea, Japan	1%	1%
Oceania	1%	1%
World	2%	3%
Mio ha	31	52

Table 4. Technological improvement and average yield change for OECD Biofuel mandates compared to the baseline, in 2020

Crop group	technological improvement	change in average yield
temperate cereals	0.2%	0.3%
rice	0.0%	-0.2%
maize	0.0%	0.7%
tropical cereals	0.0%	0.8%
pulses	-0.1%	-0.4%
roots & tubers	-0.1%	-0.6%
oil crops	0.5%	0.3%

- World average biofuel share is 2.3, 3.2, and 4.2 in Baseline, BioEU and BioOECD
- Area changes would be much larger of co-products not included
- Hardly any change in consumption

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Full GHG balance

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	Reduction of fossil fuel emissions (including rebound effect)	Reduction of fossil fuel emissions assuming no "rebound"effect in the energy system	Difference in Land use emissions	Net difference fossil & land use (including rebound effect)	Net difference fossil & land use (excluding rebound effect)
	[Pg C]	[Pg C]	[Pg C]	[Pg C]	[Pg C]
BioEU, diff with Reference, in 2020	-0.0045	-0.020	0.57		
BioOECD, diff with Reference, in 2020	-0.011	-0.048	1.66		
BioEU, Cumulative difference over 20 years	-0.135	-0.6	0.57	0.4	-0.03
BioOECD, Cumulative difference overe 20 years	-0.33	-1.44	1.66	1.3	0.22

- The rebound effect: Logical Story - Increased biofuel use leads to a relative decrease in prices of crude oil, which in turn increases the consumption of crude oil and petrol in other regions.
- The reduction in theoretical savings can be around 50%
- Consequences in the required GHG emission reduction of biofuels?

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Conclusion / Discussion

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- It's very, very complicated …. (by-products, expansion, yield increase, consumption, all crop and region specific)
- One of the reasons: no global emission tax or cap and trade across all sectors and gases

Discussion

- Estimate iLUC per crop and region (best guess and probability distribution)
- Broader view / "discomforts"
  - "Best use of land" (multiple claims food, feed, fibre, fuel, CO2, other Ecosystem Services)
  - Best climate policy (biofuels at all, 1st or 2nd generation…)
  - No (energetic) use of biomass during land convesion, forest products

Thank you !

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17. Discussion Session

This section brings together:

- the discussions made in the final discussion session
- general points which arose during/after each presentation,

The discussions are organized by topic, and are not always in chronologically order.

To represent the most transparent way as possible the important final discussion and comments raised by the attendees as a follow-up of the experts' presentations, the names (initials) of each contributor (where known) are included as follows:

Steven Berry (*SB*), Robert Edwards (*RE*), Alla Golub (*AG*), Jacinto Fabiosa (*JF*), Ian Hodgson (*IH*), Paul Hodson (*PH*), Michael O'Hare (*MO*), Timothy Searchinger (*TS*), Stefan Unnasch (*SU*), Mauro Poinelli (*MP*), Alison Burrel (AB) and Siwa Msangi (*SM*).

17.1. Linearity of ILUC and models

The most critical parameter in cropland expansion is the rate of crop demand increase compared to the rate of yield increase (See Figure 16). If the rate of demand increase equals the rate of yield increase, no net land use change occurs. In the past few decades, demand increase has run ahead of yield increase, so that about 5% of the extra demand has come from world crop area increase.

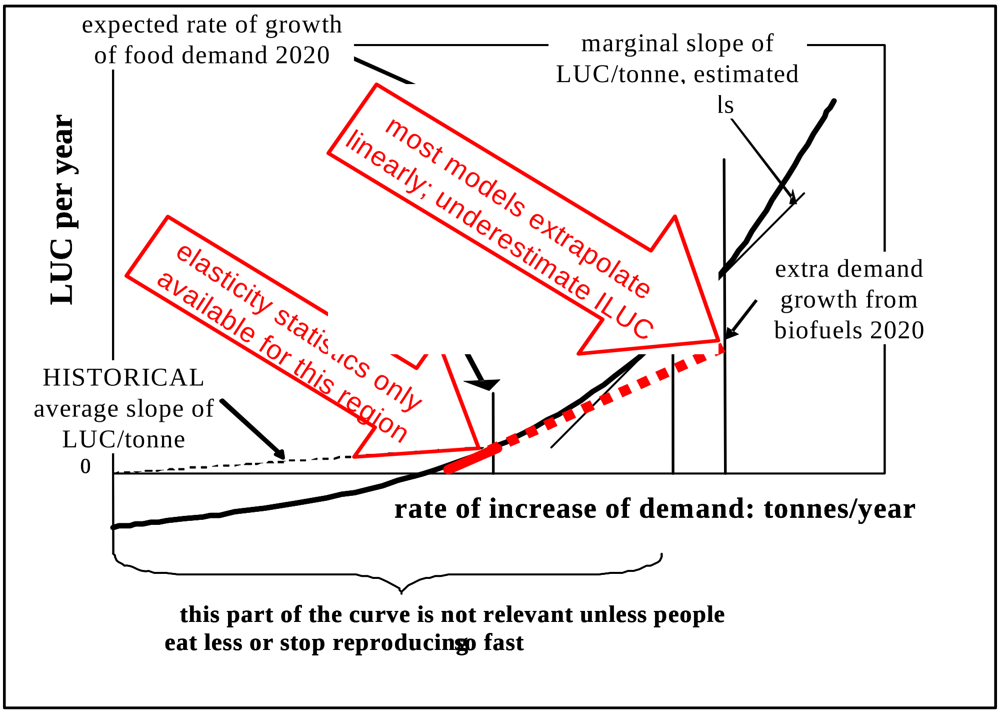

Figure 16 Cropland expansion and rate of demand

The slope of the LUC curve can be expected to increase with increasing rate of demand increase. That is because, firstly, land brought into production gets progressively less productive, and secondly, because of diminishing returns to spending money on measures to increase yield growth.

The area increase associated with an extra Mtoe of biofuel is given by the slope of the curve (the "historical average LUC" is irrelevant). In future, exponential population growth, increased prosperity in the developing world, and biofuels are likely to increase the annual rate of demand increase. That will increase the slope and hence the LUC/toe biofuels.

The results of agro-economic models depend on the various elasticities used. The only rational way to estimate these is by fitting to historical data. It is already difficult to get statistically valid linear relationships, without also trying to fit curvatures to the historical data. For this reason most relations are assumed to be linear (constant elasticities).

But that means that the elasticities pertain to the historical rate of demand increase, where the slope is less than the future one. That means that in principle the models underestimate future LUC, but this error may not be large compared to other approximations.

Of course it is possible to propose non-linear relations instead of simple linear elasticities. That means that non-linear relations can only be based on theory or expert judgment (RE).

Later, PH said that it would be much better if response is modelled as linear, because then models can give clear answers to many of the questions we are asking. If non-linearity is only a feature of model design (rather than a description of reality) it would be better to stay with linearity (PH).

GTAP is not linear in principle, but does behave linearly for small shocks (AG).

JRC note: in fact, GTAP results seem practically linear and additive for shocks as big as EU and US biofuel targets provided the yield elasticity is set high (0.65): see the experiments of Stefan Unnasch. If yield elasticity is reduced to 0.5 (the standard GTAP value for wheat), the behaviour becomes moderately non-linear, as shown in Figure 17 (taken from the presentation by Stefan Unasch). Alla Golub also subsequently reported experiments with different size shocks, where the results showed only slight deviations from linearity. The other models in this comparison seem essentially linear. Martin von Lampe at OECD says that the AGLINK-COSIMO model is linear by structure (as there are no tariff thresholds involved in the marginal runs made for this study, and reported in JRC's interim report to this project.). The same applies essentially to FAPRI-CARD and IFPRI-IMPACT models. The previous results of EU scenarios from CAPRI[19] were completely linear for different demand shocks scenarios from CAPRI were completely linear for different demand shocks in the EU

[19] See Interim Report "Modelling Indirect Land Use Change Effects of Biofuels Policy" (October 2009)

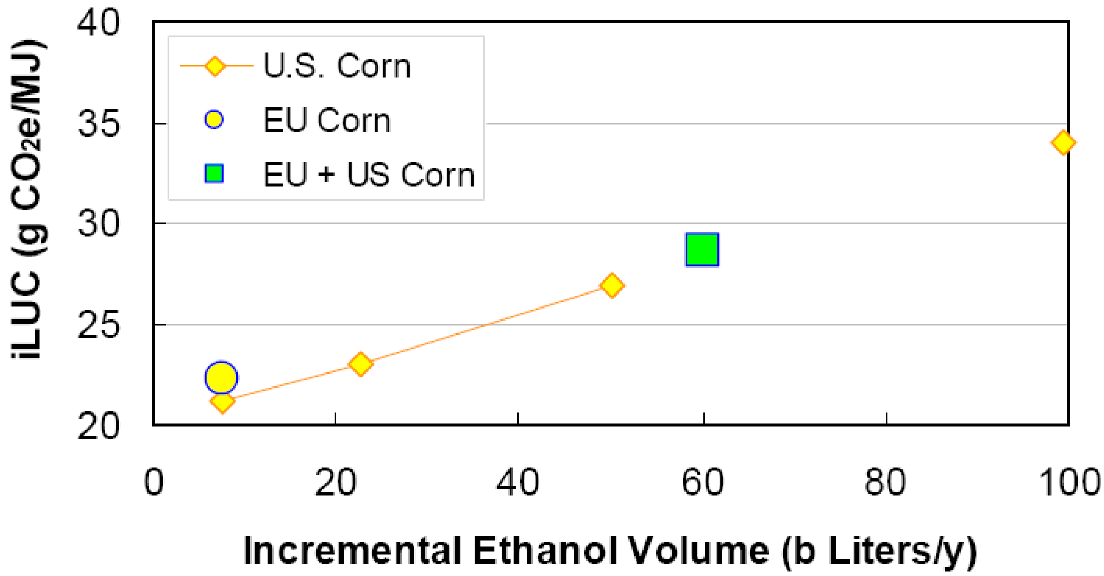

Figure 17 Non-linearity of results from LLC - Stefen Unasch presentation

17.2. Short-term vs. long term elasticities; Armington effects

Crop substitution elasticity

The tendency to use of elasticities derived from short-term data for long-term changes means that the elasticities of substitution between crops are generally too low for LUC modelling, which has a time-frame of decades. That is because it takes time for industries and consumers to change the crops they consume in response to changes in price differentials. So production changes tend to be too concentrated on the crops being used for biofuels. However, it is difficult to quantify the appropriate substitution elasticities (*RE*).

Short-term vs. long term elasticities: trade and Armington effects

The same holds for Armington elasticities, which describe to what extent the response to extra demand in one country is spread around the globe. That is because it takes time for prices and farmers in remote countries to changes in EU demand. Therefore, one expects the true response to long-term shocks to be somewhere between the predictions made by an Armington-based model (using observable short-term elasticities) and a single-world-market approximation (*RE*). The GTAP experiments of Alla Golub show that LUC is generally greater in the single-world-market approximation, as a greater proportion of production comes from developing countries with lower yields and higher land availability (the exception is her EU-biodiesel scenario, because palm oil has higher yield than EU oilseeds).

Whilst the GTAP and FAPRI-CARD global estimates of iLUC are relatively similar, there are significant differences in the regional distribution of production. The differences in this spatial dimension are a reflection of the global equilibrium solution in FAPRI-CARD, against the use of

Armington elasticities in GTAP. Trade is restricted to major trading partners in GTAP, whilst FAPRI-CARD does not account for sources and destination of trade (*JF*). IFPRI-IMPACT also takes no account of where extra production comes from.

In GTAP the model should mimic the homogenous world goods market if the Armington elasticity parameters are set to high values. Setting the Armington values high in GTAP may be useful to see how the distribution compares to FAPRI-CARD (*AG*). However, even with high Armington elasticities, it is the historical trade situation that mostly determines the supply response distribution. Countries which had small shares of trade in the past, can never reach a serious amount of trade in GTAP, even though the transfer of price information is supposed to be instantaneous.

17.3. Yield response

Understanding how yields can be increased may help identify how rapid the change in biofuels should be to avoid short term effects. It would be useful to understand if yield increase is indeed a response to price and demand, or if this response is all exogenous, so that the rate of yield increase will go on year by year regardless of what happens in the market (*PH*).

There is no argument from economic theory that proves there will be a positive net yield response to increased demand. The main issue is the yield response on the existing area versus the negative effect of area expansion onto worse land. There clearly has to be some response in terms of existing land. But a recent study showed that there is no correlation between yield increases among major producers, who are responding to the same price signal. Therefore, it could be inferred that you may get a short term yield response, but all you are really doing is implementing technology earlier, rather than later (*TS*).

JRC comment: there are two separate effects which tended to get confused in the discussions of yield response. Here we separated them out:

17.3.1. Short-term yield response (on existing land) to crop price.

There are two kinds of price responsiveness. The economic models are based on annual data, and if the yields are responsive to price, yields will fluctuate year to year because of high or low prices. The short term responsiveness to getting more yields is to apply more N fertilizer There is also a longer-term effect of prices on yields: if prices have been high for some periods, or are positively trending, or are expected to trend up in future, this will have an effect on yields in the medium to long term via price-induced technological progress (more research and development triggered by higher prices). This second effect is more difficult to link explicitly to price in a simulation model, especially in static models (AB).

If crop price goes up, simple economics means that the economically-optimum level of inputs per tonne of crop also increases, and this increases yield on a given patch of land, starting already at the following harvest. This is a reversible effect, but of course if the higher price is sustained, the higher yield is sustained.

JRC comment: this yield effect is taken into account in some way in all the models considered at this meeting. The GHG implications are discussed further below.

Can we use the response to the price spike of 2007/8 to calibrate the short-term responses to price? (RE)

Evaluation of the food price situation in 2008 would be useful as it is generally recognized that there was no significant demand shock separate from biofuels. The price shock may have been due mostly to supply shocks, but there was also a contribution from biofuels demand (*TS)*. The 2008 event was mainly an exogenous price shock due to speculation, but anyway it will have affected yields, areas and overall agricultural production, and so will be useful for calibrating short-term model parameters.

17.3.2 Response of rate-of-yield-improvement to crop price

General discussion

Yield response to long-term sustained prices involves irreversible increases due to developments in mechanization, plant breeding etc. These long-term changes are not automatically linked to an increase in N input, but they happen with a time lag. Modellers must be specific about which reference year is taken for comparison, as the reference year can make a significant difference, as to what the yield responsiveness is. For instance, the US and the EU now have biofuel mandates that may significantly increase the focus of long-term research and development on yield improvements rather than cost saving (*AB*).

In 2007 and 2008 there was seen a significant increase of capital directed into research and development of new seeds and technology, mainly related to speculation of food shortages and an increase in biofuels. At the same time many developing countries have increased their spending on agriculture. It has been shown that there is a significant correlation between long term yield increases and factors such as policy and public or private expenditure (*MP)*.

In the US we have seen a recent big shift in research attention from food crops to improving lingo-cellulose energy crops. This might reduce the rate of improvement of commercial crops, although the balance will correct itself in the long term. (*TS*)

General technological improvement and research has been going on for many years against the background of falling real product prices. Thus research has concentrated on how to achieve acceptable yields with less input. However, if the prices are seen to be increasing, the direction of research will turn towards intensification i.e. getting a higher yield even if this means more inputs. Therefore it is not clear whether this research effect will increase or decrease emissions per tonne of production (*RE*).

Biofuels alone will not cause a great surge in feedstock production (as distinguished from refining and processing) research; the land use changes given by the models are not enormous. Biofuels will be one factor amongst several, especially rising population, that seem to be introducing an era of rising agricultural prices (*AB).*

Long-term improvement of yields are not only achieved by seed improvement, but also through improvements in irrigation, management practices, adoption of already existing technologies, harvesting or reducing wastes (*MP*).

The lag for research and development in terms of their effect of yields is thought to be 20 years, maybe longer, so any effect on research spending will only be seen beyond the time-frame of most ILUC modelling. It is already difficult to find a statistically valid medium or short term price response: a long term response remains theoretical (*TS*). IFPRI found the time-lag between research developments and practical results to be at least 17 years (*SM*).

Treatment of yield response in models

This effect is modelled in FAPRI-CARD without a time-lag (see *JF* presentation), but GTAP has an exogenous rate of yield increase with time (*AG*).

The effect depends on long-term changes in global price, rather than local market prices. Long term investments are not related to current prices, but to price expectation or long-term policies that will foresee an increase in demand for a product. Therefore it can be said that it is policy that is an important driver of yields in the long-term (*JF*).

There is no basis for estimating *a priori* how much one should increase exogenous rate of yield increase to account for biofuels policy. However, it is possible to make the following experiment:-

The driver for agricultural research and improvements is profit from agriculture: if the profitability doubles, it is worth spending twice as much. However, the law of diminishing returns means that one cannot expect this to result in a doubling of the rate of yield increase. Therefore if one were to make the rate of yield increase proportional to farm profitability, one can estimate the *maximum* possible size of the rate of yield increase due to crop-price-induced research spending. One can also argue that the driver for increasing *yields* is just the price of the crop, so that the maximum gain in the rate of yield increase (rather than efficiency gains) is better estimated by making rate of yield increase proportional to crop price (*RE*).

When supply relationships are being looked at, some sort of exogenous variation would be preferable. What would be interesting are estimates of area or yield elasticities that are more plausible (*SB*).

17.4. General flaws and uncertainties in economic models

Some key questions are:

Are there fundamental flaws with the models (IH)?

Can we rank the sources of uncertainty in terms of their impact on indirect land use?

Can we provide a sensitivity analysis for those sources of uncertainty?

The main problem with models is that the parameters are either non-econometrically estimated (i.e. best-guesses) or carefully econometrical estimated but applied to different situations. The econometric estimates can be:

- Estimated for one country, and then applied to other countries in the world,
- Estimated from experimental data and then applied to conditions of farmers in the field who may react differently in reality
- Estimated in one specification with one set of *ceteris paribus* assumptions that are then taken out of that specification and placed in a different relationship where those *ceteris paribus* assumptions do not apply any more.

It is therefore important to identify how the parameters used in the models were estimated. (AB).

To minimize the different conditions and assumptions between econometric studies and models, careful calibration of the models is required, and if necessary one may need to impose limits on the application of the model. (AG)

Alla Golub asked if people considered the constant-elasticity-of-transformation (ct) parameters were too low in GTAP. JF replied that price responsiveness was very low in both FAPRI-CARD and GTAP. TS pointed out that one can still get realistic land responses if *all* the elasticities (yield, area and demand) are too low (only price changes would be affected).

The numerical parameters (like elasticities) in the models used in sensitivity analysis don’t tell you much when comparing one model to another, as the functional forms are very different. Furthermore, the significance of a parameter depends on the other parameters. You may have low land area response elasticity, but if you also have low demand response elasticity and low yield response elasticity, it’s the same as having a higher area response. So we shouldn’t compare the individual elasticities, but compound parameters (*TS*)

The way to deal with this is to look at:

- What is the percentage effect predicted of the food/crops that are diverted?
- How much are essentially replaced by DDGS?
- How much are not replaced by reduced food demand?
- How much is replaced by intensification/extensification, (this is essentially the data calculated by GTAP) (*TS*)

17.5. Comparing models

As the marginal scenarios are calculated compared to a baseline scenario which includes yield growth, the exogenous rate of yield growth is not important in determining the marginal LUC emissions. What is important, and what differs between models, is where the model allows crop expansion in the future, and how that availability may change up to 2020.

At which level should we compare the models?

Models differ in structure; for example the GTAP model and FAPRI-CARD model are conceptually different: one is an optimization model that is constrained and the other is an elasticity based model. Therefore, one cannot just compare internal model parameters. Once we have area expansion, and we know what kinds of area expansion we have, we can calculate emissions. The models can be compared using the emission results. This is one way to overcome the differences in the functional forms of the models. (*TS*)

Comparison of GHG emissions produced by the models may be very complicated as the models use different factors for above and belowground carbon stocks. It may be simpler to compare the process inputs or simply the percentage change in ha (*SU*). Once the land use change has been calculated, the results can be sorted into a few separate categories and the emissions compared. One of the big effects in iLUC is what kind of land is being converted e.g. if the land includes peat lands or not then the emissions are going to be dramatically different (*TS*).

However, not all models go as far as estimating GHG emissions: some only get as far as changes in production or changes in area. Furthermore, by comparing the results at the tonnes-of-crop-per-country and area-per-crop-per country stage, (as well as the final emissions) we can see at which point the models differ (*RE*).

From a policy point of view it is essential to identify the carbon stock numbers that the models are using as there are significant differences between the different models in the proportion of SOC that is assumed lost from the transition (land use change). For example when there is forest in the base year and cropland in the modelled year, is it appropriate to attribute all of the loss of above ground carbon and SOC to the crop or are there other processes going on, such as logging which ought to carry part of that cost? This cannot be calculated if the models give purely the change in hectares with no estimation of emissions (*PH*).

17.6. From crop area to land use change

Is double cropping taken into account? (PH).

Double cropping should be part of annual yield data (*RE*), but it was pointed out that FAO data counts double-cropping as an increase in harvested area (*MP*). Increased price will cause more double-cropping, so deriving LUC from FAO crop-area data leads to exaggerated estimates of crop area change.

The current version of the FAPRI-CARD model accounts for double cropping in Brazil. The model also explicitly and endogenously models stocking rate of animals together with the pasture crop.

Competition between pasture and cropland

Complimentary or substitution of animal feed and grazing. *How are these relationships working?* This can make a big difference to results. (*PH*)

In the area allocation, pasture for livestock is one of the enterprises considered in the competition for share of the total land available for agriculture (*JF*).

The general-equilibrium land-competition approach between grazing and crops is a (not-always-realistic) simplification of reality. That is because farmers don't always go for profit maximization. For example, cattle may be grazed on land at low density in order to secure tenure or property rights (for example, until cleared forest land can be sold for soybean farming). Furthermore, the costs of land conversion are generally ignored *(GW).*

Expansion onto Forest vs. Pasture

Modellers estimate parameters based on whatever historical data is available; often only the US; but the function using that parameter is then applied to predict what will happen in different agro-ecological zones. That is how GTAP produces the unlikely result that only 10% of cropland expands onto forest rather than pasture (*TS*).

None of the models specifically take into account the emissions from peat oxidation or fires following drainage of tropical peat-forest.

17.7. Marginal emissions from intensification

The European Commission does take into account the emissions for producing the biofuel (at a unit rate) (*PH*). However it is not clear where the calculation includes additional emissions caused by the increase of N inputs used to increase yields (*TS*).

Nitrogen fertilizer is the most GHG-intensive input because of both manufacturing emissions and the extra N_2O emissions from the soil. Short term increases in yields can also come from other practices: where labour is readily available yields may be improved by careful weeding, cultivation and improved harvesting (by hand) or adoption of organic farming methods (*MO*).

In the literature, some studies have assumed that *all* the extra spending went on fertilizer, and this *overestimates* the marginal emissions per tonne of extra crop production. On the other hand, ENSUS (UK bioethanol manufacturer) have treated crop-price induced yield increases as equivalent to an acceleration of recent time-trends; in particular the recent improvements in N use efficiency in some developed countries (against the long-term and world trend). This approach is wrong, as it illogically assumes that price increase will have the same effect as moving forward in time, even though real crop prices fell with time. Even using long-term world data, this approach *underestimates* the marginal emissions (*RE*).

When yields are increased through both fertiliser and technology, the fertiliser used per unit of output may be lower (*JB*). In this case there may not be any additional emissions or the emissions may even be reduced (*TS*). However, simple profit maximization theory means that if crop price goes up, the economically-optimum spending on inputs goes up, *also on a per-tonne-of-crop basis*. The extra spending on inputs per tonne of crop tends to increase emissions per tonne of crop, but *by how much* depends on the distribution of the extra spending between different inputs (*RE*).

In GTAP, fertilizer emissions per bushel are taken from GREET, and to find emissions from extra fertilizer would require recursion to GREET (*TS*). Whilst the GTAP assigns extra fertilizer for extra yield, it assumes that yield is proportional to all inputs, so the assumed fertilizer use per bushel stays constant anyway (*RE*, quoting *AG* report). AG asked if any model took into account emissions from increased marginal fertilizer rates. There was no response.

17.8. Miscellaneous Questions

<u>Policy related questions</u>

<u>Fossil fuel comparator.</u>

A fossil fuel comparator is not as important directly in the land use comparison, but if the net effect of a biofuel policy is to be calculated then the GHG savings from biofuels versus fossil fuels is required. For that a marginal fossil fuel comparator is needed. (PH)

<u>How do the models decide which biofuels get used?</u>

In the US biofuels are biofuel specific (*JF*).

JRC comment: The marginal calculations in this comparison exercise are wherever possible for specific biofuels from specific feedstocks.

<u>If you have a category which biodiesel can sell into, which biodiesel is it going to be?</u>

In terms of modelling the choice of biodiesel is based on relative cost of the different sources (*JF*).

<u>Do any of the models have a realistic representation, once you have set the biofuel requirement, of policy effects? i.e. will policies (e.g. minimum GHG requirements or incentives) alter the attractiveness of one biofuel over another?</u>

This will only be represented if we have an effective way of choosing which biofuels get used. In order to model the impact of an LCFS you have to be able to choose what biofuels are to be used (*PH*).

17.9. Final points

Policy options have to be robust to an irreducibly wide range of judgments about what iLUC is for different kinds of products. It cannot be the condition of a good policy that you have to know a certain number, that no-can dispute (*MO*). The right number is essential, but will this ever be achieved? (PH). Some key questions that need to be answered from an iLUC modelling exercise:-

- *How substitutable are different vegetable oils and where will they come from?*
- *What types of land are converted?*
  None of the models have a particularly good system here.
- *What is the aggregate demand response (e.g. in terms of area and yield increase)*
  the models get the demand response from many own price elasticities and substitution elasticities all working together. However, until now few modellers have reported the aggregate effects on the results.

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Abstract

This study is performed under request of DG CLIMA, in support to the preparation of the policy proposal on the assessment of the effects of Indirect Land Use Change (ILUC). Agro-economic models are used to provide estimates of how much cropland area increases in response to an increase in crop demand, but they often differ in their structure (i.e. partial or full equilibrium, agro-economic, bioenergy and biophysical models etc), in the input parameters, baseline and scenarios studied. The European Commission (EC) is debating internally how to address ILUC emissions in biofuels legislation. Legislators need to understand how ILUC differs between biofuels from different feedstocks and regions. In fact, if ILUC emissions are to be added to direct emissions in legislation, they need to be quantitatively assessed for all biofuels/feedstocks. Anyway, to compare model results it is necessary at least to compare the results vs. baseline per unit quantity of biofuel.
For these reasons the JRC proposed to carry out a survey of marginal calculations from various models/methods developed by the relevant consortia in EU and US, to compare results from marginal shocks along the lines of recommended common scenarios discussed with the involved experts:

A marginal extra ethanol demand in EU
B marginal extra biodiesel demand in EU
C marginal extra ethanol demand in US
D marginal extra palm oil demand in EU (for biodiesel or pure plant oil use)

For modelling the GHG efficiency of different feedstock, the experts agreed that the extra biofuels scenarios should optimally be marginal increases in demand for different biofuels-feedstock in different regions. These results would be relatively easy to compare between scenarios.
Results of this survey were discussed during a workshop organized by the JRC in Ispra on 10th and 11th of February 2010, and this report presents the outcomes of the workshop, highlighting the main results of the studies and key points raised in the concluding discussion.

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