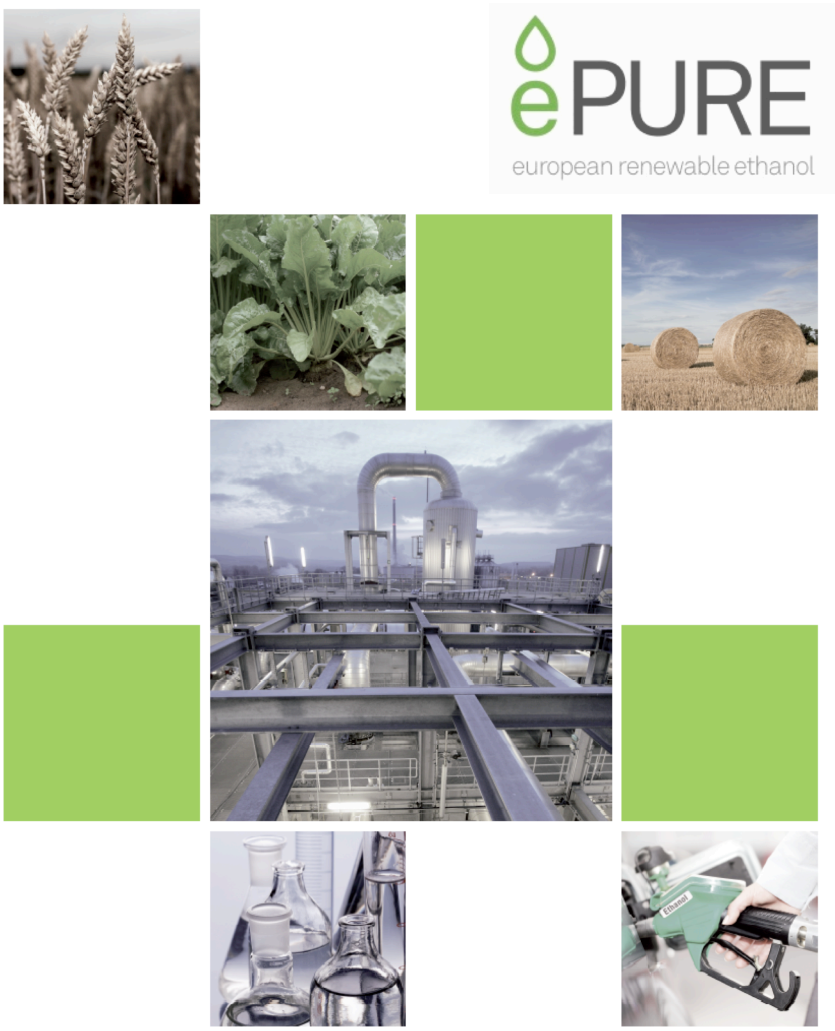
Position Paper

European Renewable Ethanol Association (ePURE)

Indirect land use change impacts of biofuels

- Contribution to the public consultation -



ePURE is Europe's industry association that promotes renewable ethanol, providing advocacy, authoritative analysis and industry data to its members, European institutions, strategic partners and the media. It represents the majority of European renewable ethanol producers, European market leaders as well as a broad cross-section of businesses related to the European renewable ethanol industry. ePURE was formed in 2010 after a merger between UEPA (European Union of Ethanol Producers) and eBIO (European Bioethanol Fuel Association).

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A. Introductory remarks

The academic work on modeling of the land use change impact of biofuel is still very much in its infancy. It is highly theoretical and hypothetical. Questions over the availability and adequacy of data, and the great variation to date in results both in land use change and GHG emissions do suggest that the existing science and methodology on land use modeling presented in the consultation documents, raise more questions than provide clear and indisputable answers.

The question if the science/modeling to date is right is very relevant. After all the results from the scientific work will have a decisive impact on policy decisions and ecological, social and economic consequences.

In case policy is justified by science, the science has to be conducted in an academic rigorous way, yielding results that are sound and beyond reasonable doubt.

In its submission ePURE will demonstrate that the modeling work carried out for the European Commission and under scrutiny in this public consultation has too many flaws, uncertainties and inconsistencies to be appropriate for policy purposes in whatever form.

1. The modeling work: basic scientific flaws

Attributing ILUC effects to the biofuels industry need to be scientifically sound considering the potential major negative impact on the sector and legal measures in case of reasonable doubts about the robustness of theoretically derived results. Given the vast diffierentiation in results from various modeling work done, the question seems justified how much of the recent ILUC literature is scientific. Have predictions been tested? Is the scientific work transparent and verified? Is the work objective?

Adequacy of models. ILUC effects are regularly calculated within the framework of equilibrium models. The results of these models (or "algebraic theories") always depend on the assumptions made, whereas there have to be considered uncertainties and lack of knowledge concerning the theory of these models (e.g. formulation of functions, choice of variables, determination of parameters) as well as their empirical implementation (e.g. data availability, data quality). Therefore, ePURE sounds a note of caution when applying theoretically derived results in policy. Algebraic determined results are only valid under model conditions which necessarily oversimplify highly complex economic processes.

Testing of predictions. A scientific method of inquiry consists of the collection of data through observation and experimentation, and the formulation and testing of hypotheses or predictions by experiments or observation. If the predictions are not accessible by observation or experience, the hypothesis cannot be proven. To the best of our knowledge no attempt has been made to test any ILUC prediction. Consequently, for now, ILUC remains an hypothesis and the predictions need to be tested.

Objectivity through transparency and verification. A basic expectation of the scientific method is to document, archive and share all data and methodology so they are available for careful scrutiny, giving the opportunity to verify results by attempting to reproduce them. This practice of full disclosure, also allows statistical measures of the reliability of these data to be established. However, a significant number of analyses are neither transparent nor reproducible even for external experts due to the opaque characteristics of the models (e.g. data, algorithms, system boundaries).

One attachment to the consultation is a review of 150 contributions to the literature by DG ENER of the European Commission. The review compares the data and methodological choices of 22 studies, including those attached to the consultation. On the question of transparency and verification, the report concludes (p.7):

"the reports assessed in this review are generally not explicit enough for the purposes of this review as regards data and methodology. It has not been possible to make a full comparison of the modelling choices made because in many cases, the reports do not reveal what these choices are."

Where data and methodology are made available, DG ENER concludes that (p. 6):

"consensus is far from being reached among scientists on many key aspects of methodology and data; there are still aspects that no studies have addressed; and these issues have a significant impact on the studies' results."

The review proceeds to list and describe 17 "main issues" (p. 6-7) that include contradictory or missing methodology and data. Any one of these issues will have a fundamental impact on the results, especially regards co-products (ePURE reflects on this in detail in the answer to question 1).

Bearing in mind the fundamental problems with data and methodology above, DG ENER states that:

"In terms of results, the estimated impact of the land use change attributed to biofuels has fallen over time, presumably as study methods have become more refined. While the original work of Searchinger et al. suggested that the greenhouse gas impact of biofuels' land use change was twice as great as that of the fossil fuel consumption avoided, three of the four most recent studies estimating greenhouse gas impacts – including the only one dealing with the EU – have concluded that biofuels are beneficial in greenhouse gas terms even when their land use impact, as well as a full life cycle analysis, is taken into account."

This conclusion suggests to us that in response to the second question of the consultation, there is no immediate requirement to take action on ILUC. Instead, we should be focusing on improving the quality of the science.

DG ENER goes on to state that:

"Studies that look at the relative impact of different types of biofuel give widely varying results. Most commonly, they suggest that one or another type of biodiesel – most frequently, soya – performs worse than ethanol."

This adds weight to our belief that the answer to the third question is that if the analytical work were done to a sufficient quality, it should be possible to determine the ILUC impacts of biofuels by feedstock type and by geographical location.

2. Comparing apples with apples

DG ENERGY make another criticism of the analysis to date of the ILUC impacts of biofuels by pointing out that apples are being compared to pears: (p. 7)

"The modelling exercises compare the land use impact of demand for biofuels with the emissions avoided by biofuels replacing fossil fuel. For this comparison they use an average value for present-day emissions from conventional sources of crude oil. This is not correct. The comparison should be with the long-term marginal source of fossil fuel (that is, the marginal source in a perspective under which investment decisions play a role). In the literature on that topic there is consensus that this will be a nonconventional source with higher emissions. Using such a comparator would be equivalent to reducing the estimated greenhouse gas impact from land use change by about 30%."

DG ENER's analysis only counts the direct GHG emissions of non-conventional oils such as tar sands and shale oils. A recent Parliamentary question to the European Commission, in another context, points out that there are other GHG emissions resulting from the exploitation of non-conventional oils:

> *"Apart from the GHG emissions which arise from extraction, refining, transport, and fuel combustion, significant emissions come from the direct land use changes which occur when oil is extracted from tar sands. If currently planned tar sands development projects unfold as expected, approximately 3,000 square kilometres of Canada's boreal forests (which represent one-quarter of the world's remaining intact forests) will be cleared, drained and strip mined in order to access tar sands. Such land use changes result in high amounts of green carbon being emitted in the atmosphere and contribute directly to climate change.[1]"*

An even bigger indirect GHG emission arises from methane being released from the permafrost of Siberia and in shallow coastal waters due to global warming. A recent analysis has attributed a GHG 63g CO2eq/MJ to gasoline from this release.

A policy that includes the indirect GHG emissions of biofuels only makes sense if it is based on a comparison that includes the indirect emissions of petrol and diesel.

3. Land use and Common Agricultural Policy reform (CAP)

It is argued by some, that due to the fact that biofuel use is policy driven – a government created market – ILUC effects should be taken into consideration. The reform of the CAP has also created new markets in third countries and consequently more land use to supply the EU market with for example sugar and meat. From a perspective of fair treatment and consistency in policy the ILUC effects of the reform of the CAP should be studied as well.

The reform of the CAP and the continuous ongoing of trade liberalization of agricultural commodities either through multi-lateral agreements (WTO, GSP and EBA) or bi-lateral agreements determine to a very large extent EU imports and exports of agricultural products and thus the impact of the EU on world agricultural markets balance and indirectly on the behaviour of individual farmers outside the EU. Consequently, ePURE supports the policy of the European Union to establish robust social and environmental standards within its policy regime, such as the already established protection of carbon-rich habitats (e.g. rainforests, savannahs) in the context of the RED regulation.

One very important reason for these important changes in policies, as stated by Commission and several NGOs, was to "promote the growth of the agriculture of poor countries" with the aim of reducing poverty. Would such a policy have an "ILUC" effect has not been assessed to our knowledge?

One of the effects of these important changes in CAP and Trade policy is that EU farmers had to choose between "reducing production" or "finding new outlets such as non food markets, biofuels for example". Whether they choose the one or the latter has no impact regarding ILUC, as it has already been widely demonstrated by DG AGRI work.

ePURE strongly recommends assessing separately the "ILUC impact" of this "promotion of growth of the agriculture of poor countries" policy, in order to prevent from blaming EU grown biofuels for something they are not responsible for.

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1 Doc PE448.842v01-00, dated 13.9.2010, question by the Committee on Environment to the European Commission.

4. Addressing land use and its change effectively

One of the striking outcomes of the ILUC public consultation in 2009 was that the majority of the stakeholders concluded that the best guarantee to address ILUC and preventing unwanted land use changes is having international agreements on protecting carbon-rich habitats. International agreements and their implementation into national law are most suitable to establish appropriate regulations concerning ownership and utilization of land. We believe that this is a more effective way to avoid irresponsible land use outside the EU than applying an ILUC factor on biofuel production. With an ILUC factor for biofuels, there would no longer be an incentive for regional efforts to prevent land use changes. ePURE would once more like to underline the importance of this policy instrument.

There are many drivers for land use changes, directly or indirectly that have no relationship with biofuel production. We already pointed out that CAP reform and trade agreements have resulted in land use change as well. The precise scope and geographic location of land use changes cannot be quantitatively allocated. Land use changes can be positive, e.g. when degraded land is used, or negative, e.g. when rain forests are cleared. Structural ways to improve land use is through applying adequate land regulations, modern farming techniques and land optimization (for example: yield improvement, use of less land for cattle raising). If the debate on ILUC continues to focus on biofuels exclusively (using only 3% gross of global cropland) we risk ignoring the obvious land use change drivers: timber harvesting, increased meat consumption and soy meal production as well as poor subsistence farming techniques due to insufficient technology transfers to developing countries.[2]

5. Get policy priorities straight

Finally, the most effective first step to minimize land use change emissions from biofuel production is to ensure that the sustainability criteria laid out in the Renewable Energy Directive (RED) are a success and embraced by producers both inside and outside of the EU. The sustainability criteria contain important elements that protect high carbon stock areas and encourage the production of better greenhouse gas (GHG) performing biofuels.

Member States are in the process of transposing the RED and the economic operators along the entire value chain are working hard to put the instruments in place to be able to comply with the sustainability requirements. The first certification schemes are already in place and auditing of crops is taking place.

From a perspective of investment security, policy stability is a prerequisite. Changing the RED immediately after it has entered into force effectively will not deliver this policy stability.

6. A fair debate

The European bioethanol industry would like to express its concern about the way the debate on biofuels and ILUC has been conducted in the public domain to date.

Contrary to what it should be i.e. an objective debate based on science it has been turned by some stakeholders and the media into a witch-hunt. The biofuel industry is being demonized and biofuel policy pictured as an irresponsible policy.

We think that this is biased and wrong.

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2 Food and Agricultural Organization of the United Nations, "Climate Change, biofuels and land" ftp://ftp.fao.org/nr/HCLinfo/Land-Infosheet-En-pdf.This paper shows that based on FAO modelling work, by 2030, projected growth in biofuel demand will require 35 million hectares of land. Based on the current global arable land area of ~1.5 billion hectares, this projection equates to around 2.3% of the current global arable land area. In this context, direct measures on other sectors and on land protection outside the biofuels space are very important since it will be impossible to control or even materially slow down global land use change by focusing mainly on biofuels which only uses 2.3% of that (arable) land.

The EU bioethanol industry is a responsible industry that complies with high social and environmental standards, the highest in the world.

The EU has put in place the most advanced legislation on sustainable production of biofuels in the world even though the EU represents only a small percentage of global biofuel production and use. The EU industry is committed to produce according to these very high standards as we already do as we speak even before the legislation is in force.

Moreover, the Renewable Energy Directive already explicitly addresses from a precautionary perspective the policy concern over ILUC, by requiring that all sales of biofuels achieve at least a 35% reduction in direct greenhouse gas emissions compared to the average of EU consumed petrol and diesel, to rise to 50% and to 60% for new plants.

7. In conclusion

Considering all the significant issues raised above, ePURE inextricably holds the view that in response to question 4 of the consultation, no action should be taken for the time being. However, the Commission should be proactive in building a broad stakeholder consensus on ILUC based on transparent, rigorous science and, if necessary, proposing corrective action at a later date. Such a scientific method of inquiry has been successfully developed and trialled by E4tech in its ILUC analysis for the UK Government. If properly applied at a European level, it should rapidly deliver a scientific analysis with broad stakeholder consensus over the results. It will also demonstrate that the sustainability credentials of the European ethanol industry are only enhanced when taking into account indirect greenhouse gas emissions.

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B. Questions and answers

1) Do you consider that the analytical work referred to above, and/or other analytical work in this field, provides a good basis for determining how significant indirect land use change resulting from the production of biofuels is?

No, the work referred to above does not provide a good basis for determining the levels of ILUC from biofuels. There are several fundamental errors in the models used for the Commission work, some of which were identified in DG ENER review and nearly all of which lead to an overestimate of the amount of ILUC.

There is however, other recent work, which has been peer reviewed and which is based on sound science, which provides a better basis for determining ILUC impacts.

Recently published modeling work by E4tech, sponsored by UK Department for Transport uses a cause and effect approach to model ILUC. This is based on data and methods, developed from extensive consultation with industry, academia and NGOs and has been peer reviewed by the UK Department for the Environment (DEFRA) scientific panel. This analytical work avoids most of the problems identified in the DG ENER review of other models referred to above. The E4Tech studies could provide the basis of more accurate ILUC calculations within the next few months.

Many of the models used for the Commission work were not developed for the purpose of modelling ILUC and the appropriate science for modelling ILUC is not included. The purveyors of these models have been reluctant to make the necessary changes to model structure and methods to properly model ILUC and it is unlikely that they could make these changes in the next few months. The errors in ILUC models used for the Commission work that are likely to be relevant to EU biofuels production are summarised below and dealt with in more detail in the attached annex.

1) Accounting for biofuel co-products

Biofuel co-products used for animal feed displace other crops and provide a substantial credit to the GHG emissions from ILUC. None of the models properly take account of biofuel co-products and the crops that they displace. Leitap does not account for co-products at all, while most models do not recognise the protein content of the cereal biofuel co-products.

- The lack of proper accounting for high protein biofuel co-products causes an overestimation of the GHG emissions from ILUC.

2) Modelling of oilseeds market

- Most oilseeds are grown primarily for the oil, with a lower value meal by-product, while soybean is primarily grown for the meal. It is widely accepted therefore that soybean is the marginal source of high protein meal for animal feed. In many models oilseed crops are aggregated together or are represented by aggregate vegetable oil and oilseed meals. It is therefore not possible for the model to allow for soybean to be modelled as the marginal source of high protein animal feed and hence to model the land change effects of biofuel co-products that substitute for oilseed meals.

- The aggregation of oilseeds will therefore lead to an overestimation of the iLUC impact.

3) Modelling land area and yield changes

- The crop demand growth for use as biofuels and hence higher prices will lead to an increase in crop yield growth. Most models do not account for the increased yield growth due to increased demand growth and the yield growth estimate is often an exogenous value based on historic data. These models therefore assume that all the increase in demand above the estimated yield growth is met by land area change.

- The lack of modelling of the proportion of demand growth from yield growth and area growth will cause an overestimation of the GHG emissions from ILUC.

4) Change to trade of biofuel crops

For crops, such as cereals, which are widely grown locally, the transport costs are high compared to the value of the crop and therefore many regions maintain a self sufficiency of these crops and the crop output is adjusted to meet demand. Any increased demand for these crops will therefore primarily be made up by increased production in that region. Most models use arbitrary elasticity factors to determine the amount of increased biofuel crop demand, that will be provided by increased imports or reduced exports. These factors do not take account of logistics cost and their applicability to cereals crops has never been justified.

The models overestimate the proportion of EU demand for cereals that will be met by EU imports or reduced EU exports. This results in the replacement cereals being modelled as being grown at lower yields than in the EU and gives an overestimation of the land use change and GHG emissions from ILUC.

5) Type of land changes

The methods for determining land use changes determine the amount of pasture and forest that will be displaced by extra cropland, but rarely include the re-use of unused and idle land in the EU and FSU. When the re-use of idle land is included, the factor used for foregone carbon sequestration is far too high since it is primarily based on carbon accumulation by afforestation, instead of by natural succession.

The lack of inclusion of unused and idle land and high factors for foregone carnon sequestration will cause an overestimate of the GHG emissions from ILUC of biofuel crops grown in the EU.

<u>Importance of co-products</u>

Taking the co-product issue in more detail, DG ENER states in its literature review that:

> *"…It is clearly important, therefore, for modelling exercises to incorporate a correct treatment of co-product questions… there is much greater divergence between studies in the rate at which biofuel co-products are assumed to substitute for other types of animal feed, and for the types of animal feed they are assumed to replace. (The type matters because the production of soya meal is more land intensive than the production of cereals, and an increase in soya production is more likely to trigger conversion of forest land in Brazil than is an increase in cereal production.)"*

DG ENER is referring to the problem that many models fail to account for the high protein value of European biofuel co-products and its substitution of imported soy meal. Instead, they simply compare the co-product with a home-grown animal feed, such as wheat or maize, on a weight basis. The significance of this can best be summarised by two peer reviewed scientific papers that take into account the protein content of the co-product of wheat bioethanol grown in the UK and Europe:

A paper by Ensus Limited showed that the net land requirement for growing wheat in Europe is only 4% of the gross wheat area after taking into account the crops displaced by co-product.

A paper of ADAS UK Limited, published after the release of the DG ENERGY literature, has estimated the greenhouse gas (GHG) credit of 82g CO_2eMJ from the reduced soy meal demand. ADAS notes that this is almost double the direct GHG savings from the bioethanol itself (of 45 gCO_2eMJ, stated in the Renewable Energy Directive).

In conclusion, the damning critique of DG ENER of the existing analytical work, combined with the continuing emergence of new work, tells us that the correct response to the first question of the consultation is that the existing work does not provide a good basis for determining the significance of indirect land use change from the production of biofuels.

Our answer to this question is therefore NO.

2) On the basis of the available evidence, do you think that EU action is needed to address indirect land use change?

On the basis of what is stated under Q1 the answer to question 2 is therefore NO.

From other analytical work, drawing on available scientific evidence, ePURE does not believe that indirect land use change represents a material risk arising from the production of bioethanol from cereals and sugar beet, as long as the co-products are used for animal feed.

3) If action is to be taken, and if it is to have the effect of encouraging greater use of some categories of biofuel and/or less use of other categories of biofuel than would otherwise be the case, it would be necessary to identify these categories of biofuel on the basis of the analytical work. As such, do you think it is possible to draw sufficiently reliable conclusions on whether indirect land use change impacts of biofuels vary according to:

- feedstock type?
- geographical location?
- land management?

If so, please say which, and indicate the evidence used to reach your conclusion.

Indirect land use impacts for biofuels used in the EU are primarily determined by feedstock type and the use of the co-products. This is because the feedstock type is the major determinant of nearly all the factors that cause higher or lower ILUC.

These factors are:

- The land use change effects of the biofuel co-products.
- The proportion of the increase in demand for a feedstock that is met by yield increases versus land area increases.
- Whether the extra land requirement will be met from utilising recently abandoned land or by land use change from natural vegetation.
- The type of natural vegetation and hence the carbon stock of the land that is converted to meet increased demand.

With regard to geographical location, cereals and sugar beet used for biorefining in the EU are principally grown in the local market where they are used. Any increase in demand will primarily be met mainly by increased growth within the country or local region. Therefore for biofuel from EU cereals and sugar beet, the iLUC impact will only relate to cultivation in the EU.

Land management has substantial environmental benefits but is mainly an issue for direct land use change. It is only relevant to indirect land use change for land management changes at an international scale. It is assumed that any biofuel supplier that includes the direct land use change for a consignment of biofuel will not also incur an ILUC penalty. It may well be possible to reduce direct land use change impacts by good land management practices, but this is not an ILUC issue.

4) Based on your responses to the above questions, what course of action do you think appropriate?

The course of action we consider to be justified is **A:** Take no action for the time being, while monitoring impacts including trends in certain key parameters and, if appropriate, proposing corrective action at a later date. Due to the inadequacy of the models, insufficient data, and lack of knowledge concerning the complexity of economic processes, monitoring and further research as well as analysis and evaluation of the implementation of RED in third countries are necessary. In addition, theoretically derived results must be subject to a better empirical review.

Annex

Issues of concern with models for calculating GHG emissions from indirect land use change

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Summary

Several issues of concern have been identified with most existing models for calculating GHG emissions from indirect land use change (ILUC). Nearly all of the concerns with current models; in particular accounting for co-products, yield growth and use of idle land, will lead to an overestimation of the GHG emissions from Indirect Land Use Change (ILUC), especially for crops grown within the EU. The magnitude of these concerns is:

- Lack of accounting for the protein level in high protein co-products underestimates the ILUC credit of co-products by a factor of up to 30.
- Lack of accounting for increased yield growth as a result of increased demand growth, overestimates the land use change for EU cereals by 4.5 times.
- Lack of accounting for the use of idle land in the EU overestimates the GHG emissions from and use change for EU crops by a factor of between 2.5 and 4.

Due to these concerns, the results from current equilibrium models cannot be used to provide a reasonable estimate of the GHG emissions from indirect land use change for biofuels.

It is important to try to move to some level of agreement between modellers, as to which factors need to be modelled and how this is best done in the ILUC context: i.e. deterministic cost optimisation, price elasticities, direct elasticities, or other empirical historic relationships.

There is also a concern that much of the effort on modelling has been to enhance equilibrium models and has resulted in more complicated models that lack transparency. Less effort has been applied to provide justification of the methods and model parameters used to evaluate GHG emissions from ILUC. It may be of more value to develop simpler models, for example spreadsheet based differential models, which use agreed methods for modelling those factors and determine the parameters that are most important for determining GHG emissions from ILUC.

The major issues of concern with the equilibrium models that are likely to be relevant to EU biofuels production are summarised below.

1) Transparency

In order to check the validity of a modelling approach, or to understand why different models give different results, it is important to know the justification for the modelling approaches that are adopted, the data fitting processes and data that have been used to determine parameters, for example elasticities, in the model. In many cases this is lacking in current equilibrium models.

2) Accounting for biofuel co-products

Biofuel co-products used for animal feed, displace other crops and provide a substantial credit to the GHG emissions from ILUC. In the EU, high protein biofuel co-products such as DDGS and rape meal will economically displace a mixture of soy meal and cereal to give a similar metabolisable energy and digestible protein level in the resulting animal feed. Most models do not take account of the protein content of biofuel co-products and hence the crops that they displace.

The failure to take proper account of the protein content of biofuel co-products such as DDGS and rape meal, used as animal feed in most ILUC models will underestimate the co-product credit by up to 30 times and cause a substantial overestimation of the GHG emissions from ILUC for biofuels from cereals and oilseed rape in the EU.

3) Modelling of oilseeds market

Most oilseeds are grown primarily for the oil, with a lower value meal by-product, while soybean is primarily grown for the meal. Soybean is the marginal source of high protein meal for animal feed, while palm is the marginal source of vegetable oil. In many models oilseed crops are aggregated together, or are all assumed to be grown primarily for the oil. The model does not allow for soy bean and oil palm to be modelled as the marginal sources of meal and vegetable oil respectively. It is then not possible to model the land change credit of biofuel co-products that substitute for oilseed meals.

The aggregation of oilseeds, or the assumption that soy bean is grown primarily for oil, rather than primarily for its meal will not enable proper accounting for the land saved by soy meal displacement, or use of soy oil for biofuels. These will both cause an overestimation of the GHG emissions from ILUC.

4) Modelling land area and yield changes

The crop demand growth for use as biofuels and hence higher prices will lead to an increase in crop yield growth. Most models do not account for the increased yield growth due to increased demand growth and the yield growth estimate is often an exogenous value based on historic data. The models therefore effectively assume that all the increase in demand above the estimated yield growth is met by land area change.

The lack of modelling of the proportion of demand growth from yield growth and area growth will cause an overestimation of the GHG emissions from ILUC for most crops and an overestimation of 4.5 times in the case of EU cereals.

The use of a factor to relate the yield on new land to existing yields is not justified and results in overestimation land area changes as a result of crop demand increases.

5) Change to trade of biofuel crops

For crops, such as cereals, which are widely grown locally, the transport costs are high compared to the value of the crop and therefore many regions maintain a self-sufficiency of these crops and the crop output is adjusted to meet demand. Any increased demand for these crops will therefore primarily be made up by increased production in that region. Most models use arbitrary elasticity factors to determine the amount of increased biofuel crop demand, that will be provided by increased imports or reduced exports. These factors do not take account of logistics cost and their applicability to agricultural crops such as cereals has not been justified.

The models overestimate the proportion of EU demand for cereals that will be met by EU imports or reduced EU exports. This results in the replacement cereals being modelled as being grown at lower yields than in the EU and gives an overestimation of the land use change and GHG emissions from ILUC.

6) Type of land changes

The methods for determining land use changes determine the amount of pasture and forest that will be displaced by extra cropland, but rarely include the re-use of unused and idle land in the EU and FSU. When the re-use of idle land is included, the factor used for foregone carbon sequestration is far too high since it is primarily based on carbon accumulation by afforestation, instead of by natural succession.

The lack of inclusion of unused and idle land will cause an overestimate of the GHG emissions from land conversion by a factor of between 2.5 and 4, for biofuel crops grown in the EU.

7) Validation of models

For predictions to be trusted, the equilibrium models need to be validated, by demonstrating that their predictions of past perturbations in crop land areas, trade flows etc satisfactorily match those observed. It is not clear whether any equilibrium models have been validated in this way.

Introduction

Increased global production of crop-derived biofuels creates a significant risk of indirect land use change with potential impacts upon local environmental quality and biofuel lifecycle greenhouse balances. If the EU is to realise its climate change goals to 2020 and beyond.then biofuel policy must visibly and scientifically account for the indirect impacts on land use. If this is achieved, it will create the necessary confidence for sustainable investment to meet these goals

It is inevitable that GHG emissions from ILUC will need to be quantified for different biofuels and feed-stocks and this is reflected in both US and EU legislation. However, there is currently no consensus on the modeling methods and model parameters that should be used to determine the GHG emissions from ILUC.

Several models and methods have been developed to calculate GHG emissions from indirect land use change (ILUC) due to biofuel production. The models are intended to be used to:

- Identify biofuel crops/regions where production is liable to lead to adverse land use changes, so that additional sustainability requirements can be applied to the production of such biofuels.
- Determine an indirect land use change factor (ILUC factor) in greenhouse gas calculations for biofuels. The ILUC factors would need to depend on type of biofuel, where the biofuel crop is used and the use of the biofuel co-products.

Steps in ILUC Modelling

All ILUC models will need to include the following steps (DGTREN 2009).

- What crops are displaced by biofuel crop co-products?
- How much of the increased production of each crop in each region is met by land area change and how much by yield growth?
- How much of the increased demand in a region is met by increased production in the region land how much by changes in trade?
- Where extra cropland is required, what type of land is converted to cropland?
- What are the carbon stock changes from land conversion?

Models that are aiming to determine the ILUCs effects of the biofuels for transport policy also need to determine the extra quantity of different crops will need to be produced.

It is generally accepted that the effects of biofuels on land use change should be determined on a consequential (substitution or system expansion) basis, rather than an allocation (attributional) basis (DGENVI 2009, EPA 2009).

Some methods for estimating GHG emissions from ILUC use an allocation method and do not include the steps above. These methods are answering the question of GHG emissions from ILUC due to cultivation in general, rather than the ILUC effects of a biofuels policy. They do not attempt to adequately differentiate between the ILUC effects of different biofuel crops and regions and are not considered further.

Consequential modelling of demand and supply relationships must be done by establishing empirical economic driven relationships between variables by fitting historic data. Since biofuel targets are quantity driven, the effects can modelled directly, using direct elasticities related to demand growth, for example by establishing the proportion of demand changes that will be supplied by yield changes and area changes. Alternatively the effects can be modelled indirectly using price elasticity factors, for example by determining the effects of increased demand on prices and then fitting land area changes to these prices. Both approaches should give similar overall results, although there is more 'noise' in price relationships due to price volatility and variations in regional price and input costs.

Consequential modelling of the effects of biofuels can either be done using integral models to compare a biofuel scenario to a baseline scenario, or if response functions are linear, a differential model can be used to determine ILUC factors directly. With the use of integral models, there is much debate about what baseline and biofuel scenarios should be used, but with differential models this unnecessary for calculating the GHG emissions per MJ of biofuel.

Types of ILUC model

Most of the work on ILUC modelling has been done using complex "equilibrium" models which are used to determine the extra quantity of different crops will be produced to meet a biofuel policy target and with additional modules can be used to determine the ILUC impact of the policy and/or of the different biofuel pathways.

An alternative approach is to use "cause and effect" models to determine the ILUC impact of different biofuel pathways.

Equilibrium models

Equilibrium models are integral models, which model economic relationships via prices and can be divided into two types:

- Computable general equilibrium models.
- Partial equilibrium models

<u>Computable general equilibrium (CGE) models</u>

These models are all based on the Global Trade Analysis Project GTAP (O'Hare 2009), ? which was written to determine the effects of tariff changes on international trade flows. Various versions of the GTAP model are available and different versions have been or are being used for ILUC modelling by different groups. GTAP based models allow inter-sectoral and international trade interactions, but the model architecture poses restrictions in modelling some specific aspects of ILUC, such as co-product substitution. GTAP based models have or are being developed by CARB (CARB 2009), IFPRI(Valin 2009), LEITAP(Prins 2009).

<u>Partial equilibrium models</u>

These models are more varied and flexible than the GTAP based models. Some models have been developed specifically to model ILUC and are able to take a more sophisticated approach to the agricultural sector. Partial equilibrium models have been or are being developed by Aglink (OECD 2008), EUFASOM, ESIM, IIASA, CAPRI, FAPRI and FASOM.

The US Environmental Protection Agency (EPA 2009) has used a combination of FAPRI and FASOM to determine ILUC factors for US biofuels.

<u>“Cause and effect” models</u>

“Cause and effect” models are differential, spreadsheet based models, which uses cause and effect logic to describe and derive ILUC impacts. The model are intended to determine the ILUC impact of different biofuel pathways, but not the extra quantity of different crops will be produced to meet a biofuel policy target. Such models can be made completely transparent and are more flexible than equilibrium models. They can be used for detailed modelling of ILUC to evaluate ways of mitigating the risk ILUC impacts. A “cause and effect” model has recently been developed by E4tech for the UK Dept for Transport.

Details of issues with ILUC models

The issues with equilibrium models below are based mainly on the CARB work (CARB 2009) and EPA work (EPA 2009), since detailed data on the calculation and the results of these models are readily available. Some issues are also based on IFPRI work (Valin 2009a), (IFPRI 2010), LEITAP (Prins 2009), work by JRC (JRC 2010a), (JRC 2010b) and the DGEnergy literature review (DGEnergy 2010). Many of these issues raised also apply to similar modelling approaches that are used in other equilibrium models.

The issues of concern with the equilibrium models that are likely to be relevant to EU biofuels production are explained in detail below. For each step in the ILUC calculation, the underlying science is discussed and then alternative modelling approaches are compared relative to the science.

1) Transparency

In order to check the validity of a modelling approach, or to understand why different models give different results, it is important to know the justification for the modelling approaches that are adopted, the data fitting processes and data that have been used to determine parameters, for example elasticities, in the model. In many cases this is lacking in equilibrium models.

Although the database and source code for the GTAP model is available on the internet, this does not provide the data needed to validate the models.

Some examples of the transparency issue are listed below and explained more fully under relevant sections.

- Lack of clarity of modelling approach: modelling of oil seed markets and changes in trade patterns
- Lack of justification of modelling approaches: assumption of constant yield growth rate and use of Armington elasticities for changes in trade patterns.
- Lack of references: sources for the model elasticities factors are not provided.
- Lack of a firm basis for assumptions: the elasticity used to account for lower yield on new land used to grow biofuel crops is justified by “best judgement”.

2) Accounting for biofuel co-products

The production of biofuels from crops such as cereals and oilseeds gives high protein co-products that are normally used for animal feed. They will replace the variable animal feed components in the production regions, which for the EU, are wheat exports and soy meal imports.

In the US substantial quantities of corn DDGS is used as liquid feeds or other direct feeds in local feedlots, or is dried and exported to China as a high protein animal feed. However, the animal feed industry in the EU operates differently from in the US. In the EU, most of the DDGS from bioethanol plants is dried and used in formulated animal feed. The costs of high protein animal feed i.e. imported soy meal in the EU are substantially higher then energy feeds such as wheat. Therefore animal feed compounders will maximize the use of DDGS and rape meal (as with other co-products) to displace soy meal (CE Delft 2008, Lywood 2009a), to minimize the overall cost of the feed (FEFAC 2009). The levels of essential amino acids (EAAs) in DDGS are supplemented by addition of synthetic EAAs such as lysine, threonine and methionine to boost protein quality. The price of DDGS and rape meal (as with other co-products) used in EU animal feed adjust so that they will be fully utilised for animal feed. Therefore in the EU, biofuel co-products will economically displace a mixture of soy meal and cereal. The substitution ratios of co-product for soy meal and cereal are such as to give the same digestible energy and digestible protein level of the resulting animal feed (Marshall 2006, Lywood 2009a). The digestible protein level of DDGS is greater than that of all oilseed meals except soy meal, so will displace soy meal on the same basis as for rape meal and sunflower meal.

Studies on crop displacement by biofuel co-products in the EU have been made by CE Delft 2008, Lywood 2009a and ADAS 2010. The results from are shown in table 1.

Substitution Ratios for EU Biofuel co-products			
	Co-product	**Substution for soy meal**	**Substution for cereal**
		t / t of co-product	
CE Delft 2008			
	Wheat DDGS	0.50	0.66
	Maize DDGS	0.45	0.69
Lywood et al 2009			
	Wheat DDGS	0.59	0.39
	Maize DDGS	0.40	0.49
	Rape meal	0.61	0.15
ADAS 2010			
Current scenario	Wheat DDGS	0.33	
Future high usage scenario	Wheat DDGS	0.60	

Table 1

Typically 1 t of wheat grown in Europe will produce about 0.33 t of DDGS co-product which taking an average of the future data above (1 t DDGS replaces 0.55 t soy meal and 0.45 t wheat) will displace about 0.18 t of soy meal and 0.16 t of wheat.

2.1 Accounting for co-products in models

Many studies and equilibrium models do not account properly for biofuel co-products. Some models such as LEITAP and DART, do not account for co-products at all, while others such as CARB do not account for the high protein value of DDGS co-products and simply substitute DDGS for corn on a weight basis. Some models e.g. IFPRI allow for rape meal to substitute for soy meal, but do not allow DDGS to substitute for soy meal, even though DDGS has a higher digestible protein content than rape meal. (Premier 2008)

A primary reason why the displacement of soy meal by DDGS is not modelled in many equilibrium models is that the architecture of the equilibrium models does not allow it. Most equilibrium models are segmented into different sectors, for example oilseeds (or oilseed meals) and cereals and this segmentation simply does not allow for the co-product from one sector i.e. cereals to substitute for part of a different sectors i.e. oilseeds (or oilseed meals).

Instead of correcting the models to enable DDGS to displace soy meal, it has apparently been argued by some modelers that although DDGS is not properly accounted for in GTAP based models, the effect of this on GHG emissions from land use change is small. On a weight basis, the amount of soy meal displaced (0.18 t / t wheat) may be regarded as small. However, when translated into GHG emissions from ILUC, the effects are far greater. The reasons for this are:

- The yield of soy is substantially lower than the yield of EU wheat
- The increased demand for EU wheat is primarily met by yield increases, whereas the increased demand for soy is primarily met by land area increases
- New wheat land in the EU will be obtained from using unused land or reducing the rate of creating idle land, while new soy land in S America is obtained from a mixture of deforestation and conversion of grassland to cropland.

The effect of these factors is illustrated in table 2.

		Feed Wheat	Displaced soy meal	Ratio SBM / wheat	Data Source
Source of crop		**EU**	**S America**		
Mass ratio		1.0	0.18	**0.18**	Table 1
Crop yield (avg 2006-9)	t/ha	5.3	2.6	**2.0**	FAO
Proportion of output from land area change		22%	90%	**4.1**	Lywood 2009b
Type of land displaced		unused / idle land	grassland / forest		
Avg. carbon stock of displaced land	t CO2/ha/yr	1.8	12.0	**6.8**	Lywood 2010 ADAS 2010
GHG emissions from ILUC				**10**	

Table 2

Although the quantity of soy meal displaced by the DDGS is only 18% of the quantity of wheat used to produce the bioethanol, the reduction in GHG emissions from ILUC associated with displacing the soy meal will be (0.18 x 2.0 x 4.1 x 6.8) = 10 times greater than those associated with growing the wheat. For models that simply substitute DDGS for cereal on a mass basis, the credit for the DDGS will only be 0.33 times the impact of growing the wheat. Thus including yield effects and the carbon stock changes of the land used to grow marginal crops, the DDGS credit when accounting for soy meal displacement is thirty times the figure when it is assumed that DDGS replaces wheat on a mass basis.

It is calculated (ADAS 2010) that with high usage of DDGS for animal feed, the reduction in GHG emissions due to the displacement of soy meal by DDGS is equal to 150 gCO2 eq / MJ ethanol. This is equal to 1.7 times GHG emissions from gasoline of 85 gCO2 eq / MJ. These figures show that modelling of biofuel co-products used for animal feed, including their protein content, is essential and the results from models that do not include appropriate modelling should be discarded.

The failure to take proper account of the protein content of biofuel co-products such as DDGS and rape meal, used as animal feed in most ILUC models will underestimate the co-product credit by up to 30 times and cause a substantial overestimation of the GHG emissions from ILUC for biofuels from cereals and oilseed rape in the EU.

3) Modelling of the oilseeds market

Modelling of the oilseeds market is needed to understand the land use changes resulting both from making biodiesel from vegetable oil and to determine the credit for high protein biofuel co-products, such as DDGS and rape meal, that are used for animal feed.

The average prices (USDA 2009a) and relative values of vegetable oil and meal from different biofuel oilseed crops are shown in table 3.

		Soy	Rape	Sun flower	Palm
Typical oil yield	t/ha	**0.4**	**1.5**	**1.0**	**4.0**
Average prices 2001-08					
Oil price US	USD/ton	542	695	858	636
Meal price US	USD/ton	212	168	106	82
Oil yield	t/t crop	0.19	0.410	0.420	0.235
Meal yield	t/t crop	0.74	0.557	0.550	0.028
Oil value	USD/ton crop	102.9	285.1	360.2	149.6
Meal value	USD/ton crop	157.1	93.4	58.1	2.3
Oil value/total product value		**40%**	**75%**	**86%**	**98%**

Table 3, Source USDA 2009a

It may be seen that for rape, sunflower and palm, the vegetable oil is significantly more valuable than the meal and it is generally accepted that the crop is being grown primarily for the vegetable oil. However, in the case of soy bean, the meal has a significantly higher value than the oil and the typical oil yield from soy is substantially lower than for other oilseeds. It cannot therefore be economic to grow soy primarily for the oil.

Data for the global trade in meals (USDA 2009b) for animal feed vegetable oils are summarised in table 4.

Global Trade		Soybean	Rape seed	Sunflowe rseed	Palm	Fish Meal	Other
Meal Exports							
Exports Avg 2006-9	mt /yr	105.5	8.1	4.5		2.7	5.7
Export growth 1999-2009	mt /yr	51.4	2.6	1.7		-1.2	2.0
Vegetable oil exports							
Exports Avg 2006-8	mt /yr	9.9	2.2	4.2	32.4		5.3
Export growth 1999-2009	mt /yr	2.8	0.8	1.7	21.4		2.2

Table 4, Source USDA 2010

It can be seen that between 2006 and 2009 soy bean meal accounted for 83% of the trade of high protein meals and 91% of and growth in trade in high protein meals over the last 10 years. It may therefore be concluded that soy meal is the variable global source of protein meals to meet the demand for high protein animal feed. This confirms earlier work by LMC 2007 and is consistent with FAO work on animal feed demand (FAO 2006). It may also be concluded that soya bean growth is being driven by the global demand for soy meal to meet the increasing demand for animal feed protein. It follows that the substitution of soy meal by high protein biofuel co-products will reduce the growth rate of soya bean output growth. This is also supported by FEFAC work (FEFAC 2009)

It may also be seen from table 4 that while there has been an increase in soy oil trade as a result of the increased production of soya bean, 80% of the increase in trade in vegetable oils over the last 10 years has been from palm oil. Since the soy oil increase is driven by the increased demand for soy meal, 89% of the increase in the marginal trade of vegetable oils has been met by increased palm oil production. It may therefore be concluded that palm oil is the primary variable global source to meet the growing global demands for vegetable oil. It follows that the use of soy oil to make biodiesel will not primarily affect the growth rate of soya bean and will be replaced in the vegetable oil market by increased production of palm oil.

The CARB GTAP model aggregates all the oilseed crops into a single sector. Therefore as well as not being able to model the soy meal substitution of co-products (see section 2), it also has to assume some sort of average yield of vegetable oil for the production of biodiesel. The oil yield of palm oil is about ten times that of soy oil, so the increase in land area for vegetable oil for biodiesel will be very sensitive to the split of vegetable oils that is used to calculate the average oil yield. Since soy oil used to make biodiesel will be replaced by increased production of palm oil, the soy oil yield is not relevant in calculating the average oil yield. Inclusion of the soy oil yield in the calculation of the average oil yield will overestimate the land area required for biofuels.

In the EPA study, there is a large discrepancy in the trade response from the production of soybean biodiesel between the FASOM and FAPRI models. This appears to be due to different assumptions between the models as to whether soy is grown primarily for the oil or for the meal. The EPA FASOM model appears to assume (EPA 2009, fig 2.6-2) that the use of soy oil for biodiesel production will be met by growing more soybeans and that the soy meal co-product will substitute for cereals and hay. However, the EPA FAPRI model appears to assume (EPA 2009, fig 2.6-14) that soybean is grown primarily for the meal and the demand for vegetable oil will be met by imported soy oil. It can be shown below that soy is grown primarily for the meal, rather than primarily for the oil.

The assumption that soy is just grown primarily for its oil, rather than primarily for its meal will lead to an overestimation of the overall land used for the production of soy biodiesel and underestimate the land saved by soy meal replacement by other high protein biofuel co-products. These will both cause an overestimation of indirect land use change.

4) Modeling land area and yield changes

Economics of supply and demand dictate that higher demand for crops for biofuels will drive higher prices, which will in turn drive investment for increased output. Increased output will require additional investment and can either arise by land area increase, yield increases, or by increases in the frequency of cropping. Therefore in the medium term, the proportion of the increased supply of crops that will be met by land area change, or yield change, will differ by crop and region, depending on the relative economics of obtaining increased output from additional cultivated land area, additional yield and increased cropping frequency. Most of the available data on crops, e.g. FAO provides crop yield and crop harvested area, but there is much less data on cropping frequency. The effects of cropping frequency are therefore not often considered.

There are many ways in which crop yields can be improved, for example: crop variety development, fungicide treated seeds, adoption of technology, increases in inputs such as fertilisers and pesticides, increased mechanisation allows a longer growing season, precision farming allows improved timing selective spatial input addition, improved drainage, use of improved crop varieties and pesticides allows changes to the crop rotation to reduce the proportion of fallow land and maximise the use of higher yielding crops.

Some authors try to differentiate yield growth between increased inputs and improved technology. It is then argued (Searchinger 2008b) that improved technology happens anyway, so is constant and is not a function of price or demand growth. However, other authors show that underlying or ‘trend’ rate of yield growth for a crop is not constant and is itself dependent on prices or land availability: For example Guyomard et al. (1996) and Benjamin & Houee (2005) show that European yield growth was responsive to support prices under the EU CAP.

4.1) Relating land area and yield growth to prices

While many views have been expressed on the relationship between yield growth and price, little analytical work has resulted in statistically significant elasticity factors. Keeney (2008) summarised some of this work and concluded that taken as a group, the studies show that there is a relationship between price and yield growth. Searchinger (2008b) draws a different conclusion from these data that yield is unresponsive to price in countries that have adopted modern agriculture.

It cannot be assumed that just because a statistically significant relationship between yield changes and prices has not been found, that the effect of price on yield growth is negligible. To justify the assumption of "inelastic yield", analysis must show that there is a relationship between land area growth and prices with no corresponding relationship between yield growth and prices. Little if any evidence has provided on this.

Clearly since increased crop output is driven by higher prices, there must be relationships between land area growth, yield growth and prices or margins. If it is not possible to find significant price elasticities from simplistic models, then more appropriate ways of relating yield growth and area growth to prices must be found. Three reasons why elasticity factors relating yield changes and area changes to price changes, have been difficult to determine are:

- the timescale for yield increases,
- large year to year yield changes due to weather.
- use of prices rather than price changes

Most of the analysis work has focused on short term relationships between price changes and yield changes to obtain a yield : price elasticity, it takes time to obtain increased output as a result of higher margins. The effect of prices takes between one and five years to be fully reflected in yield and land area changes due to the investment timescale of cultivating new land, infrastructure improvements, introduction of modern machinery, and adoption of higher yielding crop varieties in the years following high prices.

As pointed out by Searchinger (2008b), high yields in one year will tend to produce abundant crops that lower prices and low yields result in high prices, confusing the causal relationship. These problems can be largely overcome by using a one year lag between prices and yield changes and by averaging yields changes and prices over a few years.

Technology improvements are not discarded in the case of falling prices (Kloverpris 2008). The increase in output growth is therefore related more closely to prices, or margins than to price changes

Reasonable fits to historic data can be found, by fitting to the prices relative to the long term trend price as long as it is done in an appropriate way (Lywood 2009b). For example, the relationship between land area growth, yield growth and prices is demonstrated in figure 1 for the case of global wheat supply.

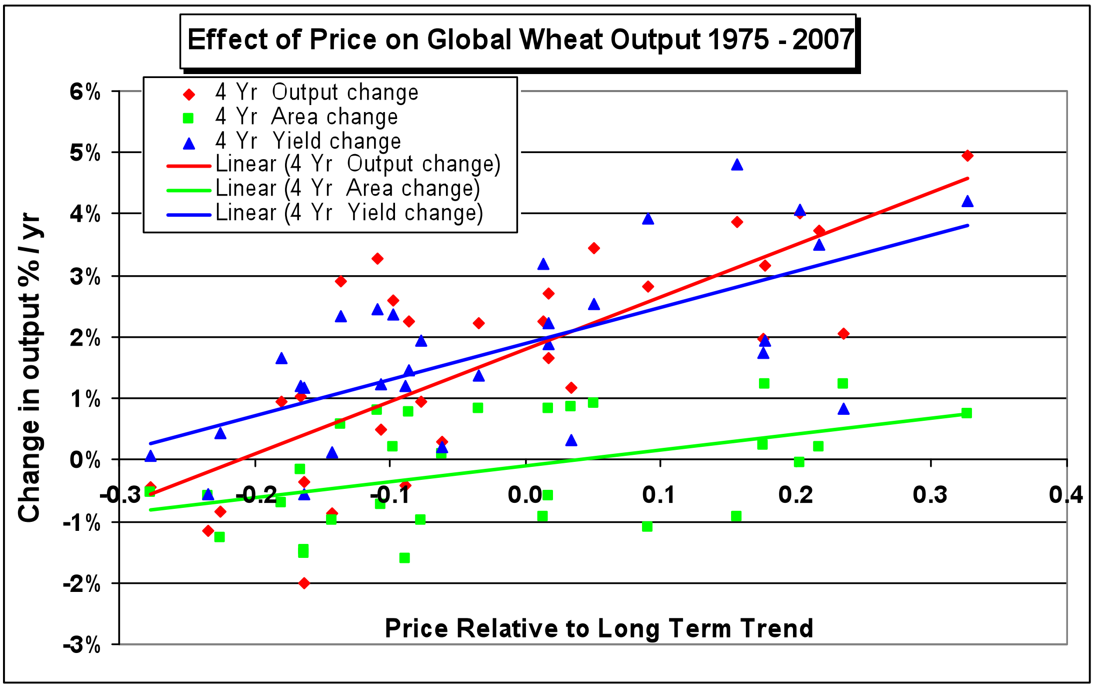

Figure 1, Source – FAOstat, Lywood 2009b

Each point represents one year using the compound annual growth rate (CAGR) over a four-year time span. The trend-lines show the historic relationship established by linear regression. There is a quite a lot of scatter on these models and the price relationships cannot be determined accurately. However, it may be shown that:

- There is a statistically high confidence that yield growth is not independent of price
- There is therefore no apparent 'normal' rate of yield growth independent of prices.
- Most of the increased output of wheat is from higher yield growth, not from higher land area growth.

It is therefore not valid as in many equilibrium models to assume that the rate of yield growth is unrelated to price or to the growth in demand.

For some crops in some regions, it is still difficult to find relationships between changes in output and prices, due to other factors such as changes in variable input costs and changes in agricultural subsidies. In these cases alternative approaches can be taken to determine the split between yield growth and area growth.

IFPRI (Rosegrant et al. 2001) assume that yield growth and area growth both respond to increased prices, and derives elasticity factors for yield and area based on expert estimates.

Some GTAP based models, for example the CARB model include an elasticity factor for yield changes with price changes. The source data for the elasticity factor of 0.25, used in the CARB GTAP model is not provided. Since neither an output: price or area : price elasticity is provided, the relative proportions of the demand growth that is met by yield growth and area growth is not known.

4.2) Relating land area growth and yield growth to demand growth

The effects of demand growth can alternatively be modeled by relating changes in yield growth to changes in area growth. The relationship between yield growth and land area growth is shown in figure 2 using FAO EU cereals (wheat, maize, barley, rye and triticale) data from 1961 to 2008.

Each point represents one year with changes averaged over a six-year time span. The trend-line shows the historic relationship established by linear regression.

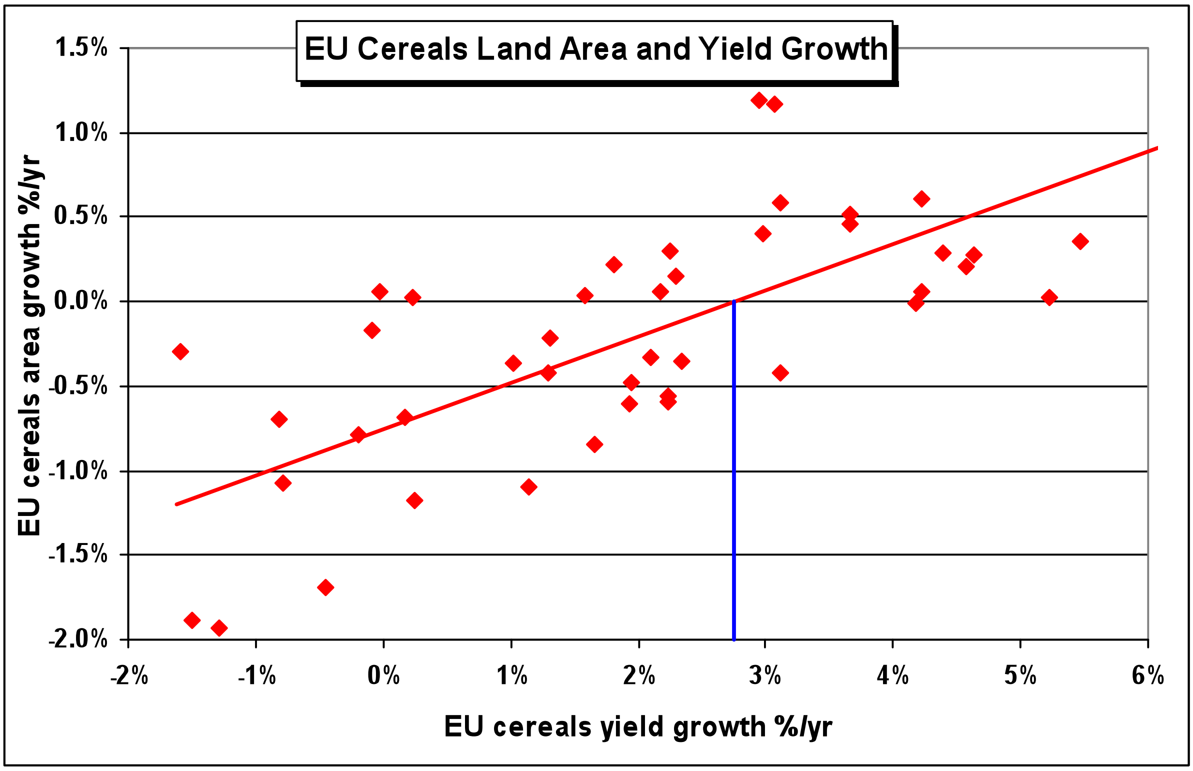

Figure 2, Source – FAOstat, Lywood 2009b

This graph confirms that there is no apparent 'normal' rate of yield growth and most of the increase in output of cereals comes from increased yield, not from increased land area. There is significant scatter of data, but the best regression fit shows that 78% of incremental EU cereals output growth is from yield growth and 22% from land area growth. No extra land would be needed to meet an increased output growth of cereals in the EU up to a growth rate of 2.7%/yr. This compares to the output growth rate since 1990 of 0.3%/yr.

Similar analyses have been done for other crops both globally and regionally (Lywood 2009b). For all the crop region combinations that were modeled there was always a positive correlation between area growth and yield growth. The results for different crops and regions from this analysis are shown in table 5.

Region	Cereals EU	Rapeseed EU	Maize US	Soy S Am	Sugar cane Brazil	Oil Palm S E Asia
Yield growth change / output growth change	78%	37%	58%	10%	23%	23%
Area growth change / output growth change	22%	63%	42%	90%	77%	77%

Table 5 Source Lywood 2009b

The proportion of incremental output growth from land area growth varies between 22% for EU cereals and 90% for S American soy. This compares to the value of 100% used in most equilibrium models.

This analysis of crop yield growth was not included in the DGEnergy peer review (DGEnergy 2010), even though it was published as a peer reviewed paper in 2009.

Figures 1 and 2 demonstrate two different ways to show how appropriate modeling can be used to determine the proportion of output growth that is met by yield growth and land area growth. Modelers should use these or other methods to determine the proportion of incremental output growth from land area growth and yield growth.

4.3) Modelling of yield growth in current models

It might be expected that economic models would determine the proportion of the increased demand of crops from land area change and yield change, by relating these changes to prices in the same way as they determine output/price elasticities. However none of the equilibrium models determine crop land area changes in this way. Even though the determination of land area changes is a primary step in the calculation of ILUC, few equilibrium models determine or use factors to relate land area changes to prices.

IFPRI and E4tech models take account of the effect the effect of demand growth on yield growth, to determine the proportion of marginal demand growth that is met by yield growth and land area growth. However, the basis of the IFPRI figures is not given.

Most equilibrium models attribute increases in yield to technological gains that are independent of market signals, while attributing year to year variations in yield to the weather. (Keeney 2008). Other models split yield growth into increased inputs and improved technology. The models determine the land area growth indirectly by subtracting a yield growth estimate from the demand growth. The yield growth is estimated in different ways. Some equilibrium models e,g, FAPRI, FASOM assume an exogenous yield growth rate based on average historic yield growth rates. Thus in these models, yield growth is not related to price or to output growth at all. The effect of this assumption is that if the forecast output growth is greater than the exogenous yield growth rate, the incremental land area growth will be assumed to be met entirely by land area growth. For EU cereals, this approach leads to a modelled land use change which is 1/0.22 = 4.5 times higher than when the effect of demand growth on yield growth is properly accounted for.

It is not clear that any equilibrium models have validated their approach by demonstrating that their predictions of past perturbations in crop land areas satisfactorily match those observed.

The lack of proper modelling of land area change in equilibrium models, by assuming that yield growth rate is unrelated to output growth rate causes an overestimation of the GHG emissions from ILUC for most crops, with an overestimation of 4.5 times for the case of EU cereals.

4.4) Factor for lower yield on new land area

It is possible that when new land is needed to grow extra crop, the new land will be more marginal than the existing cropland, so the yield on the new land will be lower than on existing land. In GTAP based models this effect is termed "slippage" and the models use an elasticity factor to relate the yield on new land to the yield on existing cropland. The effect of slippage is subtracted from the yield growth. It is accepted by CARB that "little empirical evidence exists to guide modellers in selecting the most appropriate value". The CARB GTAP model work uses "best available professional judgement" to choose a central case elasticity factor of 0.5, meaning that the average yield on new land will be half of that on existing cropland. A range of the elasticity factors was modelled and a factor of 0.25 resulted in a 77% increase in GHG emissions compared to using a factor of 0.75.

When there is a lower yield on new land area, then:

Net yield growth = yield growth on existing crop land - land area growth x (1- slippage factor)

Historic yield change data for example from FAO is collected on an average regional or country basis and is the net yield growth. Therefore these yield changes already take into account any effect of lower yield on new land. As long as a relationship derived from historic yield data is used to relate yield growth to prices or to demand growth, as in figures 1 and 2, then these relationships already includes the effects of slippage and there is no justification for a separate elasticity factor for a fractional yield on new land area.

It may be seen from the equation above that if the yield growth on existing land is constant and the slippage factor is less than unity, the yield growth and area growth will be negatively correlated. However, as seen in Figure 2 for EU cereals and is also for the other crop region combinations this was not the case. For all crop region combinations, yield growth increases with area growth. If modellers believe that changes in demand effects net yield growth, they must derive a relationship between demand growth and yield growth. If modellers believe that changes in demand growth do not effect net yield growth, they cannot justify the use of a slippage factor. Modellers can't have it both ways, by using a yield growth that on exiting land that is independent of demand growth and then adding a slippage factor.

The use of an elasticity factor to relate the yield on new land to existing yields is not justified. When yield growth estimates are based on historic regional yield data. The effect of introducing such a factor results in overestimating land area changes as a result of crop demand increases.

4.5) Increased yield with increased price

Some models include a yield vs price elasticity such that the yield in any year may be higher due to a higher price in that year. This is attributed to increased crop inputs such as fertiliser. However, this effect of price only applies to the specific year, so has a minimal effect on the yield increase over a period of years. It does not model the increased yield growth with increased demand over a multi-year period, which has a major effect on the proportion of demand growth that is met by yield growth and area growth.

5) Changes to trade in biofuel crops

When crops are used for biofuel production, in is important to determine in which country or region the additional crop will be grown, in order to determine the land use changes. If there is an increased demand for a crop, for example in the EU, due to increased biofuel demand, then some of this demand is met within the EU, while some of the demand is met by changes in trade: reduced exports or increased imports. For biofuel crops that are primarily imported into the EU or where a crop product or the biofuel itself is imported into the EU, it may be assumed that increased EU demand will be met primarily or entirely by increases in imports.

Crops, such as cereals, which are widely grown locally, the transport costs are high compared to the value of the crop and therefore many regions maintain a self sufficiency of these crops and the crop output is adjusted to meet demand. It is shown that increased demand for crops for which the region is self sufficient will primarily be made up by increased production in that region.

The cumulative world trade balance for wheat is represented in Figure 3. Each point represents a country with the countries sorted by the ratio of imports/consumption.

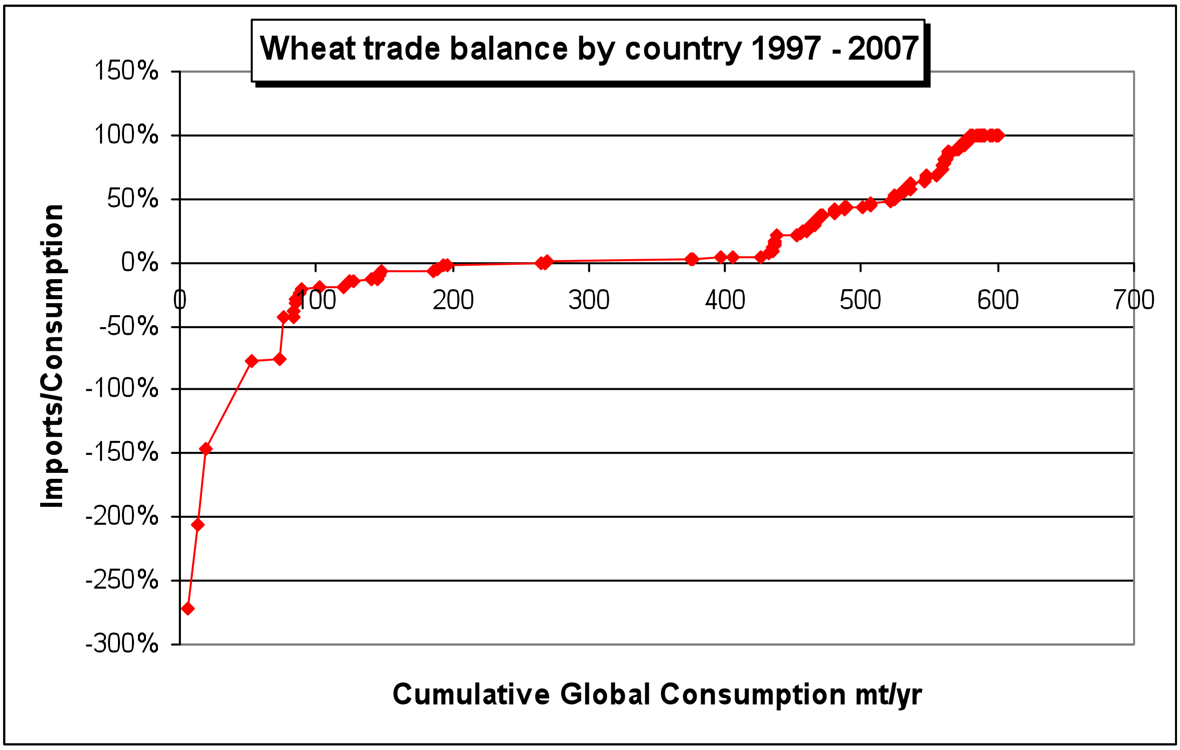

Figure 3 Source USDA 2010, Ensus analysis

It can be seen that a large proportion of countries are in a trade balance for wheat. 41% of total global wheat consumption is by countries that have a ratio of imports/consumption between -10% and 10%. The cumulative world trade balance for maize is similar, with 42% of total global consumption being by countries that have a ratio of imports/consumption between -10% and 10%.

When regional groups of countries are taken together the traditional intra regional trading can maintain a close trade balance. In the EU, France exports cereals to countries such as Italy, Spain, Algeria and Morocco which don't grow all there own cereals. The production, consumption and trade balance of cereals in the EU27 + Algeria + Morocco is shown in figure 4, by plotting four year moving averages, of USDA data from 1960 to 2009.

It may be seen that in the period from 1960 to 1980, the consumption of cereals was increasing rapidly, but since 1980, the demand has levelled out. The increasing demand up to 1980 was met by increased production within the EU, but with a lag. The rate of production continued to increase till about 1985 and then levelled out to keep cereal production close to a trade balance. It can be shown (Lywood 2010) that although cereal yields continued to increase in the EU, increased production was avoided by idling of excess land. The EU maintains a rough trade balance on cereals because of the significant differences in logistics costs associated with being a net importer and net exporter.

The proportions of increased crop demand that will be met by increased production and by changes in trade can be determined directly using factors to relate the change in trade flows and change in production to changes in demand.

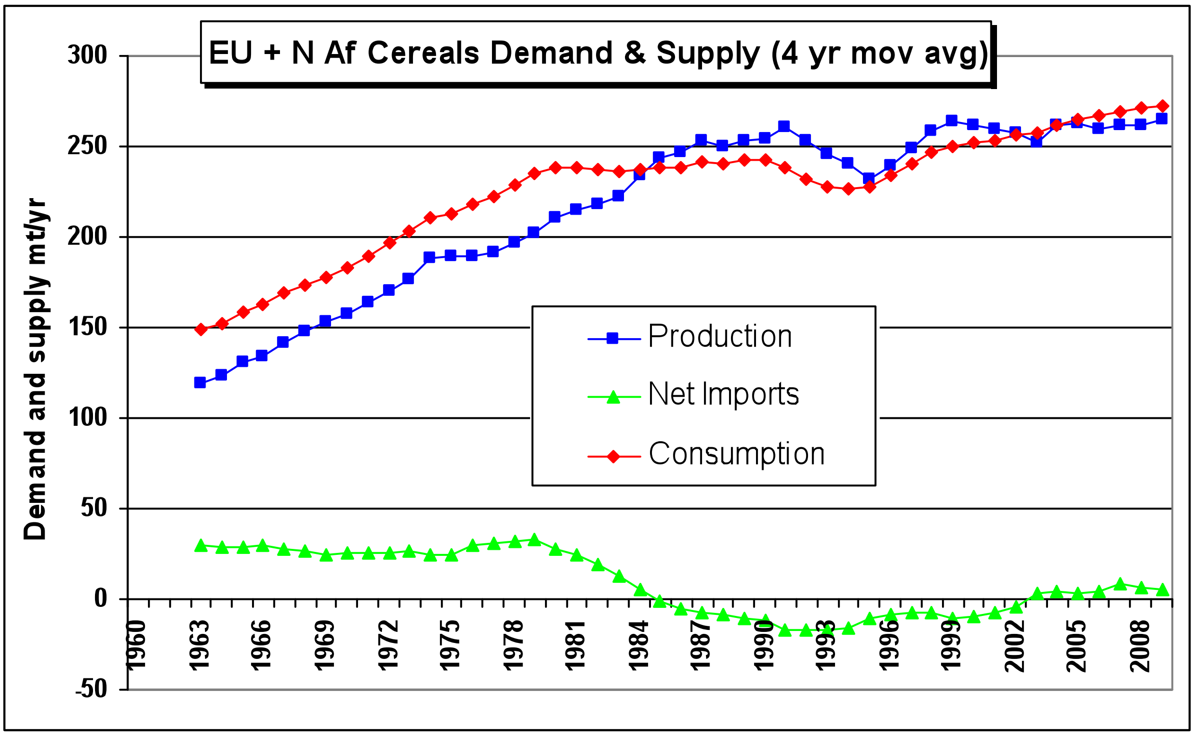

Figure 4, Source – USDA 2010, Ensus analysis

The results for the case of changes in EU + Alg + Mor cereals trade and production as a result of changes in demand within the EU are shown in figure 5. This uses a one year time lag between demand changes and trade and production changes and four year averages to reduce annual noise.

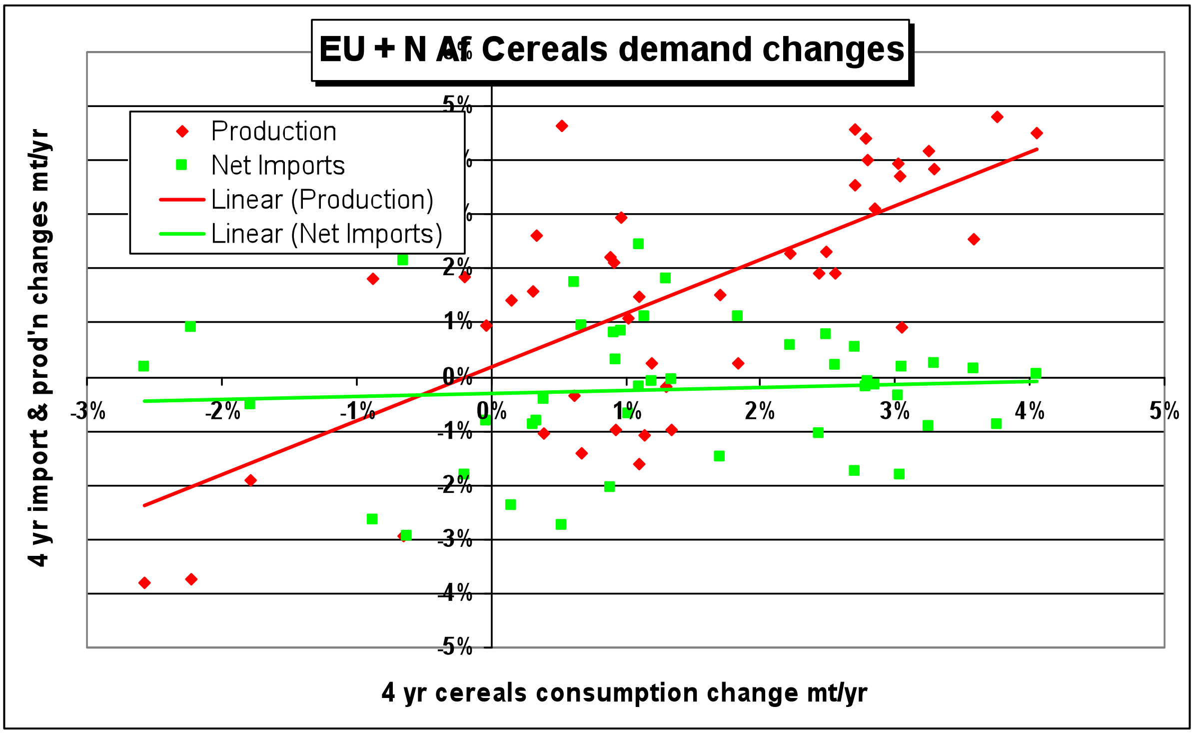

Figure 5, Source – USDA 2010, Ensus analysis

The best fit to these data is that 99% of the changes in demand are met by changes in EU production. There is a substantial scatter in these data and so there is some uncertainty in the fiffing. However, there is no statistically significant relationship between EU demand changes and changes in net imports. These data shows that nearly all the change in EU demand for cereals is provided by changes in EU production and very little will be met by changes in trade.

5.1) Modelling Changes in trade

Most equilibrium models, for example FAPRI and FASOM do not even state how changes in trade are modelled. Many use an elasticity of substitution to determine how much of the change in crop demand due to biofuels crops is met by increased imports or reduced exports. The elasticity (often referred to as an Armington elasticity) factor relates the change in marginal imports to changes in prices in trading countries or regions. None of the models details the value or the source of the elasticity of substitution being used, let alone provide any justification of the factor.

There are some concerns about the use of the Armington model for modelling cereals in the EU:

- The Armington elasticity model assumes that each country produces its own set of products which are somewhat differentiated from products from elsewhere and therefore products from different countries are imperfect substitutes of each other. However, cereals, for example wheat used in animal feed rations from different sources is interchangeable and not differentiated between countries.
- The Armington elasticity model does not take account of changes in logistics costs associated with switching from net import to net export or vice versa, when a country or region is close to a trade balance. Due to the high transport cost, relative to the production cost of cereals, it would be expected that local production changes would be used to meet changes in local demand.
- There has been much debate on what is the correct value of Armington elasticity factors to be used for changes in trade as a result of duty changes. (McDaniel 2002). The source for the value of 2.6 used in the CARB GTAP model for US cereal grains trade is not provided.

The issue of modelling changes in trade was not addressed in the DGEnergy literature review (DGEnergy 2010).

If equilibrium modellers still want to use Armington elasticity factors, based on theoretical price changes and hypothetical demand elasticities, they should validate their factors, by showing that they give similar results as those obtained by the data analysis in Fig 5.

6) Type of Land Changes

Various approaches have been taken by different models to determine what types of land are converted to cropland in different countries. These include:

- Extrapolation of historic data
- Use of cross elasticity factors
- Economic analysis using cost curves and agro-economic zones.

Different models use different categories of land which is converted to cropland. These can include various types of grassland and forest and idle land.

6.1) Extrapolation of historic data

Historic land use data is available from FAO, MODIS satellite data and studies made for specific countries. FAO data provides the most comprehensive set of historic data covering all countries, with crop area data since 1961 and forest area data since 1990. The FAO cropland area data is similar to USDA data (USDA 2009) and compiled from official country annual statistics and is expected to be generally accurate. However, the forest area data is based on data every 5 years and is less accurate. There is an issue with large countries such as Brazil, that the land use change to provide extra cropland will be different for different crops e.g. sugar cane and soy bean depending on where the crop is grown within the country. FAO data is may not be representative for any particular crop, but several land use change studies have been done for Brazil, which will provide appropriate historic data.

An alternative source of data is from the MODIS satellite imaging, from 2001 to 2004, which was analysed by Winrock (2009). These data are used to determine the changes in cropland areas and the proportions by which new cropland displaces forest, grassland, savanna and shrub land between 2001 and 2004. However, the MODIS data is not consistent with FAO for cropland area change for some regions. The data are compared in table 6.

	Change in Cropland Area 2001-2004	
	MODIS	FAO
EU	17.9%	-1.1%
Brazil	-2.0%	20.7%
US	7.1%	1.1%

Table 6, Source FAO 2009b, Winrock 2009

The EU Member States crop data is required for the Common Agricultural Policy and should be accurate, so the differences between FAO and MODIS data must be attributed to errors in the MODIS data. A more detailed analysis and comparison of MODIS data has been submitted to the EPA (Lywood 2009c). This work shows that the accuracy of satellite data must be considerably improved before it can be used for monitoring land use changes.

While FAO data includes idle land, the MODIS data doesn't.

FAO data is used by Searchinger (2008), MODIS data is used by EPA (2009) and historic data for Brazil from specific papers are used by ADAS(2010).

6.2) Other methods of modelling types of land use change

The CARB GTAP model uses land substitution elasticities to determine the proportion of land that any crop will displace, in terms of: substitutable crops, other crops, grassland and forest. The elasticities proposed for the EU are listed (Valin 2009a) based on OECD work. The substitution elasticity factors between agricultural v forest and cropland v pasture can be used to determine the proportions by which new cropland will displace forest and pasture, or by which forest and pasture will arise on idled cropland.

The IFPRI (Valin 2009b) and LEITAP (Prins 2009) GTAP models are also evaluating an option to use land supply curves in a deterministic modelling approach to determine the lowest cost option for obtaining new cropland from different areas of natural vegetation.

It is not clear that any of the other methods for modelling types of land use change have been validated against historic data and much more work is required to justify such an approach instead of extrapolating historic data on land use changes.

6.3) Inclusion of idle land

Within the EU and FSU, any additional land to meet the demand for EU biofuels crops will come from the uses of former arable land that is now idle and in the EU from the reduction in the rate of abandonment of arable land. About 4 million ha of former set-aside idle land were created within the EU, which were released for use as normal cropland in 2008, to meet the increased demands for biofuels.

A detailed analysis of agricultural land in the EU, using FAO data (Lywood 2010) shows that:

- The area of arable land in the EU has reduced continuously since 1961 with an average reduction of 0.4 million ha/year from 1985 to 2007 (FAO 2009a)
- The rate at which EU cropland is idled is related to the EU demand of arable crops.
- Therefore the increase in demand for EU biofuel crops will be met by use of former set-aside land and a reduction in the rate of creation of idle land in the EU.
- Most of the idled land in the EU is left for natural succession and only 12% of the the idled land is subsequently afforested.
- Using carbon accumulation rates of 0.34 t C/ha/yr for natural succession (Post and Kwon 2000) and 1.5 t C/ha/yr for managed afforestation (Greig 2007), the average level of foregone sequestration is 0.48 t C/ha/yr

This figure can be compared to values of carbon stock changes for conversion of other land to cropland in the EU, amortised over 20 years of 1.2 t C/ha/yr and 1.9 t C/ha/yr from JRC (2010c) and IFPRI (2010) respectively. Thus if models do not take account of idle land in the EU, they overestimate the GHG emissions land use changes by a factor of between 2.5 and 4.0.

Most models have been developed for global land use change modelling and do not take into account changes in fallow land, temporary grassland and unused land, which are relevant in the EU and FSU. Only the E4tech (2010) models take account of the re-use and reduction in the rate of abandonment of idle land in the EU.

The lack of inclusion in models of unused and idle land in the EU and abandoned land in FSU will cause an overestimate of the GHG emissions from land conversion to cropland. This will be an overestimation of a factor of between 2.5 and 4, for biofuel crops grown in the EU.

7) Validation of models

It may be seen that several of the issues of concern with equilibrium models are common to several of the models. Also nearly all of the issues of concern appear to lead to an overestimation of the GHG emissions from ILUC, especially for crops grown within the EU. It is therefore not valid to draw any conclusions on the accuracy of equilibrium models, or the uncertainties in ILUC factors, or the potential range of ILUC factors by comparing the results of equilibrium models with each other.

For predictions to be trusted, the equilibrium models need to be validated, by demonstrating that ex-ante predictions of past perturbations in crop land and grassland areas, trade flows etc satisfactorily match those observed. It is not clear whether any equilibrium models have been validated in this way.

There are problems with validating equilibrium models against recent predicted outcomes (Babcock 2009), due to other random variables that might affect these outcomes. However, other ways must be found of validating these models.

Price elasticities used within the models can be validated against historic data. For example land area : price and yield : price elasticities can be validated for crops as in figures 1, 2, and 7, while price elasticity factors for determining changes in trade can be validated as in figure 5.

8) Evaluation of policy

Some equilibrium models are seeking to evaluate the land use changes and GHG emissions from ILUC associated with a complete policy, for example the EU 2020 renewable energy for transport target. Since equilibrium models are derived from trade models and are to some extent based on prices, they attempt to determine the most economic mixture of biofuels production to meet the 2020 RED target. However, there are substantial difficulties with this approach:

- Some biofuel pathways will be restricted by the higher RED GHG savings thresholds that will be in place from 2014 and especially after 2017
- The choice of options for meeting the RED transport target will also depend on the GHG savings of different biofuel pathways and the need to meet the FQD target.
- There are limitations in the rate at which some biofuels, such as sugar cane bioethanol can be made available due to infrastructure bottlenecks
- The relative proportions of biodiesel, bioethanol and other renewable fuels will depend on vehicle limitations on the use of fuel blends in the EU
- The use of high blends such as E85 will depend on decisions by car manufacturers
- The uptake of high blends by motorists will depend on incentives provided in different Member States.

These difficulties may explain why different models have provided very different estimates of hw the 2020 target will be met.

9) Modelling Approach

Although equilibrium models use price relationships for modelling crop and biofuel trade and the mixture of biofuels production to meet the 2020 RED target, the calculation of most of the factors in the equilibrium models associated with the calculation of ILUC are not based on economic drivers. Several factors for ILUC modelling have been modelled using assumptions or exogenous factors, rather than by economic analysis, or market understanding. These include:

- Displacement ratios of other crops by biofuel co-products
- Which oil seed crops are grown primarily for the oil or the meal
- Proportion of increased crop output supplied by land area changes
- Type of land that is converted to extra cropland

This may be because more work is needed to be able to include better economic modelling and market understanding, or because economic modelling is not appropriate for some of these relationships. The recent E4tech model (E4tech 2010), which has had the benefit of a wide range of experienced input, using a multi-functional expert advisory group has been able to include market understanding based on economic drivers, for the first three issues above.

Different models have chosen different ways of modelling these and other factors. It is important to try to move to some level of agreement between modellers, as to which factors are best modelled by different methods i.e. margin optimisation, price elasticities, direct elasticities and empirical models based on historic data. Use of assumptions, unvalidated factors and “expert judgement” is not appropriate, for the derivation of ILUC factors that could determine the viability of some biofuel investments.

A substantial part of the reports and presentations on equilibrium models is associated with description and justification of model platforms, model structure and model linking. There are also descriptions of novel approaches or methods for modelling particular relationships. There is somewhat less justification for the method chosen for modelling different relationships. There is little or no justification of the parameters used in the models and the data sources.

There is a concern that much of the effort has been in developing more complicated models rather than determining and justifying modelling methods and values of the parameters used in the models. It may be of more value to develop simpler models, for example spreadsheet based differential models, which use agreed methods for modelling those factors and determine the parameters that are most important for determining GHG emissions from ILUC.

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