REVIEW OF IFPRI REPORTS ON LAND USE CHANGE FROM EUROPEAN BIOFUEL POLICIES

Prepared For:

European Biodiesel Board

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EXECUTIVE SUMMARY

The European Commission has undertaken a number of land use modelling studies to try and understand the potential impacts of the EU biofuels policy on global land use change. These studies are designed to help the Commission develop a report for 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 (article 19.6 of the Renewable Energy Directive (2009/28/CE)) and article 7d.6 of the Fuel Quality Directive (2009/30/CE)).

The most recent study was prepared by the International Food Policy Research Institute (IFPRI) of Washington DC. This study is a follow-up study to a report published in March 2010 by the same group. The most recent study is the subject of this review but the earlier study has also been considered as it provides additional information on the modelling framework and results from the model.

IFPRI utilizes the MIRAGE model. The MIRAGE model has been developed primarily to study trade policy scenario and has been intensively used to assess bilateral and multilateral agreements. It is a global computable general equilibrium (CGE) model. CGE models are useful whenever one wishes to estimate the effect of changes in one part of the economy upon the rest. For example, a tax on diesel fuel might affect freight costs, the CPI, and hence perhaps wages and employment. They have been used widely to analyse trade policy. More recently, CGE has been a popular way to estimate the economic effects of measures to reduce greenhouse gas emissions.

CGE models must be modified to estimate the greenhouse gas (GHG) emissions due to land use change so that they include land data, elasticity factors that influence how land use changes are determined and emission factors for converting land use estimates into GHG emissions.

The most recent IFPRI study has reported different indirect land use emissions compared to the March 2010 report, as shown in the following table. Palm and rapeseed biodiesel have higher emissions and soybean and sunflower biodiesel have lower emissions. By comparison all of the four ethanol pathways had lower emissions in the 2011 work.

Table ES- 1 Crop Specific Land Use Change Coefficients

	March 2010 Report	2011 Report
	g CO_2/MJ	
Palm Biodiesel	46.4	54.3
Rapeseed Biodiesel	53.0	53.8
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CGE models currently tend to give generally linear results. This is primarily due to limitations in the models and their basic assumptions about perfect competition. The 2011 work looked at the impact of a full mandate and a half mandate. There are some differences in the land use change emissions but they are driven primarily by different assumptions regarding the ratio of biodiesel to ethanol in the two different scenarios.

For the central scenario, the EU biofuel consumption is increased to 8.7% in 2020. The overall split is 22% ethanol and 78% biodiesel. In addition, there were individual model shocks modelled. To develop a specific feedstock LUC factor, the modellers increase the blending rate in the EU by 0.5% (from 8.2 % to 8.7 %, for instance), maintaining the consumption of all other feedstocks by all other biofuel industries in the world . Therefore any increase in biofuel supply that should match the new EU demand could be generated with only one feedstock. However, there is no restriction about the location of production and transformation of the crop.

Understanding what has not been modelled is as important as what has been modelled.

1. No restrictions have been placed on land expansion. The RED requires certification of the feedstocks used for biodiesel production to come from land that was in production prior to Jan 1, 2008 or if from new land, land that has low carbon stocks. While this does not eliminate the leakage issue (old land used for fuel and new land used for feed and food) it will have some impact on land expansion.
2. No allowance has been made for biofuels produced from waste, which are counted as double the volume under the RED. This will impact total land use but, due to the linearity of the model projections, it will probably not impact the individual crop values.
3. No technical constraints have been put on feedstock for biodiesel consumption. There are relatively high elasticity values between the four types of biodiesel, even though palm oil biodiesel has poorer cold weather properties and whose use is limited in Europe. Palm's share of the EU market grows from 4% in 2008 to 17% in the 2020 shock.
4. No changes in the rates of improvement of technology are assumed. The 2020 baseline is developed from the 2008 case using business as usual assumptions with respect to historic rates of change.

The indirect land use modelling undertaken by IFPRI has a large number of problems and the result is that the ILUC emissions are greatly overestimated. While the MIRAGE modelling effort has a number of unique factors and could be considered an improvement over other similar models, such as GTAP, not all of these unique features are utilized in the work undertaken for the European Commission. In addition, the model has a significant number of shortcomings that seriously impact the reported results.

Land Database

The land inventory database that has been added to the MIRAGE model is missing all of the cropland that is used to produce forages for livestock feed and all of the cropland that is temporarily idle. These two sub categories of cropland amount to about 400 to 500 million hectares. This land is available for increased crop production and some of it is currently creating GHG emissions without producing a crop. The land demands that are calculated by MIRAGE for the increased EU biofuel demand range from 1.74 to 1.87 million hectares, a small fraction (less than one half of one percent) of the land that is available.

Addressing the missing land issue is more than just adding new data to the model, as it needs to be added as a new land category with its own CET function. It is most likely that if this were done and the appropriate CET function used the ILUC emissions for the EU biofuels mandate would drop to very close to zero.

In addition, the land data that is in the model appears to significantly underestimate the land devoted to the major biofuels crops. This will underestimate the impact of intensification. Finally, the model currently has no way of modelling double cropping, an important management practice in many parts of the world. 150 million hectares of cropland are double cropped and there is evidence that this area is very responsive to price signals, at least in some parts of the world.

Oilseed Crushing Sector

There are important issues with the way that the model deals with the oilseed crushing sector and the livestock industry. First, it is not clear how the livestock sector can be modelled accurately without including the production of forages in crops produced. Replacing forages with oilseed meals would be one possible response to an increase in meal availability. Secondly, the description of the crushing sector implies that it is considered as part of the biodiesel sector, yet it existed as a very large part of the ag value added sector long before biodiesel existed. The change in the price of oilseeds and the crush products, oil and meal, indicate that the profitability of this sector disappears as demand for the products increase. This scenario is not possible in the real world. It is believed that oilseed meals can't be traded on their own, just through the livestock sector, and this is partially the reason for the incorrect results for the crushing industry. The net result of all of this is that the meals probably don't receive the proper credit in terms of displacing other agricultural crops and this leads to higher demands for additional land.

Elasticity Factors

There are other issues with the model and the assumptions that have been made and these lead to either higher estimates of land converted to cropland or higher emissions from the converted land.

There are significant issues with the elasticity factors used in the MIRAGE model. The elasticity factors related to crop displacement and substitution should be the strongest of the electricity factors used in the model since they are at the core of how the model has been traditionally used. While this is probably still the case for the response of consumers to different meat prices and vegetable oil prices, the response of the livestock sector to different feedstock availability and prices is not clear.

It appears that the livestock model is not modelled adequately. Forages, an important component in the diets, are not specifically included in the model or the land database created. Thus co-products can not substitute for these feed components. The oilseed crushing industry does not appear to be modelled independently of the biodiesel producers as oilseed meals are identified as a co-product of the biodiesel sector. This creates major problems for the model and the sector response. It appears that crushing margins (value of oil and meal less cost of oilseed) go negative in response to increased demand for crushing, not a likely response from the sector.

Being an econometric model, there is no way for the model to balance diets for protein and energy, it just balances for lowest cost based on the elasticity factors between different co-products that are chosen by the modellers.

Less than 1% of the new supply for biodiesel feedstock is produced through intensification efforts on existing land. A relatively low elasticity factor has been applied to these effects. Higher elasticity factors were recommended by the EWG in California.

The elasticity factor for the yield of crops on expanded land is an assumption chosen by the modellers. Based on the data that is available and the results of other more sophisticated models the values chosen are too low by 25% to 50%. This directly impacts the GHG emissions attributed to the biofuels, so this one assumption alone increases the ILUC factors by 25% to 50% over what they should be.

An even larger issue are the assumptions made with respect to the CET function values. The modellers have used the same value for pasture land and managed forests, whereas in reality the available data indicates that there should be a difference of 20 to 30 times between the values. This error increases the quantity of forest land converted by more than an order of magnitude and this increases the ILUC factor by 30% in the case of the scenarios modelled by IFPRI.

These errors are additive. The combined impact of just the improper elasticity with respect to land expansion and the CET function, is that the real values should be 35% to 50% of the values reported in the report. The improvement of the modelling of co-products would be expected to provide addition reductions in the reported values.

Other Issues

The reported soil carbon losses appear to be high and could not be duplicated or reconciled with the information that is reported.

The above ground biomass loss makes no provision for natural mortality of the forests and thus overstates the above ground carbon losses.

The peatland impacts are new to the 2011 report and are a major reason why the biodiesel emissions are as high as they are. Depending on the feedstock, these emissions account for 20% to 60% of the total emissions, as shown in the following table. There is a great deal of uncertainty in these emissions, both due to the emission rate and the area impacted. Several recent papers indicate that the emission rate used in the IFPRI report is overstated and could be reduced between 30% and 60%.

Table ES- 2 Peatland Impacts

Feedstock	Total ILUC Factor	Peat Portion	% Peat Portion
	g CO_2eq/MJ		
Palm	54.3	33	60.1
Soybean	55.8	16	28.7
Sunflower	51.8	10	19.3
Rapeseed	53.8	15	27.9

The 20 year amortization period chosen for the calculation of the emissions is arbitrary. A 30 year (also arbitrary) period has been used both by the US EPA and the California Air Resources Board (CARB). One problem with both the 20 and 30 year time periods is that all of the rest of the GHG emissions are calculated based on 100 year GWPs. If they were calculated using 20 or 30 year GWPs, the baseline emissions for petroleum fuels would all be higher.

Finally, the individual ILUC factors deliver results that are 11.5% higher than the result from the combined shock. This finding is consistent with the analysis of other work in this area undertaken by the US EPA and CARB. Artificially constraining the response to a single commodity limits the ability to choose the best options. In the following table the individual factors and their shares are summed and compared to the combined shock of 38.4 g CO_2eq/MJ.

Table ES- 3 Individual Impacts

Fuel	ILUC Factor	Fraction of Total Shock (%)	Contribution to total
	g CO_2eq/MJ		g CO_2eq/MJ
Ethanol Sugar Beet	6.6	5	0.3
Ethanol Sugar Cane	13.4	13	1.7
Ethanol Maize	10.3	4	0.4
Ethanol Wheat	14.4	6	0.9
Palm Oil	54.3	17	9.2
Rapeseed Oil	53.8	41	22.1
Soybean Oil	55.8	11	6.1
Sunflower Oil	51.8	4	2.1
Total			42.8

Summary

The IFPRI modellers acknowledge the limitations of the MIRAGE model and state;

> *First, the model has tested the limits of the CES/CET framework. Both for co-products and for land use allocation, this conventional modeling approach leads to too many simplifications. For co-products, the two-level CES approach has helped to reinforce the substitution of the protein contents between meals and DDGS. Unfortunately, it has also forced simplify simplification of the representation of substitution between proteins and carbohydrates. Similarly for land use, even if our multi-nested CET has helped to capture substitution between crops, it is not flexible enough to provide the right full substitution matrix across crops and their yield consequences. More importantly from a long-term perspective, it is not designed to capture issues such as multi-cropping and crop rotation, both important issues for land use considerations in a dynamic approach.*

The challenges with the model go beyond just these limitations.

1. There appear to be errors in the fundamental assumptions about how much oil and meal is extracted from each feedstock.
2. There are concerns about how the oilseed crushing sector is modelled and the negative impact this has on co-product displacement for the oilseed meals.
3. The land database is missing idle land and the model has no way to directly access this land with the current structure.
4. A very low assumption has been made with respect to the intensification potential of existing land. An elasticity factor an order of magnitude lower than the CARB EWG recommended is used. The higher value would allow double cropping to be included in the modelled, which the modellers acknowledge should be included.
5. The assumptions regarding the CET values, which determines how much of which kind of new managed land is brought into production, and not aligned with the limit data that is available on this subject. The modellers use the same value for pasture and forest, whereas the data suggests that pasture is 20 to 30 times more likely to be converted than forest. This has a huge impact on the final calculations since forests are more carbon intense than pasture. If idle land were included as a new land category, then the CET function should be very high compared to the values used for pasture and forests.

6. The reports have little transparency with respect to the carbon calculations but the soil carbon losses could not be reconciled.
7. There is a great deal of uncertainty with respect to emissions from peat soils and the growth of palm plantations onto peat lands. New findings in the past 12 months suggest that peat loss emissions used in the 2011 report may be overstated.
8. The choice of a 20 year amortization period is purely arbitrary and 30 years has been used by both the EPA and CARB in their work.
9. Finally, the individual ILUC factors are inconsistent with the result from the total shock and overstate ILUC emissions by 11.5%.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

The European Commission has undertaken a number of land use modelling studies to try and understand the potential impacts of the EU biofuels policy on global land use change. These studies are designed to help the Commission develop a report for 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 (article 19.6 of the Renewable Energy Directive (2009/28/CE)) and article 7d.6 of the Fuel Quality Directive (2009/30/CE)).

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Table 1-1 Crop Specific Land Use Change Coefficients

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The authors suggest that all feedstocks benefit from higher yields assumed in the baseline case in the 2011 work, less land is required because the land is more productive. The new results also include increased land use emissions from revised assumptions about new palm areas.

1.1 SCOPE OF WORK

The European Biodiesel Board has requested a peer review of the March 2011 report assessing the key assumptions influencing the model results and taking into account the key aspects listed below:

1. The overall trend of results between the first and second version of the report raises questions. Why have the results changed so much between the two versions of the study, which were conducted with only few months time differences? Why do only palm biodiesel and rapeseed biodiesel see their LUC value increase compared to the first version of the study?
2. The assumption that peatland emissions will represent one-third of total emissions linked to the 10% EU mandate is very pessimistic. What impact do different assumptions make on the final results?
3. The livestock sector seems to be more important to the oilseed sector than it does to the grain sector. Why is this? Is the livestock sector sufficiently detailed in the model to give accurate results?

4. Are the price elasticity assumptions used in the model realistic? Are the impacts on the broader ag sector and on consumers considered in the final policy framework?
5. What impact would different substitution elasticities for vegetable oils have on the results? Are the base models realistic in that they factor in all know technical issues?
6. Is 20 years an appropriate time frame over which to amortize carbon changes ? Does this assumption have any impact on the baseline emissions of the other fuels?
7. Whether the 2011 IFPRI study accounts for the impact of double-counting biofuels in the overall iLUC impact of the EU 2020 target.
8. Whether the 2011 IFPRI study reflects the impact of regulations restricting land use in tropical countries.

We will review the MIRAGE documentation to determine if they also apply to this work. These issues include:

1. The actual land inventory values for each aggregated region. Does the model accurately model the existing land base?
2. The level of aggregation of land cover types in the ag land category can reduce the ability of the model to reflect some of the most likely ag producer responses to increased prices, i.e., double cropping, reducing idle land, and conversion of temporary pasture.
3. The CET function for the conversion of forest and pasture land to new ag land. The use of the same CET value for both types of land results in overestimating the forest land converted and overestimating the LUC emissions.
4. Are the carbon stocks in the various AEZ's accurate? The CARB work identified gross over-estimation of carbon stocks.
5. Does the model properly characterize trade in oilseed meals or is this accounted for in the livestock sector? If it is the latter, this could introduce large errors in the results.
6. Are there other changes in GHG emissions that occur besides land use change? Crop switching can result in differences in GHG emissions because the emissions per hectare differ between crops. Reductions in the livestock herd will result in reductions in GHG emissions. Is this factored in to the overall results?

This review includes both the 2010 and 2011 IFPRI reports and all of the accompanying documentation. This report is a result of this review and discusses the modelling framework, modelling shortcomings and limitations and key findings.

2. IFPRI AND MIRAGE

Indirect land use change emissions cannot be measured. They result from changes that might happen in the future as a result of the deployment of a certain policy. Indirect land use change estimates are derived from models, and there are many econometric models that have been adapted in order to estimate these emissions. The focus of this review is the results produced by the MIRAGE model as run by IFPRI. The organization and the model are briefly described in this section.

2.1 INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI) seeks sustainable solutions for ending hunger and poverty. IFPRI is one of 15 centres supported by the Consultative Group on International Agricultural Research (CGIAR), an alliance of 64 governments, private foundations, and international and regional organizations.

IFPRI's Vision is "A World Free of Hunger and Malnutrition". This vision is based on the human right to adequate food and freedom from hunger, and the recognition of the dignity inherent in all human beings. It is a vision of a world where every person has secure access to sufficient and safe food in order to sustain a healthy and productive life, where food-related policy decisions are made transparently, including the participation of consumers and producers.

IFPRI is committed to providing global food policy knowledge as an international public good. New knowledge on how to improve the food security of low-income people in developing countries is expected to result in large social benefits. IFPRI views both public organizations and the private sector in food systems as objects of study and as partners.

Given the large body of national and international food policy research, IFPRI claims that its added-value derives from its own cutting-edge research linked with academic excellence in other institutions, such as other CGIAR centres, universities, and other research institutes in the South and the North, and from its application of this knowledge to national and international food policy problems.

The Markets, Trade, and Institutions Division of IFPRI seek to understand how countries can best develop markets, institutions and infrastructure in ways that contribute to agricultural growth and help alleviate poverty and ensure food security for all. As part of this work, IFPRI utilizes the MIRAGE model. The MIRAGE model has been developed primarily to study trade policy scenarios and has been intensively used to assess bilateral and multilateral agreements. As a global computable general equilibrium (CGE), it provides a rich set of indicators for each region, which allow for the impact of policy changes to be measured. Such indicators include: changes in production, production factor uses, real wages, value added by sector, real GDP, real income, exports, imports, terms of trade.

2.2 COMPUTABLE GENERAL EQUILIBRIUM MODELS

Computable general equilibrium (CGE) models are a class of economic models that use actual economic data to estimate how an economy might react to changes in policy, technology or other external factors. A CGE model consists of:

(a) equations describing model variables and

(b) a database (usually very detailed) consistent with the model equations.

The equations often assume cost-minimizing behaviour by producers, average-cost pricing, and household demands based on optimizing behaviour. However, some CGE models may allow for non perfect behaviour, such as:

1. Non-market clearing, especially for labour (unemployment) or for commodities (inventories)
2. Imperfect competition (eg, monopoly pricing)
3. Demands not influenced by price (eg, government demands)
4. A range of taxes
5. Externalities, such as pollution

A CGE model database consists of:

1. Tables of transaction values, showing, for example, the value of coal used by the iron industry. Usually the database is presented as an input-output table or as a social accounting matrix. In either case, it covers the whole economy of a country (or even the whole world), and distinguishes a number of sectors, commodities, primary factors and perhaps types of household.
2. Elasticities: dimensionless parameters that capture behavioural response. For example, export demand elasticities specify by how much export volumes might fall if export prices went up. Other elasticities may belong to the Constant Elasticity of Substitution class. Amongst these are Armington elasticities, which show whether products of different countries are close substitutes, and elasticities measuring how easily inputs to production may be substituted for one another. Expenditure elasticities show how household demands respond to income changes.

CGE models are useful whenever one wishes to estimate the effect of changes in one part of the economy upon the rest. For example, a tax on diesel fuel might affect freight costs, the CPI, and hence perhaps wages and employment. They have been used widely to analyse trade policy. More recently, CGE has been a popular way to estimate the economic effects of measures to reduce greenhouse gas emissions.

CGE models always contain more variables than equations—so some variables must be set outside the model. These variables are termed exogenous; the remainder, determined by the model, are called endogenous. The choice of which variables are to be exogenous is called the model closure, and can give rise to controversy. For example, with land use change modelling, some modellers hold food consumption fixed; others allow this to vary. Variables defining technology, consumer tastes, and government instruments (such as tax rates) are usually exogenous.

2.2.1 MIRAGE Model

The MIRAGE model is a CGE model originally developed at CEPII (The French Centre for Research and Studies on the World Economy) for trade policy analysis. It was extensively modified at IFPRI in order to address the potential economic and environmental impact of biofuels policies. The key adaptations to the standard model are the integration of two main biofuels sectors (ethanol and biodiesel) and biofuel feedstock sectors, improved modeling of the energy sector, the modeling of co-products and the modeling of fertilizer use. The land use module, which includes the decomposition of land into different land uses, and the quantification of the environmental impact of direct and indirect land use change (ILUC), was introduced in the model at the Agro-Ecological Zone

(AEZ) level, allowing for infra-national modeling. This feature is particularly valuable for large countries where production patterns and land availability are quite heterogeneous. The overall architecture of the model has been modified to allow for various sensitivity analyses, as well as for the computation of marginal ILUC under specific assumptions.

The MIRAGE model relies on the Global Trade Analysis Project (GTAP) database for global, economy wide data. The GTAP database combines domestic input-output matrices, which provide details on the intersectoral linkages within each region, and international datasets on macroeconomic aggregates, bilateral trade, protection, and energy. IFPRI started from the latest available database, GTAP 7, which describes global economic activity for the 2004 reference year in an aggregation of 113 regions and 57 sectors (Narayanan and Walmsley, 2008). The database was then modified to accommodate the sectoral changes made to the MIRAGE model.

Twenty-three new sectors were carved out of the GTAP sector aggregates -- the liquid biofuels sectors (an ethanol sector with four feed-stock specific sectors, and a biodiesel sector), major feedstock sectors (maize, rapeseed, soybeans, sunflower, palm fruit and the related oils), co- and by- products of distilling and crushing activities, the fertilizer sector, and the transport fuels sector. IFPRI developed an original and specific procedure aiming at providing a database that is consistent in both values and quantities. They make the following claims:

1. Agricultural production value and volume are targeted to match FAO statistics. A world price matrix for homogenous commodities was constructed in order to be consistent with international price distortions (transportation costs, tariffs, and export taxes or subsidies);
2. Production technology for new crops is inherited from the parent GTAP sector and the new sectors are deducted from the parent ones;
3. Vegetal oil sectors are built with a bottom-up approach based on crushing equations. Value and volume of both oils and meals are consistent with the prices matrix, the physical yields, and the input quantities;
4. Biofuels sectors are built with a bottom-up approach to respect the production costs, input requirements, production volume, and, for the different type of ethanols, the different byproducts. Finally, rates of profits are computed based on the difference between production costs, subsidies and output prices;
5. For steps 2, 3 and 4, the value of inputs is deducted from the relevant sectors (Other Food, Vegetal Oils, Chemical products, Fuel) in the original SAM, allowing resources and uses to be extracted from different sectors if needed (mapping n to n).
6. At each stage, consumption data are adjusted to be consistent with production and trade flows.

This level of disaggregation is unique to MIRAGE and is an improvement over the GTAP model, which suffers from a lack of detail in many sectors. There is no evidence in the available documentation that this work has been peer reviewed and checked.

The authors correctly acknowledge the importance of this effort and the need to tie price substitution effects (it is an economic model) to physical effects but little evidence is presented to demonstrate that the model is functioning correctly.

2.2.2 Model Changes for 2011 Work

There were four more model changes that were reportedly undertaken for the 2011 work. The first was a calibration of land supply and demand elasticities. This allows for different conversion rates of forest and pasture lands in different countries. This is an important change, however, since the underlying data for the factors is still a problem, it allows the modellers to determine where they think the biggest responses may come from.

The second change was further development of the co-products. The new structure allows greater substitution between DDGs and oilseed meals and between protein and energy feeds. Theoretically this should lead to reduced emissions.

The third change was additional data on peat emissions. This has a significant impact on the biodiesel emissions but it is based on an assumption of the rate of expansion of palm into peat areas. These changes increased emissions for biofuels (and very significantly for the biodiesel fuels).

Finally, there were changes in the model to maintain food demand elasticity to reduce the demand displacement in 2020. This would generally increase the emissions.

The impact of these changes are discussed later in the report.

2.3 CALCULATING INDIRECT LAND USE CHANGE EMISSIONS

Using CGE models to estimate indirect land use emissions is a multistep process. In general the existing CGE models need to be expanded to undertake this work. They require land use data and an understanding of how new land may be brought into production. Information on the carbon stocks of new land is required and a view of how long this new land might be in production. The general steps that the models go through are:

1. The modellers choose the new biofuel requirement.
2. The model calculates the market response to the new biofuel demand. This include determining the increase in price for the commodities used to produce the biofuel, the increased price will encourage intensification of the existing producers, it may allocate some of the existing demand to biofuel production, it will determine the impact of co-products on the livestock sector potentially freeing additional land for biofuels, and it will bring new land into production to reach an equilibrium. There are a large number of elasticity factors that are used for these calculations.
3. The quantity of new land brought into production is calculated based on an assumption about the yield of the new land.
4. Once the quantity of new land is determined, the type of new land (pasture, managed forests, unmanaged lands) is calculated using additional elasticity factors.
5. With the new land determined by region and type, estimates can be made of the change in carbon stocks between the existing use of the land and agricultural production. This change in stocks is divided by the energy content of the biofuel produced over the assumed project lifetime to arrive at an indirect land use emission factor in g CO_2eq/MJ.

3. MIRAGE SECTOR AGGREGATION

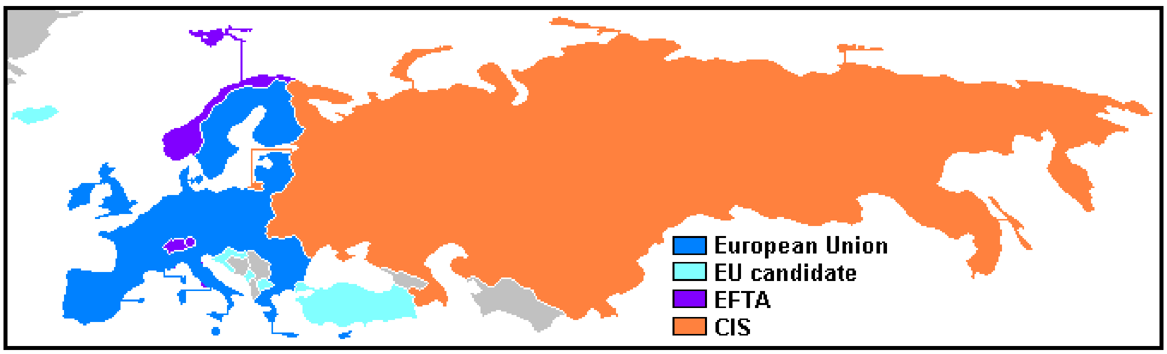
The GTAP 7 database used by the MIRAGE model is very large, it includes 69 groups of commodities, 67 industries, and 117 regions. Running the model with this large a number of options requires considerable computing power and so most users aggregate commodities, industries and regions in order to create manageable runs. The danger of aggregation is that important parameters and differences get lost. In the MIRAGE model, at the same time as there is sector aggregation; the modelling effort has also disaggregated the ethanol and oilseed sectors so that the differences between feedstocks can be explored.

The aggregation and disaggregation efforts undertaken for the model still have issues, as discussed below.

3.1 REGIONAL

The MIRAGE model has combined the 117 GTAP regions into 11 regions. Major markets and /or producers that are aggregated include India, Canada, Australia and others. The aggregation of EU27 and CIS does not include all European countries as shown in the following figure.

Figure 3-1 EU27 and CIS Coverage



The contribution of the Balkan states and Turkey will not be significant in the modelling results, even though they would be major trading partners for the EU27. Increased regionalization, to at least include the countries that could be major suppliers, would be beneficial to the modelling effort. Canadian canola would be a good example of a significant potential supply that is buried in the aggregation of the model.

3.2 OILSEED CRUSHING

The ability to model four different biodiesel feedstocks in the model is a great improvement in the model compared to GTAP itself. The remaining problem with this sector is how it is organized and limitations of the GTAP database. In recent development work on GTAP, Dr. Tyner has acknowledged that the GTAP database does not allow the direct trading of oilseed meals. The meals are traded indirectly through the livestock sector. This is not consistent with the actual structure of the industry and in many cases leads to price changes for oil and meal that result in negative crushing margins for the industry. That is, the value of the sum of the products is less than the cost of the oilseed.

There are indications that the same thing is happening with the MIRAGE model. In table 7 of the 2011 report, protein prices drop by 3.87%. In the appendices of the 2010 work, rapeseed oil prices in the EU increase by 1.36%, and rapeseed prices increase by 2.16% (it didn't report meal prices). It is obvious that crushing margins decrease as the seed prices increase by more than the oil price and the meal price drops. This cannot happen in the real world as all of the crushers would go out of business. GTAP has the same issues and this is a fundamental problem with oilseed modelling in the MIRAGE and GTAP models.

Another issue with the modelling of the oilseed sector is that it appears from Table 6 that the oilseed crushing sector has not been properly modelled. The calculated meal production rates are compared with typical industry values in the following table. The table indicates that more soybean meal is created than soybeans are consumed. Every oilseed is incorrect in the table. Soybean meal production is overstated and the rest are understated. Since the protein meals displace other crops in the food and feed system, it is critical to get these ratios correct.

Table 3-1 Meal Production Rates

	Calculated From Table 6	Typical Industry
	kg meal/kg seed	
Palm	0.0027	0.025
Rapeseed	0.51	0.58
Soybean	1.17	0.81
Sunflower	0.26	0.51

In the case of the sunflower crushing industry, there are also hulls that are produced. These hulls may be used for feed or energy purposes. Some crushers may leave a portion in the meal. The metabolized energy content used in the model assumes no hulls in the meal.

Also, from Table 6 it appears that some oilseeds are being used directly in livestock rations, as there is a large displacement of oilseeds in the livestock sector at the same time as there is an increase in oilseed meal by livestock. The livestock sector uses very little seed directly. It could be that this is just because the sector is incorrectly modelled.

The oilseed crushing industry should be modelled independently of the biodiesel industry, as the demand for oil is much larger for food purposes than it is for biodiesel. The meals are incorrectly identified as a by-product of the biodiesel industry in many of the MIRAGE documentation presentations and papers.

The following table on oil production rates compares the information in the Annex 1 with typical industry data. Three of the oilseeds have underestimated the oil produced from the feedstock. This increases the feedstock requirements, the new land that is needed, and the indirect land use emissions.

Table 3-2 Oil Production Rates

	Calculated From Annex 1	Typical Industry
	kg oil/kg seed	
Palm	0.237	0.215
Rapeseed	0.373	0.400
Soybean	0.162	0.192
Sunflower	0.387	0.415

The errors in the oil crushing statistics are inconsistent and additive. For example, rapeseed and sunflowers both have too little meal and oil produced. Both sets of errors (meal and oil) increase the land requirements of the biodiesel shocks and will drive the ILUC emissions.

3.2.1 Protein Demand

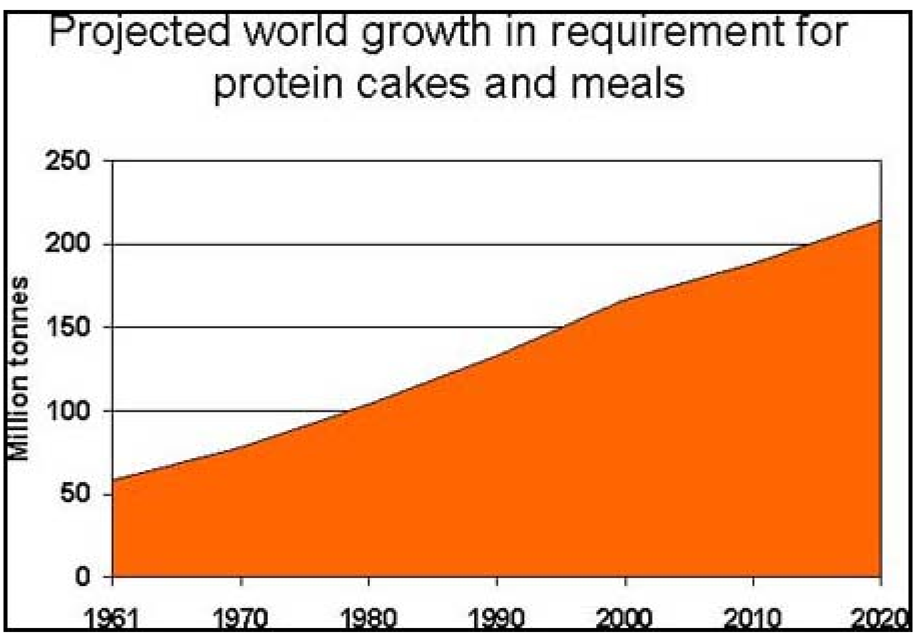
The other issue with the oilseed sector is a lack of understanding of the economic impact of increased or decreased use of protein in the livestock rations. In this model, proteins substitute for energy feeds based on their metabolized energy content. On this basis a tonne of rapeseed meal displaces 0.88 tonnes of maize in cattle rations and 0.69 tonnes of maize in other animal rations. This assumes that animal rations are optimized for protein today and increased protein use will have a detrimental impact on performance.

Proteins are needed to grow new tissues and to repair old tissues in an animal. The highest amounts of proteins can be found in the muscles of animals. Proteins are important for weight gain, growth, and gestation. Young animals need diets higher in proteins than older animals. Animals in gestation or lactation stages also need higher levels of proteins in their diets.

The most common nutrient deficiency in livestock is that of proteins. Since most feedstuffs are low in proteins, protein supplements may be necessary. Sources of proteins include soybean meal, cottonseed meal, fishmeal, and legume hay. Symptoms of a protein deficiency include anorexia, slow growth rate, decreased feed efficiency, low birth weight, and lower milk production.

The FAO (2002) reported that the demand for protein meals has been matched by the increase in demand for vegetable oils. The four primary sources of oils and meals are oil palm, soybeans, sunflower seed and rapeseed. They developed the projection for future protein demand as shown in the following figure.

Figure 3-2 Projected Demand Growth of Protein Meals



The issue for modellers is how does the market respond to changes in demand for oil and protein when the supply is provided by the same products. This FAO paper showed that over the past 50 years livestock rations have become more protein dense. Demand for protein has thus increased at a faster pace than the demand for meat. Are we at an optimum point in all livestock industries?, Is there an unsatisfied demand for more protein? Unless the econometric models balance the livestock sector modules for protein and energy, it is unlikely that the results will be reflective of what actually happens in the world. The 2011 paper acknowledges that the MIRAGE model has reached its limit in terms of its capabilities of modelling co-products, leading to too many simplifications. Unfortunately, it is not yet sophisticated enough to model the sector competently.

The GTAP model is in the process of being modified so that protein meals can be traded both directly and indirectly. In all of the existing GTAP modelling, these products could only be traded indirectly through the livestock sector. Thus an increase in oil demand from biodiesel forced an increase in protein use in the local livestock sector because that was the only way that the increased production could clear the market. The price of the protein would have to decrease to displace energy feeds in diets. This lead to the observed behaviour where oilseed crushing margins went negative, a condition that wouldn't happen in the real world.

There is a lack of documentation of the MIRAGE model to determine if it allows protein meals to be traded directly but the results would indicate that it does not allow for this to happen. The model does appear to allow a high degree of substitution between the three oilseed meals for their protein content. After the protein is satisfied then the meals are used to substitute for energy feeds based on their metabolized energy levels. This essentially assumes that existing rations are optimized for protein.

If the models could balance for protein and energy and there was an increased demand for oil then that should drive demand away from soybeans and towards rapeseed, sunflower, and palm, as these products have higher oil contents. While there is some evidence that this is happening on the regional level, there is no evidence that this has happened at the world level. In the following table (from Annex1 of 2010 work) the changes in crop and oil production as a result of the biofuels shock for the four oilseed crops are shown.

Table 3-3 Results of Biofuel Shock in 2020.

	Increase in Oilseed Demand	Increase in Oil Demand
	% over 2020 Baseline	
Palm	5.86	5.26
Sunflower	4.43	5.32
Rapeseed	5.19	5.41
Soybeans	6.34	5.75

First, it is not clear how the change in oil demand can be different than the change in oilseed demand, given that there is a fixed oil content in each oilseed. Of a greater concern is why the low oil, high protein feedstock (soybeans) increases more than the other feedstocks. This is the opposite response one would expect if the demand for oil were the source of the shock. This is further evidence that the modelling of the oilseeds and biodiesel sectors are inadequate and not reflective of real world conditions.

3.3 CROPS

The model has the advantage that it has disaggregated maize from coarse grains and has the oilseed sector disaggregated but there is still a large amount of aggregation. It would be beneficial if fodders and forages were disaggregated, as these have important roles to play in the livestock sector and proper modelling of this sector is critical for a good understanding of how biofuel feedstocks and co-products impact this sector. The oilseed meals should substitute for high protein forages but the model does not have a mechanism to do this.

3.4 SUMMARY

The work undertaken to disaggregate the oilseed crushing sector is a step in the might direction for modelling the potential impact of biofuels, in general, and biodiesel fuels in particular. However, there are errors that have been made as part of this in determining how much oil and protein meals are produced from the oilseed crops. These errors mostly result in ILUC emissions that are overstated.

Econometric models cannot model the livestock sector for physical constraints such as protein or energy requirements, only for the costs of the inputs. This limits the ability of the model to properly adjust to the new equilibrium after a biofuel demand shock.

The authors of the report stated that the model has reached its limit in terms of modelling co-products but there is no indication that it is adequately modelling the demand and supply for protein meals. This is a critical issue for biodiesel.

4. MODELLING DESCRIPTION

It is always important to understand the modelling scenarios when trying to understand the results. The base case for the model and the shocks applied to the model are described below.

4.1 BASE CASE

The GTAP 7 database has data for the year 2004. The MIRAGE model first updates this information to the year 2008 using macroeconomic data (GDP, population, labour force etc,) and by observed data with respect to the biofuels production and consumption. The model then runs for the year 2020 based on all of these pre-programmed factors except for oil prices and some macroeconomic variables.

The model accounts for the 2008 level of duties on biofuels and the anti-dumping duties on US biodiesel. It also factors in the EU sugar reform and the end of the land set aside policy in the EU.

The description of the set aside impacts has some potential to influence the results. The inclusion of set aside drives EU crop yields down and influences the response of yield from fertilizer and intensification. The authors of the report acknowledge that this modelling should be improved.

In the baseline it is assumed that biofuels use is in the EU is maintained at 2008 levels of 3.3%. Surprisingly, the biodiesel consumption in the EU increases between 2008 and 2020, indicating an increase in diesel fuel consumption in spite of existing trends and increases in prices. Biofuel mandates in the rest of the world are implemented in the 2020 baseline. Compared to the 2010 modelling work the level of ethanol use in Brazil is increased to 35%. This means that less Brazilian ethanol is available for export.

Worldwide biodiesel production more than doubles between 2008 and 2020 due to mandates and increased demand outside of Europe. The baseline projects an increase in the EU biodiesel production sector by 28.8%, between 2008 and 2020. This is due to the increase in consumption and reduction in imports. The supply and demand situation is summarized in the following table. There is a small discrepancy in the change in oil consumption versus the biodiesel production. The oil consumption is too high by 3%.

Table 4-1 Baseline Supply and Demand

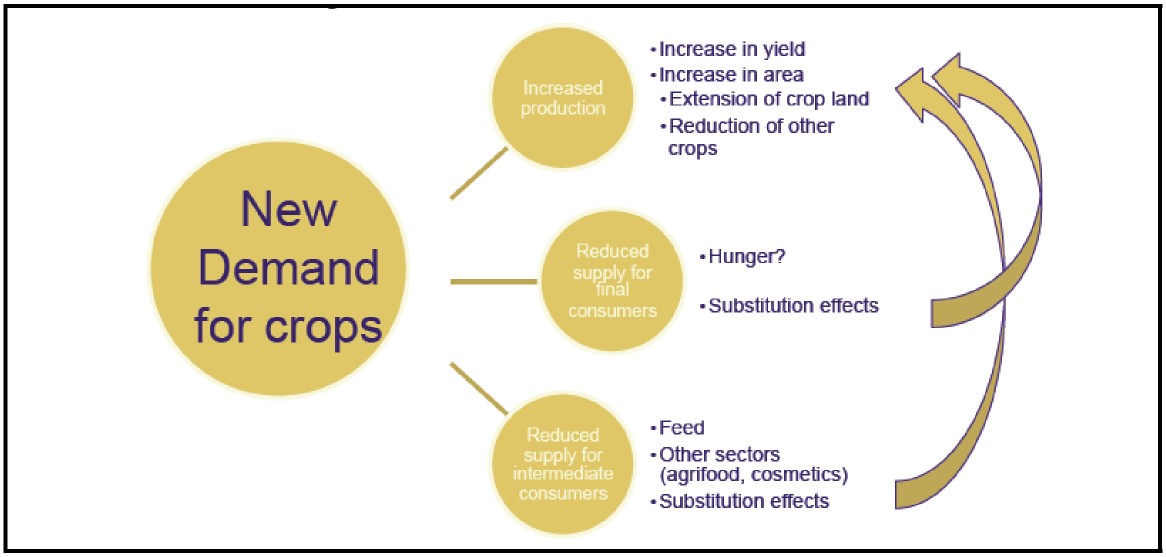
Parameter	2008	2020 Reference
	Million toe (except feedstock million tonnes)	
Biodiesel Production	6.33	8.15
Biodiesel Imports	1.76	0.64
Biodiesel Consumption	8.08	8.79
Feedstock Oil Consumption	6.97	9.23

Overall the demand for all crops increase by 27% between 2008 and 2020 and, even with the forecast yield increases, the world cropland expands by 122 million hectares. However, according to the 2010 report, cropland area decreases in Europe by 5% during this period but the detail tables in the Excel annex that accompany the report indicates that the area of EU crops increased by 15.7% during this period. This is a significant inconsistency.

4.2 MODELLING LAND USE CHANGE

Once the baseline scenario is established, a shock is introduced into the system and the model is allowed to reach a new equilibrium. For biofuels, the shock is an increase in biofuel demand, which causes an increase in demand for new crops. The system response is shown in the following figure. There can be a re-allocation of crops from the food and feed markets, yields can increase on existing cropland, or there can be an increase in area cropped.

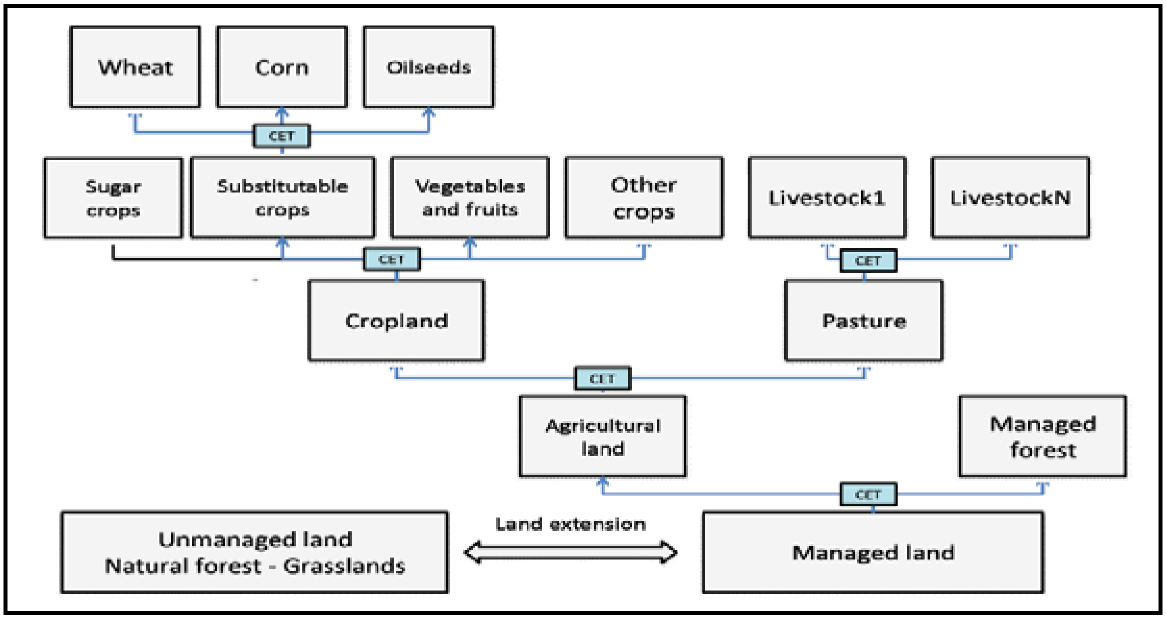
Figure 4-1 The Modelling Concept



Source: IFPRI

If the model determines that there must be an increase in area cropped, then that new land can come from the pasture portion of agricultural land, from managed forests, or if there is insufficient supply from unmanaged lands (primary forests, savannahs, etc.). This is shown in the following figure. This is an important figure in the modelling and while the concept is generally correct, it has been misapplied by the modellers through their choice of land data used, and elasticity factors chosen.

Figure 4-2 Land Markets



Source: IFPRI

4.3 SHOCKS

For the central scenario, the EU biofuel consumption is increased to 8.7% in 2020. The overall split is 22% ethanol and 78% biodiesel.

CGE models currently tend to give generally linear results. This is primarily due to limitations in the models and their basic assumptions about perfect competition. The 2011 work looked at the impact of a full mandate and a half mandate. There are some differences in the land use change emissions but they are driven primarily by different assumptions regarding the ratio of biodiesel to ethanol in the two different scenarios.

4.3.1 Individual Feedstock Co-efficients

To develop a specific feedstock LUC factor, the modellers increase the blending rate in the EU by 0.5% (from 8.2 % to 8.7 % for instance), maintaining the consumption of all other feedstocks by all other biofuel industries in the world. Therefore any increase in biofuel supply that should match the new EU demand could be generated with only one feedstock. However, there is no restriction about the location of production and transformation of the crop.

During the shock, all trade flows can adjust but trade surplus/deficit are maintained constant. Therefore, some real exchange appreciation can occur in some regions and they face contraction of agricultural exports for some countries providing the key feedstock in the simulation. In this case, there is a double source of land reallocation:

- direct competition effect, i.e. the price of studied feedstock increase, the land rent increase for this crop and other crops are displaced,
- and the external account effect: additional exports of the key product in volume plus increase of the world price of this commodity will increase export values.

Then, depending on the hierarchy of import demand elasticities across products and regions, some exports will decrease (and they can be land intensive) or some imports may expand (and they can save local use of land). The impact of this approach is discussed later in the report.

The indirect land use emissions for the biodiesel feedstocks for the full mandate with two different assumptions about trade policy are shown in the following table. The emissions are amortized over a twenty year period.

Table 4-2 Indirect Land Use Emissions

Crop	Status Quo Trade Policy	Trade Liberalization
	g CO_2eq/MJ	
Palm	54.3	55.0
Rapeseed	53.8	56.2
Soybean	55.8	57.4
Sunflower	51.8	54.9

When these estimates are compared to the previous work, palm is increased significantly, rapeseed is little changed and soybean and sunflower are significantly reduced.

The total cropland expansion calculated by the model ranges between 1.74 and 1.87 million ha, depending on the trade policy assumption. This is about 1.5% of the cropland expansion that the model predicts will occur between 2008 and 2020 in the development of the baseline case.

4.4 EXCLUSIONS FROM THE SCENARIOS

Understanding what has not been modelled is as important as what has been modelled.

1. No restrictions have been placed on land expansion. The RED requires certification of the feedstocks used for biodiesel production to come from land that was in production prior to Jan 1, 2008 or, if from new land, land that has low carbon stocks. While this does not eliminate the leakage issue (old land used for fuel and new land used for feed and food) it will have some impact on land expansion.
2. No allowance has been made for biofuels produced from waste, which are counted as double the volume under the RED. This will impact total land use but, due to the linearity of the model projections, it will probably not impact the individual crop values.
3. No technical constraints have been put on feedstock for biodiesel consumption. There are relatively high elasticity values between the four types of biodiesel, even though palm oil biodiesel has poorer cold weather properties and whose use is limited in Europe. Palm's share of the EU market grows from 4% on 2008 to 17% in the 2020 shock.
4. No changes in the rates of improvement of technology are assumed. The 2020 baseline is developed from the 2008 case using business as usual assumptions with respect to historic rates of change.

5. MIRAGE Inventory Data

The Inventory data in any model has a very significant role to play in the development of the final results. The econometric models that are being used to estimate land use change have had land inventory data added to their database. The quality of this data strongly influences the results.

There is no single source of high quality data on land use. Different countries track the data differently. Different models have used different sources of information. This is a major issue with these types of models. An overview of the MIRAGE data follows.

5.1 Land Inventory

The MIRAGE land inventory information has been developed for this model. There are three types of managed lands in the model: cropland, pasture, and managed forests. There are also unmanaged land inventories for primary forest and savannah and grassland. In addition to a regional breakdown by type of land, it is also necessary to break the land types down into AEZ.

The high degree of regional aggregation used for this modelling effort make it difficult to verify much of the land inventory data but it is possible to compare information for the EU27, the US, Brazil, the CIS, and the total World data. These comparisons are discussed below.

The United States has excellent records of the area of cropland and the area in the major crops each year. In the following table, the data from the MIRAGE model (Excel file Annex 1) is compared to USDA data for 2008.

Table 5-1 Land Inventory Comparison USA - 2008

Crop	MIRAGE	USDA	Difference
	1,000 ha		
Maize	27,581	34,788	7,207
OthCrop	10,486	12,409	1,923
OthOilSds	6,648	1,864	-4,784
Rapeseed	324	409	85
Rice	1,293	2,995	1,702
Soybeans	28,210	30,636	2,426
Sugar_cb	842	351	-491
Sunflower	440	1,018	578
VegFruits	3,732	-	-3,732
Wheat	18,699	25,568	6,869
Hay	0	25,430	25,430
Total Principal crops	98,255	131,494	33,239

It is apparent from the table that there are large differences between the cropland area used in MIRAGE and the official USDA data. The total cropland category in the US National GHG Inventory report submitted by the US EPA to the UNFCCC is even larger than shown above at 163,147 thousand hectares. The difference between the area in principle crops and total cropland is land in the conservation reserve program, land fallow for a year, and land in cropland pasture. These three missing categories represent a large portion of the additional land available for agriculture without any land use change emissions. The difference between the MIRAGE US cropland and the official UNFCCC inventory is more than 65%.

This is 65 million hectares of cropland that exists in the United States that the model can't access. This is a serious issue with the model.

Land use data for Europe is inconsistent. EU stats have some overall data, but the crop data is not available for every country. The FAO Stats database has been used as the comparison in the following table. Again we see that only about two thirds of the cropland is included in the model and the primary difference is the quantity of fallow land and the land that is used for fodder production.

Table 5-2 Land Inventory Comparison EU-27 - 2008

Crop	MIRAGE	FAO	Difference
	1,000 ha		
Maize	8,160	8,807	647
OthCrop	19,871	25,751	5,880
OthOilSds	15,861	5,147	-10,714
Rapeseed	3,727	6,128	2,401
Rice	344	410	66
Soybeans	317	235	-82
Sugar_cb	1,808	1,531	-277
Sunflower	2,848	3,748	900
VegFruits	12,070	12,886	816
Wheat	21,789	26,491	4,702
Hay & Fodders	0	30,360	30,360
Fallow		8,142	8,142
Total Principal crops	87,795	130,636	42,841

A large number of crops are grown for fodder in the EU including maize, rye, pumpkin, alfalfa, clover and other grasses. The interaction of oilseed meals and DDGS and these non-modelled feeds in the livestock sector is critical. Displacing the protein and energy from these forage crops is an important source of land for new biofuel production.

A comparison of the CIS data from MIRAGE with FAO data shows large variation. Even without any reported hay or fallow land, the FAO land databases is larger than used in the MIRAGE model.

Table 5-3 Land Inventory Comparison CIS- 2008

Crop	MIRAGE	FAO	Difference
	1,000 ha		
Maize	2,255	5,108	2,853
OthCrop	18,667	28,508	9,841
OthOilSds	5,549	3,114	-2,435
Rapeseed	198	2,494	2,296
Rice	237	358	121
Soybeans	502	1,333	831
Sugar_cb	727	1,337	610
Sunflower	31,575	11,103	-20,472
VegFruits	6,484	8,897	2,413
Wheat	32,651	50,680	18,029
Hay & Fodders	0	0	0
Fallow	0	0	0
Total Principal crops	99,845	112,935	13,090

The land inventory for Brazil is compared in the following table. Again, there are significant differences in the databases including important crops for biofuels.

Table 5-4 Land Inventory Comparison Brazil- 2008

Crop	MIRAGE	FAO	Difference
	1,000 ha		
Maize	8,373	14,444	6,071
OthCrop	4,537	9,690	5,153
OthOilSds	19,860	919	-18,941
Rapeseed	38	100	62
Rice	25	2,850	2,825
Soybeans	2,356	21,246	18,890
Sugar_cb	15,072	8,140	-6,932
Sunflower	4,128	0	-4,128
VegFruits	47	5,815	5,768
Wheat	6,551	2,363	-4,188
Hay & Fodders	0		0
Fallow	0		0
Total Principal crops	61,987	65,570	3,583

The land inventory for the world is compared in the following table. Again, there are significant differences in the databases including important crops for biofuels. The world crop area harvested in MIRAGE is significantly lower than that reported by the FAO.

Table 5-5 Land Inventory Comparison World- 2008

Crop	MIRAGE	FAO	Difference
	1,000 ha		
Maize	112,730	160,814	48,084
OthCrop	178,346	282,645	104,299
OthOilSds	255,651	16,466	-239,185
Palm	8,582	14,702	6,120
Rapeseed	19,020	30,659	11,639
Rice	97,527	157,739	60,212
Soybeans	61,896	96,480	34,584
Sugar_cb	17,921	28,620	10,699
Sunflower	46,308	25,031	-21,277
VegFruits	168,365	242,363	73,998
Wheat	154,220	242,531	88,311
Hay & Fodders	0	166,980	166,980
Fallow	0	0	0
Total Principal crops	1,121,566	1,465,030	343,464

The world data can be compared with the widely cited Monfreda, Ramankutty and Foley (2008) data for 2000, which showed 1.29 billion ha of harvested crops without any forages included. This is very close to the 2008 FAO data.

The land inventory data in MIRAGE has significant issues. It understates the harvested land, doesn't include forages or fallow land, and many of the important biofuel feedstocks have significantly higher harvested areas than are in the model.

5.1.1 Fallow Land

There are significant quantities of cropland that are fallow in any given year. This is sometimes due to crop rotations but it can also be land that is not being managed in a sustainable way and could be in annual production with the use of synthetic fertilizers and modern management practices. Data on fallow land is not always collected by individual countries and reported to FAO. For example, the Ukraine reports fallow land, but the Russian Federation doesn't. Estimates of fallow land in the world have been made by examining satellite images.

Seibert et al (2010) published estimates of cropland, fallow land and land that is double cropped for the year 2000. The data was determined using agricultural census and augmenting the data with satellite images. The results are summarized in the following table. There are 1.6 billion hectares of cropland available compared to the 1.24 billion ha in the MIRAGE model. More than 25% of this land was fallow in 2000. Fallow land was the lowest in Western Europe and highest in southern Africa and Central America.

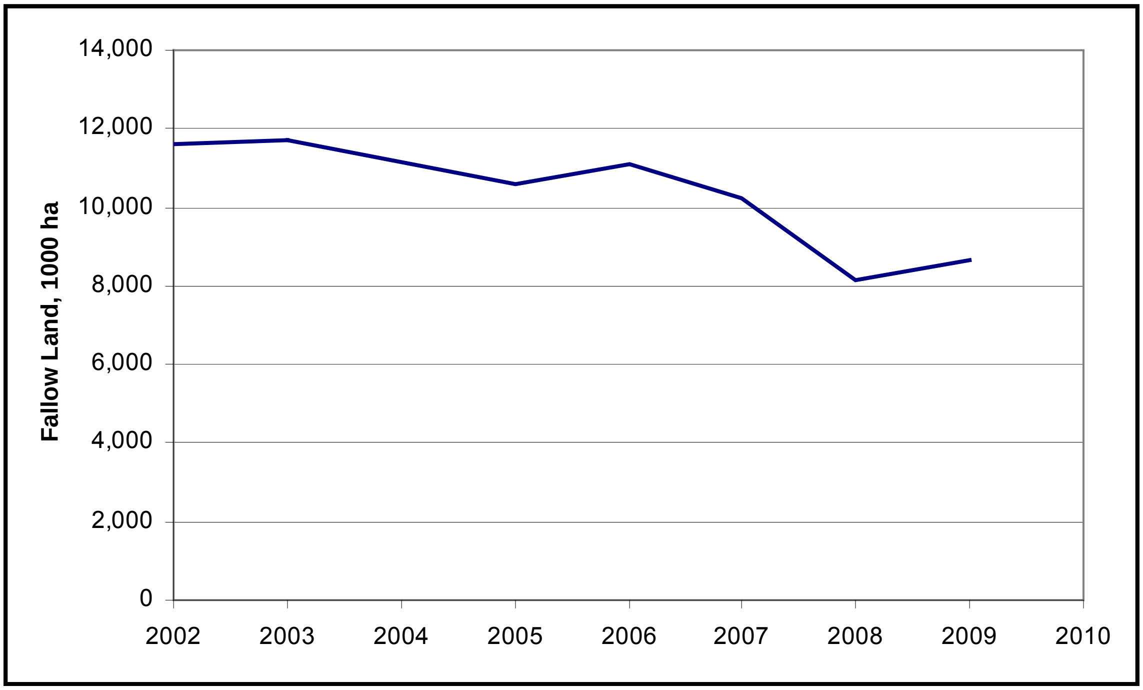
Table 5-6 Fallow Land Estimates

	Total Cropland	Fallow Land	% Fallow
	1,000 ha		
AFRICA	231,800	77,700	33.5%
Eastern	55,000	19,800	36.0%
Middle	28,000	12,900	46.1%
Northern	42,000	16,100	38.3%
Southern	18,000	10,600	58.9%
Western	88,900	18,400	20.7%
AMERICA	405,100	115,900	28.6%
Caribbean	7,900	3,400	43.0%
Central	46,000	24,900	54.1%
Northern	227,800	61,500	27.0%
South	123,400	26,000	21.1%
ASIA	620,100	161,200	26.0%
Central	35,200	11,900	33.8%
Eastern	172,600	40,500	23.5%
South-Eastern	121,800	39,200	32.2%
Southern	244,500	55,000	22.5%
Western	46,100	14,600	31.7%
EUROPE	308,800	72,900	23.6%
Eastern	208,300	59,400	28.5%
Northern	21,600	3,600	16.7%
Southern	43,000	7,300	17.0%
Western	35,900	2,600	7.2%
OCEANIA	34,200	14,300	41.8%
WORLD	1,600,000	441,900	27.6%

Russian federation is included in Eastern Europe

The MIRAGE model has determined that 1.74 to 1.87 million hectares of additional land will be required to meet the EU biofuel mandate in 2020. There were 8 million hectares of fallow land just in the EU in 2008 (Eurostats). This quantity has ranges between 12 and 8 million hectares between 2002 and 2008 as shown in the following figure.

Figure 5-1 Fallow and Green Manure Area EU

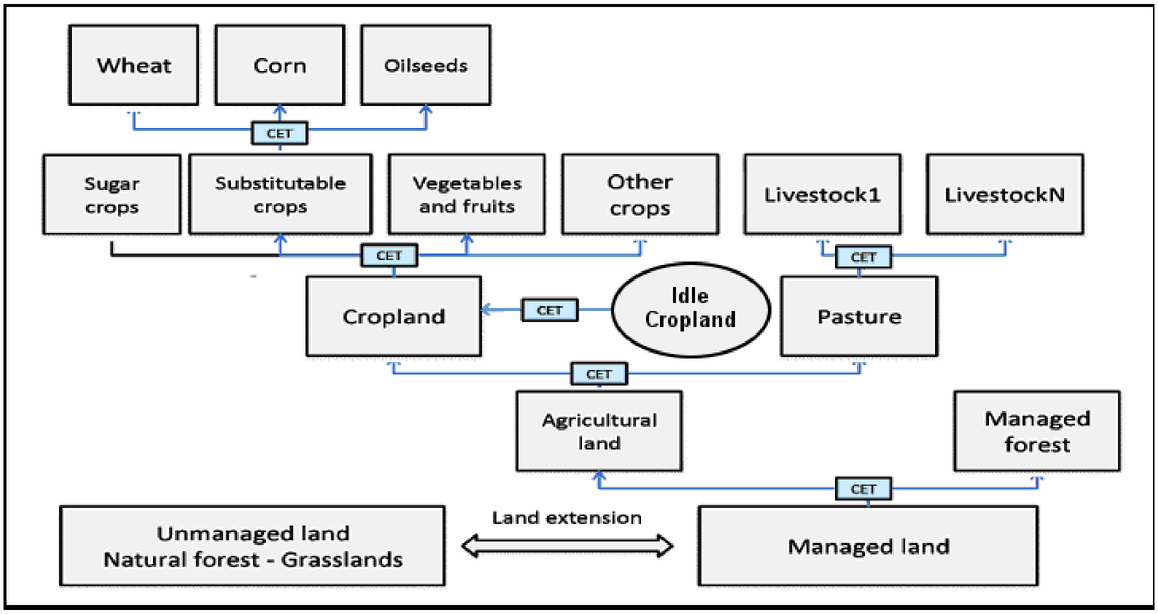


The MIRAGE model, because it doesn't include fallow land as a separate category or as part of the cropland, has no way of accessing this resource.

What is clear from this review of the data in the MIRAGE model is that the cropland is really land covered by crops and it is not the actual available cropland. It does not include the land that one would expect to be brought into production in response to a rise in prices. Essentially, the model has erroneously assumed that all cropland is 100% utilized and that any shock will lead to new land. The model assumes that there is indirect land use change and then goes about calculating it!

If one was going to use this econometric modelling approach to estimate ILUC then the model structure would have to look more like the following figure, rather than Figure 4-2.

Figure 5-2 Improved Land Markets Model



The CET function between cropland and idle cropland in the above figure would have to be very large to reflect that this is the most likely land that would be brought back into production in response to higher demand and prices. Brining this land into production would actually reduce GHG land use emissions since even fallow land creates GHG emissions without producing a crop and these could be avoided.

Given the size of the shock and the global availability of idle land, it is likely that including this land in the model would drive the ILUC emissions lower by an order of magnitude. The nature of CGE models would probably never allow no pasture or forest conversion even when the idle land available is more than 100 times higher than the land demand calculated from the fuel demand shock.

5.1.2 Double Cropping

Using idle cropland is not the only possible response to higher commodity prices. Some land in the world is double cropped and there is some evidence that the quantity of land double cropped responds to market prices.

While most land in the world produces one crop per year, there are regions where two crops can be produced. This effectively increases the land area available. None of the models for ILUC have this capability at this time.

There are two primary requirements for profitable multiple cropping:

1) There must be adequate time for the production of a second crop.
2) There must be adequate water to produce two crops, whether from stored soil moisture, rainfall, or irrigation.

There will be a double crop area response to pricing. The higher the price, the more likely that producers will take the risk that growing conditions will be adequate to produce a second crop.

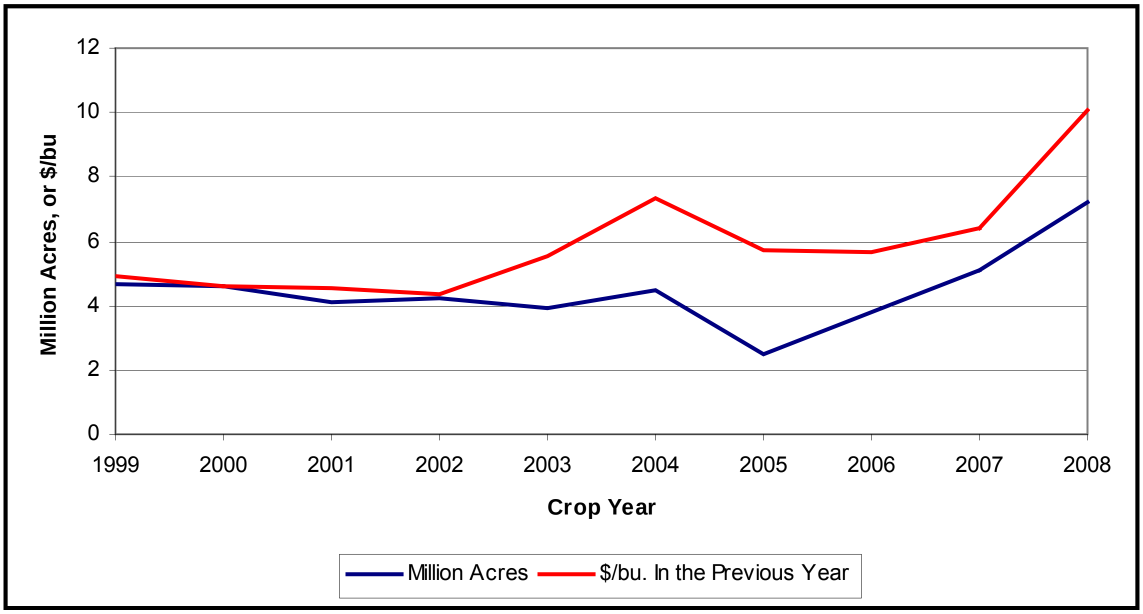
Seibert (2010) estimated the area of agricultural land that is double cropped as shown in the following table. Almost 10% of the world's cropland (including fallow area) is double cropped. As one would expect, the percentage is higher in the warmer climates but there is some double cropping found in southern and western Europe.

Table 5-7 Double Cropped Land Estimates

	Total Cropland excluding fallow	Double Cropped Land	% Double Cropped
	1,000 ha		
AFRICA	154,100	13,869	9%
Eastern	35,200	3,872	11%
Middle	15,100	-151	0%
Northern	25,900	5,698	22%
Southern	7,400	740	10%
Western	70,500	3,525	5%
AMERICA	289,200	5,784	2%
Caribbean	4,500	360	8%
Central	21,100	1,266	6%
Northern	166,300	0	0%
South	97,400	3,896	4%
ASIA	458,900	119,314	26%
Central	23,300	1,864	8%
Eastern	132,100	46,235	35%
South-Eastern	82,600	14,042	17%
Southern	189,500	54,955	29%
Western	31,500	2,520	8%
EUROPE	235,900	0	0%
Eastern	148,900	0	0%
Northern	18,000	0	0%
Southern	35,700	714	2%
Western	33,300	333	1%
OCEANIA	19,900	5,771	29%
WORLD	1,158,100	150,553	13%

Despite the data reported by Seibert, in the US, soybeans are often planted as a second crop following winter wheat production. Because the soybean is photoperiod sensitive and matures in response to day length, it is ideally suited for multiple cropping systems where planting dates for the second crop can be variable due to weather and/or delayed wheat harvest. Currently, most multiple cropping systems in the US depend solely on a combination of rainfall and stored soil moisture to supply adequate water for two crops. Double cropping area in the US typically ranges between 1 and 2.5 million ha/year (Babcock and Carriquiry). It has responded to the prices in the previous year very closely.

Figure 5-3 US Soybeans Double Cropping



Source: Babcock and Carriquiry and USDA

5.2 AGGREGATION LEVELS

Models that aggregate managed agricultural land into just one category eliminate the possibility of including fallow land, other idle lands, lands used to produce forage, and lands used for temporary pasture in the determination of indirect land use.

It has been shown that, in the United States and the EU, some of these categories have significant areas. In the existing MIRAGE modelling structure these lands are not included as cropland and they essentially do not exist, they can't even be accessed directly by the model to grow additional crops. Thus one of the most likely responses to higher prices, the better utilization of existing land, cannot be modelled, except for "tricking" the model by using high price-yield elasticity values to drive land intensification (as prices increase, more production is obtained from the same area). IFPRI has not done for this ILUC modelling exercise.

The GTAP model used by CARB had the opposite issue, it included the idle land in cropland but again has no way to access it. However, the most recent versions of the GTAP model have included, **as separate land categories**, cropland pasture and CRP (set aside) land. This is essentially the structure shown in Figure 5-2. The GTAP model developers have not been able to get the model to work properly when both new land categories are added but they have got it to work with just the addition of cropland pasture. In some model runs, this new land provides half of the required new land (the CET values used for this new land are the same as used for pasture and forests and this issue is discussed in the next section) and thus has a very significant impact on the determination of indirect land use emissions.

5.3 SUMMARY

The land inventory data in MIRAGE excludes from the cropland category land used to produce fodders and forages, fallow land, and land suitable for double cropping. Firstly, it is unclear how the livestock sector could be adequately modeled in MIRAGE if all of the forage land is excluded from the database. Secondly, since this is the most likely land that would be brought into production in response to higher prices, any ILUC estimates that are done without including the most important land resource available would be grossly exaggerated and unreliable.

These missing lands need to be included in the land database, but in separate categories from cropland (less aggregation). An appropriate CET function for this new category would also have to be added to the model, as this would be the only way that the model could access this additional land and provide realistic estimates of indirect land use emissions.

6. ELASTICITY FACTORS

One of the most important aspects of econometric models is the value for the various elasticity factors that determine the response to changes in the model inputs. The documentation of the MIRAGE model from the 2010 report identified 2,675 elasticity factors, and those were just the ones dealing with agriculture and biofuels. Most of the elasticity factors are relatively "round" numbers, indicative of the large amount of uncertainty inherent in these models.

There are three important groups of elasticity factors that have a major influence on the calculated total land requirements from the modelled shock and on the emissions resulting from that land change. These issues are additive to the issues raised in the previous section on land inventory and types of land.

6.1 CROP DISPLACEMENT AND SUBSTITUTION

The mitigation options that the model considers for offsetting the increased commodity demand from the biofuel shock are the substitution and displacement responses to higher commodity prices. Increased demand from biofuels would lead to substitution or reduced consumption in the feed, food and other sectors and the availability of co-products will also substitute for other feed ingredients and "free" more land for biofuel feedstocks. These are the kind of effects that CGE models were designed to address and the elasticity factors should be based on the analysis of the historical data in the GTAP database.

From Table 6 in the 2011 report it can be calculated that the feed demand for livestock drops by about 754,000 tonnes but it is not possible to determine how much of that is biodiesel related and how much is ethanol related. Since the use of oilseeds in livestock rations is limited, one would expect little impact on their use due to higher prices. Table 6 shows a reduction in oilseed use in the livestock sector of 3 million tonnes but an increase in oilseed meal use of 9.8 million tonnes. The problem is that they have used incorrect factors for the quantity of the meals produced from each oilseed.

It can also be determined from Table 6 that there is some (9.2%) demand reduction in oil related to higher prices. This is probably the only factor that would be close to how the market actually responds since it doesn't involve the livestock sector.

6.1.1 Co-Products

As stated earlier, since the model doesn't include forages, the consumption of livestock feed won't be accurate either. In addition, it appears that the oilseed crushing sector is not modelled correctly in that the model forces increased meal into the livestock sector and doesn't allow for the trade of these commodities.

In the model, the use of co-products in the livestock sector is balanced based on cost only, whereas in the real world the livestock ration balancing is done using least cost programs that also balance the protein and energy requirements of the animals. The oilseed co-products compete with each other and other sources of proteins at one level and then, at the next level, they compete with the energy feeds based on their metabolized energy. The metabolized energy of the important feeds is shown in the following table for cattle (there are different values for other animals). In the case of a commodity like soybeans, which are grown for their protein and not for the oil, this treatment just doesn't represent the real world. The model treats the co-product (soybean oil) like the main product and provides the meal with a credit based just on its energy content and not its main attribute of protein.

Table 6-1 Metabolized Energy Contents of Feeds

Ingredient	Metabolized Energy Mcal/tonne	% Maize
Maize	3.03	100
Wheat	3.08	102
Rapeseed Meal	2.66	88
Soybean Meal	2.94	97

Since the meals have a lower energy content, one kg of meal will replace less than one kg of grain and with the lower yield of the oilseeds compared to the grains, the land displaced by the oilseed meals will be quite a bit less than the land displaced by DDGS.

This is also evident in Table 11, where in the rapeseed biodiesel case there is an increase in the tonnes of feed consumed whereas in the soybean case there is a small decrease in the feed consumed by livestock. Table 11 also has units that cannot be correct, as the feed displacement values are much higher than could possibly be produced from 60 GJ of additional demand.

The modelling of the oilseed sector is a major problem for the model. It is probably one of the major reasons why the ILUC factors are higher for biodiesel than for ethanol.

6.2 CROPLAND INTENSIFICATION

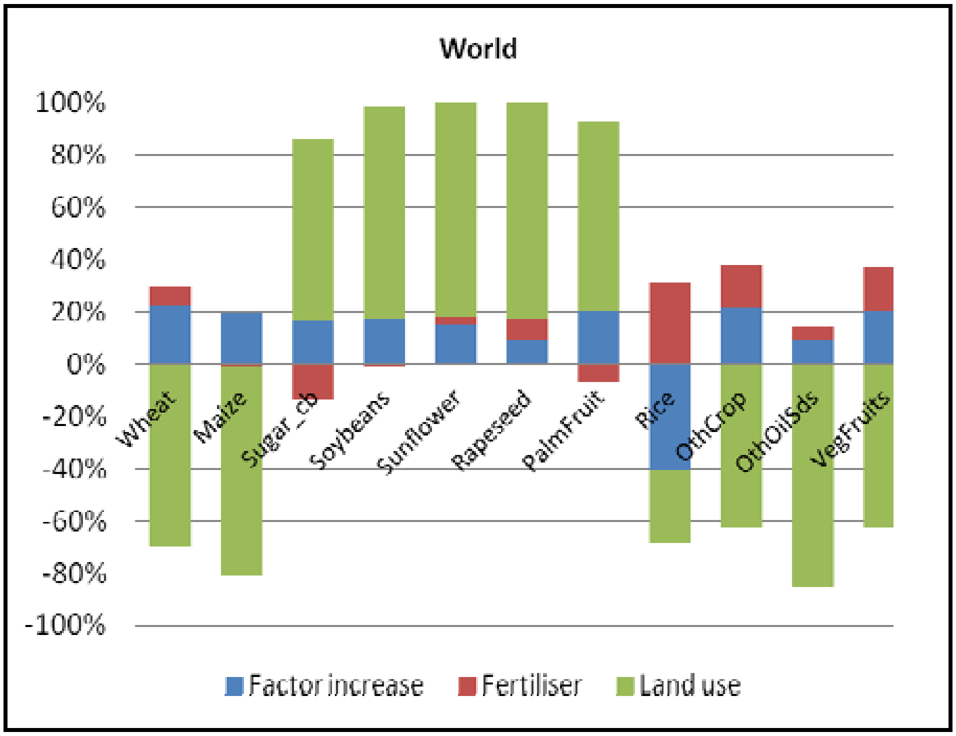
As crop prices increase there will be a response from producers. The lowest hanging fruit in any industry is always to try and produce more with the same resources, especially in the short run. Typically that might include using more and better machinery, increased labour to control weeds, and perhaps more fertilizer. It could also involve increased irrigation, better seeds, increased pest control, and other activities.

There are some who argue that there is no empirical evidence of higher yields due to higher prices, but this is very difficult to monitor and the corollary would be that millions of agricultural producers throughout the world are managing their fields to produce the maximum output, irrespective of input costs and output prices. This is just not believable and so there must be some intensification impact of higher feedstock prices.

6.2.1 Capital and Labour

The MIRAGE model includes elasticity factors for labour and capital with respect to price. As the demand increases and prices rise, increased inputs of capital and labour become economic and result in higher yields. This has a positive impact on all crops except rice, as shown in the figure below.

Figure 6-1 Intensification Results



It is almost impossible to detemine these elasticity factors empirically. There are almost always too many variables, including weather, that are beyond the control of the producer to determine the factors quantitively. The MIRAGE elasticity for capital and energy for the feedstocks appears to be relatively low at 0.03 for all feedstocks.

The recommendation of the EWG in California was that price elasticity factor should be 0.25, with some sensitivity analysis done on the factor. This factor would include the double cropping response and the fertlizer impact.

6.2.2 Fertilizer Impacts

The impact of fertilizer can be modelled separately in MIRAGE. From the previous figure it can be seen that fertilizer has a relatively small impact on the increased supply and it varies by crop. IFPRI do note that modelling the fertilizer impact is complex and they have used a simplified approach.

The base case assumptions with respect to yield are summarized in the following table for the biodiesel feedstocks.

Table 6-2 Yield Assumptions

	Palm Fruit	Rapeseed	Soybeans	Sunflower
	Tonnes/ha			
EU27		3.9	1.9	2.3
Brazil	41.4	3.5	3.5	3.1
CAMCarib	26.1		4.7	
China	36.4	2.5	2.3	2.1
CIS		1.9	1.4	2.2
IndoMalay	34.1		1.9	
LAC	26.0	2.6	3.2	1.8
RoOECD	6.4	2.4	3.4	2.9
RoW	4.7	2.6	2.0	2.0
SSA	6.6	1.9	2.0	1.7
USA		2.7	2.7	1.6
World	20.5	2.8	2.9	2.1

There is significant variation in the yields for these crops. Some of the variation will be caused by varieties, soils, climatic conditions, etc. but some could also be caused by constraints on inputs.

6.2.3 Overall Impact

The overall impact of the intensification impacts on yield is very small. This is a function of both the low elasticity factors used and the small changes in price of the commodities between the base case and the business as usual case (~1.0% for rapeseed and 0.3% for soybeans).

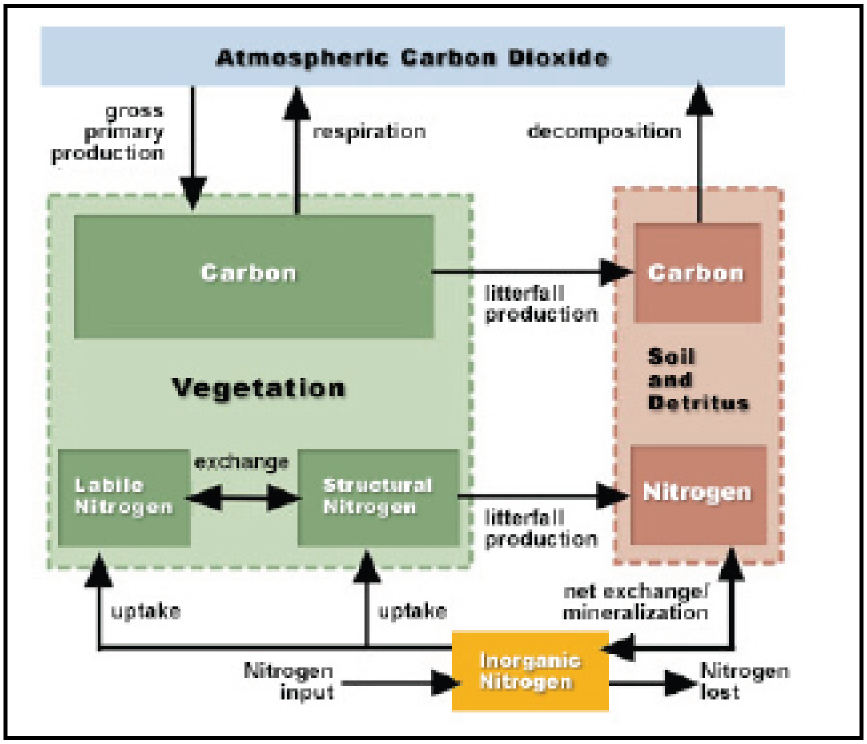
These factors were part of the Monte Carlo analysis, but there is no sensitivity analyses done for just the intensification values.

6.3 NEW LAND CROP YIELD

The important question of what is the yield of a crop planted on new land is answered by considering the yield on existing land using an elasticity factor, which is assumed, to arrive at the yield for the new land. In the 2010 IFPRI report, it is stated that a value of 0.5 is used, except for Brazil, which has a value of 0.75. The 2011 report does not state that this assumption has changed but the discussion of the Monte Carlo simulations states that the average value for this parameter is 0.75.

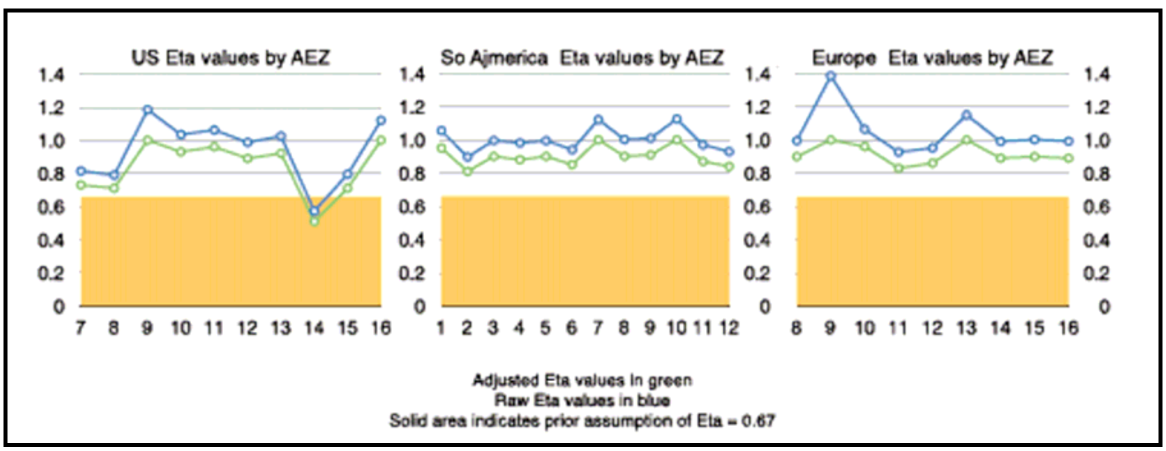
This issue was the subject of study of one of the Land Cover sub group of the CARB Expert Working group (EWG) (Gibbs, et al, 2010). In the CARB modelling this factor was 0.67 for all land. The sub group investigated several alternative approaches to deriving this factor, including the one developed at Perdue for use in the latest GTAP modelling. That effort used the Terrestrial Ecosystem Model (TEM) to estimate relative yields (Eta) on new lands. The model was run for each of the AEZs so that productivity could be estimated for specific climate and soil conditions around the globe.

Figure 6-2 Terrestrial Ecosystem Model Structure



The following figure shows selected values for Eta as estimated by TEM. The results suggest that the assumption of a fixed value of 0.67 for Eta in all AEZs is inappropriate, and that the arbitrarily selected value was probably too low.

Figure 6-3 TEM Results



The raw values for Eta are often greater than unity. The sub group found that this seems contrary to conventional economic wisdom, which would suggest that land already in production should be the most productive. To mitigate this apparent contradiction, the modellers then normalize all of the data so that no AEZ can have a value greater than unity in each region. However, it is known that not all agriculture throughout the world is optimized, so it should not be surprising that the model would find that optimized yields could be higher than presently achieved yields.

The final recommendation from this group was for CARB to adopt the TEM results for inclusion in their GTAP modelling efforts. From the figure above this would suggest that this value should be between 0.9 and 1.0.

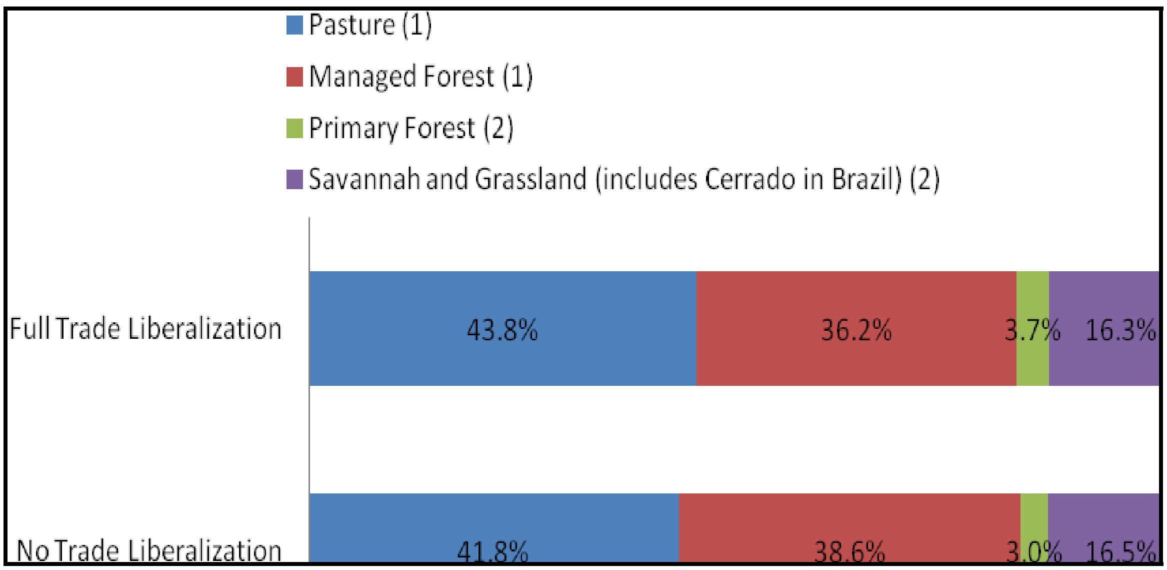
This is significantly different than the 0.5 or 0.75 that has been used for the MIRAGE modelling and would significantly (25% to 50%) lower the quantity of land required and the resulting calculated GHG emissions.

6.4 CET Factors

Once the quantity of extra feedstock is calculated and converted into a land value by applying the assumed yield, the source of that additional land must be determined. In the MIRAGE model the additional cropland could come from managed pasture, managed forests, and if those two sources can't supply enough land then it comes from unmanaged forests and savannahs. As noted earlier the model cannot access idle cropland.

In the MIRAGE modelling about 80% of the new land comes from managed lands and the remaining 20% from unmanaged lands as shown in the following figure.

Figure 6-4 Sources of New Cropland



The managed land distribution is determined by the Constant Elasticity of Transformation (CET) function. A high value for this functions means that a land owner will expand cropland into pasture or forest land at a relatively high rate compared to lower CET values. Compared to GTAP, the MIRAGE model appears to have a significant advantage in that it can use different CET values for different regions, different crops, and different types of land, whereas GTAP has a single value for all land transformation. Unfortunately, the modellers do not appear to have taken advantage of this benefit.

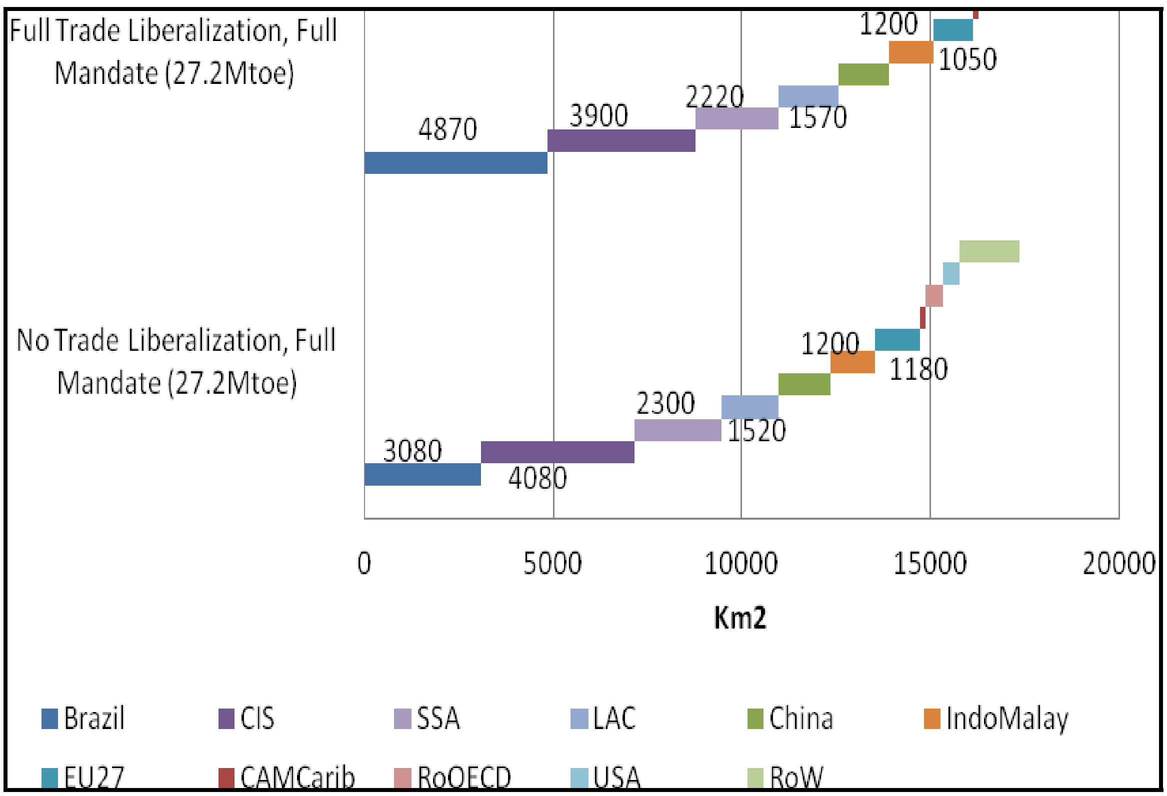
There are multiple layers for the CET function and while the values are the same in each layer, they differ between the layers. The values for each region for the 1st layer are shown in the following table.

Table 6-3 1st Layer CET Values

	Forest	Pasture	Sub Crops
Brazil	0.5	0.5	0.5
CAMCarib	0.2	0.2	0.2
China	0.2	0.2	0.2
CIS	0.2	0.2	0.2
EU27	0.1	0.1	0.1
IndoMalay	0.2	0.2	0.2
LAC	0.2	0.2	0.2
RoOECD	0.1	0.1	0.1
RoW	0.2	0.2	0.2
SSA	0.2	0.2	0.2
USA	0.1	0.1	0.1

These assumptions tell us that relatively more land is going to be converted in Brazil, the least land conversion will happen in the US, the EU, and the rest of the OECD countries, with intermediate values in the other regions. The total land availability also impacts the results, so a very large area like the CIS can have as much land converted as Brazil even with a lower CET value. This is exactly what the model shows, as seen in the following figure.

Figure 6-5 Location of New Cropland

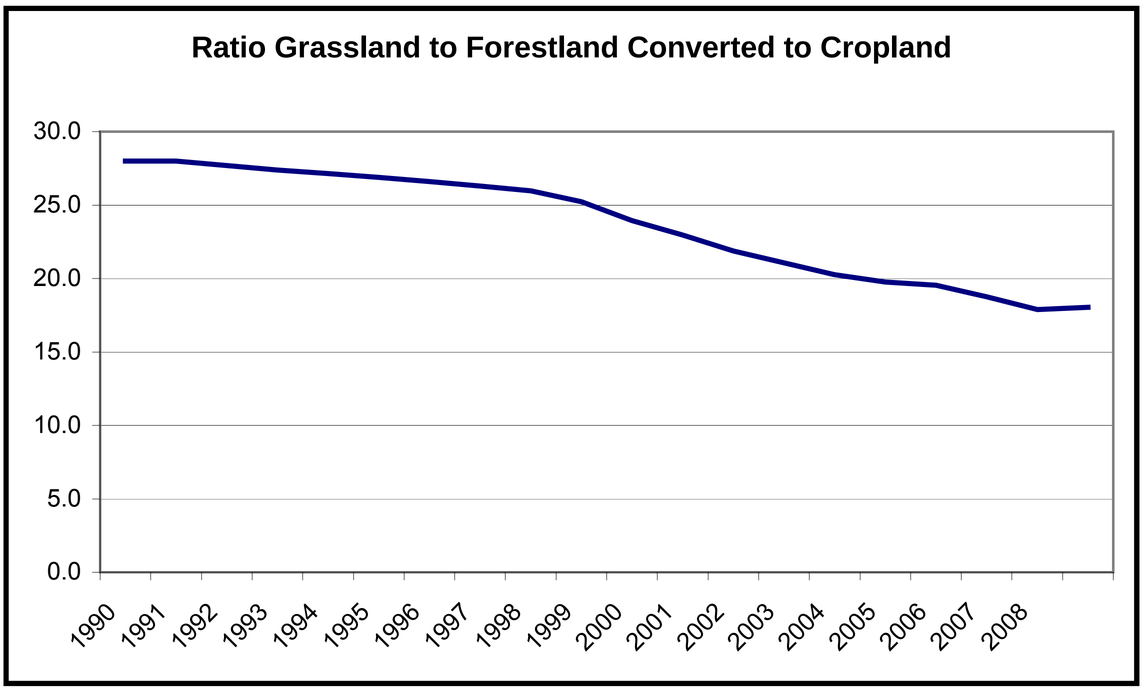


There is very little real world evidence to indicate what the CET values should be. This issue was also one identified by the CARB EWG as one of the areas that needed improvement. A paper by Babcock and Carriquiry (2010) that looked at the GTAP modelling of biodiesel explains the issue in some detail. The issue is complex but the conclusions were that pasture land should be at least 30 times more responsive to crop prices than forest land in a five year horizon rather than the assumption in the MIRAGE model that these two land categories have the same responsiveness.

It should also be intuitively obvious that it is more difficult to convert forest land to crops as there are significantly more activities required to clear a forest and prepare the land for planting compared to preparing pasture land. This high “capital cost” of preparing forest land is essentially ignored when the CET values for pasture and forest land are set to the same value.

There is also evidence from UNFCC National Inventory reports that suggest that it is much more likely to convert pasture land to crops than it is to convert forest land to crops. In the following figure the ration of Pasture Land converted to cropland to forest land converted to cropland in the European Union is shown. As suggested by the Babcock paper the ratio is between 20 and 28 to one.

Figure 6-6 EU Grassland to Forest Converted to Cropland



A similar ratio calculated from the US National Inventory report (EPA, 2011) shows that 19.3 times more grassland than forest has been converted to cropland over the past 20 years.

Unlike current versions of GTAP, MIRAGE appears to have the capacity to use different CET values for forest and pasture and, while the limited literature that is available supports different values, the IFPRI modelling work has not taken advantage of this capacity. If this capacity were used then instead of forests being responsible for 35% to 40% of the GHG emissions, they would be responsible for maybe 5% of the much lower ILUC emissions.

6.4.1 Unmanaged Land

If the model determines that there is insufficient managed land available to economically convert to cropland, then it accesses unmanaged forests and savannahs. Since these lands are unmanaged and have no economic rent, they cannot be accessed through the same CET function approach used for managed land.

The MIRAGE model then applies land extension coefficients to the unmanaged lands. These co-efficients are derived from the Winrock work done for the US EPA as part of the RFS2 modelling work. They are based on satellite images of land change from the early part of this century. Since a satellite image can't determine what caused the land use to change, it includes all drivers of land use change and essentially assumes that expanded agriculture would cause the same pattern of land use change. Land clearing for forestry, urban development, natural forest disturbances (fires, pests, climate events) and other drivers of land use change that have nothing to do with agriculture are all included. These land extension co-efficients are therefore overstated for agriculture and lead to higher indirect land use emissions.

It is interesting that for most regions land extension co-efficients for primary forest are small compared to other types of land even though they are overestimated for agricultural drivers. This further supports the fact that different CET functions should be applied to forest and pasture for managed lands.

Primary forests have the highest carbon stocks of all of the types of land that can be converted. Overestimating the conversion of primary forests leads to overestimating the ILUC factors.

6.5 Elasticity of Substitution between Feedstocks

The modellers have assumed a very high substitution level between the various types of biodiesel. This is probably inappropriate. Each feedstock gives the biodiesel some unique properties, including cloud point and stability. There are limitations placed on some of the properties by the EN specification for biodiesel. Even in the food sector the vegetable oils do not have full substitutability. Issues such as trans fat has favoured palm oil over soybean oil in many food applications. Ideally the model would have different elasticity factors for food and fuel applications and this could have a significant impact on the overall results, due to the high emissions associated with palm production in Malaysia and Indonesia.

6.6 Summary

There are significant issues with the elasticity factors used in the MIRAGE model. The elasticity factors related to crop displacement and substitution should be the strongest of the electricity factors used in the model since they are at the core of how the model has been traditionally used. While this is probably still the case for the response of consumers to different meat prices and vegetable oil prices, the appropriate response of the livestock sector to different feedstock availability and prices is not clear.

It appears that the livestock model is not modelled adequately. Forages, an important component in the diets, are not specifically included in the model or the land database created. Thus, co-products can substitute for these feed components. The oilseed crushing industry does not appear to be modelled independently of the biodiesel producers as oilseed meals are identified as a co-product of the biodiesel sector. This creates major problems for the model and the sector response. It appears that crushing margins (value of oil and meal less cost of oilseed) go negative in response to increased demand for crushing, not a likely response from the sector.

Being an econometric model, there is no way for the model to balance diets for protein and energy, it just balances for lowest cost based on the elasticity factors between different co-products that are chosen by the modellers.

Less than 1% of the new supply for biodiesel feedstocks are produced through intensification efforts on existing land. A relatively low elasticity factor has been applied to these effects. Higher elasticity factors were recommended by the EWG in California.

The elasticity factor for the yield of crops on expanded land is an assumption chosen by the modellers. Based on the data that is available and the results of other more sophisticated models, the values chosen are too low by 25% to 50%. This directly impacts the GHG emissions attributed to the biofuels, so this one assumption alone increases the ILUC factors by 25% to 50% over what they should be.

An even larger issue are the assumptions made with respect to the CET function values. The modellers have used the same value for pasture land and managed forests, whereas in reality the available data indicates that there should be a difference of 20 to 30 times between the values. This error increases the quantity of forest land converted by more than an order of magnitude and this increases the ILUC factor by 30% in the case of the scenarios modelled by IFPRI.

These errors are additive. The combined impact of just the improper elasticity, with respect to land expansion and the CET function, is that the real values should be 35% to 50% of the values reported in the report. The improvement of the modelling of co-products would be expected to provide additional reductions in the reported values.

7. OTHER ISSUES

There are some other modelling factors that can influence the overall modelling results. Some are common to all ILUC modelling efforts and others are unique to the MIRAGE model. Some are discussed below.

7.1 CARBON STOCKS

There is very little transparency in the calculation of the total carbon emissions. The carbon stocks in managed forests, primary forests, and the soil are reported by country and AEZ. This is an improvement over the CARB GTAP model, where a single value has been used for each region. The above ground biomass inventories shown in tables A3 and A4 in the 2011 paper appear to be reasonable compared to carbon stocks developed by Winrock for the US EPA.

7.1.1 Soil Carbon

Table A5 would appear to be mislabelled as the title is carbon stocks but the values appear to be carbon emissions. The emissions also appear to be significantly higher than the Winrock data developed for the EPA. It is difficult to compare since the Winrock data is not available by AEZ. In order to compare the soil carbon losses with the Winrock EPA results we have used the carbon emissions in table A5 and the land by AEZ in table 16 of the 2010 report. Table 16 is not the land that is converted but it should give a closer estimate than a simple average of the values in table A5. This comparison is shown in the following table.

Table 7-1 IFPRI vs. EPA Soil Carbon Losses

	IFPRI	EPA
	Tonnes CO_2/ha	
Brazil	95	88
EU27	91	75
USA	64	42

The soil carbon losses are higher than the EPA used. Since the ILUC emission calculation is not transparent, we have tried to back calculate some of the important parameters.

Biofuel shock=27.2 million toe

Energy content toe=42 GJ (net)

Total biofuel energy per year=1.142 10^9 GJ

Area of new cropland=1.73 million ha

Fraction of emissions from soil=30%

Amortization period=20 years

Average emissions= 38.4 gCO_2/MJ

The calculated soil carbon loss is calculated below:

CO_2/ha=(38.4 gCO_2/MJ)*(1000 MJ/GJ)*(1.142 10^9 GJ/year)*20 Years/1.73 million ha*(1 tonne/10^6 grams)

CO_2/ha=506.97 tonnes/ha

Soil Carbon=152.1 tonnes/ha

This soil carbon loss, 152 t CO_2/ha, is above all of the values that are listed in table A5. Because of the lack of transparency it is not apparent where the problem is but these emissions appear to be overestimated based on the available data.

7.1.2 Biomass Carbon

All of the calculations of forest losses in all of the models assume that trees live forever. The basic approach taken by IFPRI is that carbon stored in the forests is there permanently and unfortunately this is not true. Some of these issues are raised in a recent paper by Reijnders (2009). He argues that forestation is not an ideal means of offsetting carbon emissions. While this is a slightly different perspective than removing a forest, the core issue is essentially the same. Reijnders identifies the issues of permanence in that trees don't live forever and that unforeseen events such as fire, disease, and extreme weather events can further shorten the projected life of carbon storage in forests.

Trees are living organisms and like all living things they have a life cycle and at the end they die. The end of the lifecycle could be caused by natural fires, by disease or pests, or simply by old age. At the end of the lifecycle the carbon in the above ground biomass starts to decompose and is returned to the atmosphere. Thus if the forest land use was changed to produce crops and the carbon stored in the trees is released to the environment, then it may not change the total amount of carbon that is released but ***when*** that carbon is released. Ignoring this natural process charges agriculture with a change in carbon stocks that would have occurred anyways.

The IPCC recognize this. Equation 2.11 in the 2006 AFOLU guidelines is;

$$\Delta CL = L_{wood-removals} + L_{fuelwood} + L_{disturbance}$$

ΔCL = annual decrease in carbon stocks due to biomass loss in land remaining in the same land-use category, tonnes C yr-1

$L_{wood-removals}$ = annual carbon loss due to wood removals, tonnes C yr-1

$L_{fuelwood}$ = annual biomass carbon loss due to fuelwood removals, tonnes C yr-1

$L_{disturbance}$ = annual biomass carbon losses due to disturbances, tonnes C yr-1

The disturbances can include wildfires, disease and pests, and natural events (wind damage). The IPCC also makes estimates for mortality separate from disturbances and suggests that in actively managed stands mortality may represent 30% to 50% of the lifetime productivity of the stand.

The IPCC reports that the average mortality rate ranges from 1.16% for evergreen and deciduous forests to 1.77% for tropical forests.

Information on disturbances is more difficult to accurately assemble but the FAO 2005 Global Forest Resource Assessment reported that the annual disturbance rates for all regions due to fire was 0.70%, due to insects was 0.93%, due to disease was 0.78% and due to other factors was 0.21%. The total annual forest disturbance rate was thus 2.6%. This would be in addition to the average mortality rate. The total annual disturbance rate could be as high as 4% to 4.5% per year. The report contains information on individual countries so an in-depth analysis for each country could be performed.

7.1.3 Amortization Period

The report uses a 20-year amortization period for the carbon losses. This is an arbitrary number. Both CARB and the EPA used a 30-year period, also arbitrary. While 20 years is used by the IPCC, that is for a GHG inventory calculation and not necessarily for life cycle analysis. One of the principles of life cycle analysis is that the determination is always done on a relative basis and consistent basis. Biofuels are being compared to fossil fuels. The carbon intensity of the direct emissions for fossil fuels and biofuels is being done using the 100 year GWP. The carbon intensity of fossil fuels when calculated using the 20 year GWPs is higher than the 100 year values because of the higher GWP of methane measured over the 20 year time frame compared to the 100 year period. Amortizing the carbon loss over the 20 year period and then adding it to the direct emissions determined over a 100 year period and comparing those to the fossil intensity over the 100 year period is problematic.

7.2 PEATLAND IMPACTS

One of the changes in the 2011 report is that the peat land emissions are changed. Two changes have been made. The first is that it is assumed that 30% of the palm expansion in South East Asia takes place on peat lands and the emission factor for peat land conversion is increased to 55 g CO_2eq/ha/year. It is believed that this is a typo and the actual measured emissions are 55 tonnes CO_2eq/ha/year. This has a large impact on the biodiesel feedstocks as shown in the following table. This is one of the main reasons why the palm and rapeseed biodiesel emissions increased.

Table 7-2 Peatland Impacts

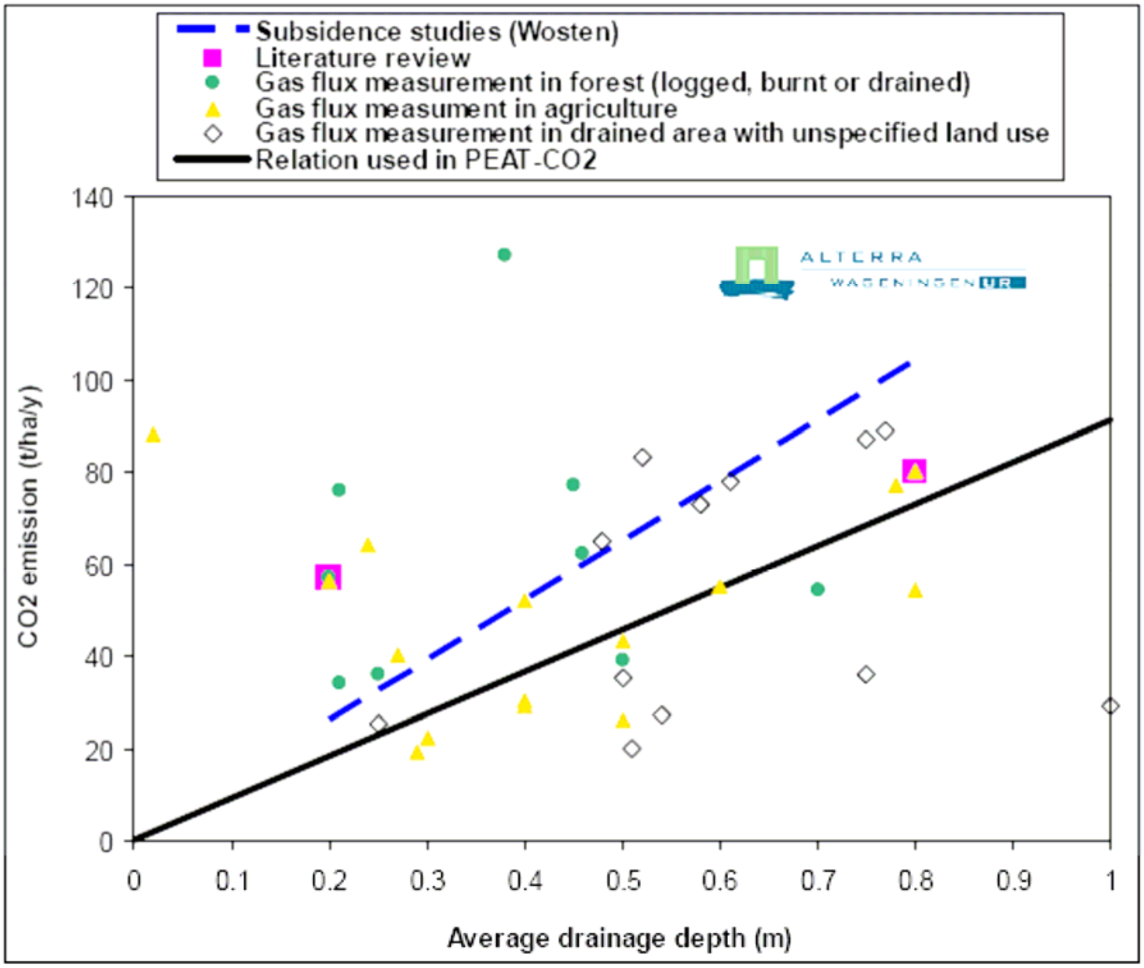
Feedstock	Total ILUC Factor	Peat Portion	% Peat Portion
	g CO_2eq/MJ		
Palm	54.3	33	60.1
Soybean	55.8	16	28.7
Sunflower	51.8	10	19.3
Rapeseed	53.8	15	27.9

The higher rate of peat land conversion and the higher emissions are a response to criticism of the first report by the JRC (Edwards et al, 2010). There are two aspects to these emissions, the emission rate per hectare from drained peatland and the area of drained peatland.

7.2.1 Peatland Emissions

There is no question that drained tropical peatlands emit CO_2 due to oxidation of the peat when it is exposed to the air. There is a question of what the rate of emission actually is. The following figure was published by Hooijer et al in 2006. In that work they adopted the relationship that the CO_2 emission rate=91*Depth (metres) t CO_2eq/ha/year. If depth of the water table was 0.6 m, then the emission rate would be 55 tonnes CO_2eq/ha/year. In a more recent paper, Hooijer et al (2010) admit to a large number of uncertainties in estimating the CO_2 emissions from drained peat soils, including the rate and the depth drained.

Figure 7-1 CO_2 Emissions from Drained Peatland



More recently, Agus et al (2011) have adjusted the equation to account for root related respiration and reduced the emission rate by 30%, thus confirming the uncertainty acknowledged by Hooijer.

A recent paper by Koh et al (2010) estimated the carbon losses from the conversion of forested peat lands to oil palm plantations at 5.2 +/- 1.1 tonnes of C/ha/yr (19.1 tonnes CO_2eq/ha/year).

7.2.2 Area Expansion on Peatland

Several facts are well established, oil palm area has been increasing in Indonesia and Malaysia over the past several decades; natural forest areas in those two countries have been decreasing; and there has been some draining of peat areas in the two countries. There is some information available on the fraction of existing oil palm plantations on peatland. Koh et al (2010) reported about 10% of the oil palm in Malaysia is on peatland but there was no estimate of how this has developed over time.

7.3 INDIVIDUAL FACTORS

The total ILUC emissions are calculated using the combined shock of increased demand from all biofuels. The individual ILUC factors are calculated from an incremental shock on a constrained model. The question is, are they consistent? It has been found in both the analysis of the EPA RFS2 work and in some GTAP modelling in California that the sum of the individual shocks is greater than the impact of the total shock.

That is the case in this work as well. In the following table the individual factors and their shares are summed and compared to the combined shock of 38.4 g CO_2eq/MJ.

Table 7-3 Individual Impacts

Fuel	ILUC Factor	Fraction of Total Shock (%)	Contribution to total
	g CO_2eq/MJ		g CO_2eq/MJ
Ethanol Sugar Beet	6.6	5	0.3
Ethanol Sugar Cane	13.4	13	1.7
Ethanol Maize	10.3	4	0.4
Ethanol Wheat	14.4	6	0.9
Palm Oil	54.3	17	9.2
Rapeseed Oil	53.8	41	22.1
Soybean Oil	55.8	11	6.1
Sunflower Oil	51.8	4	2.1
Total			42.8

The sum of the individual shocks is 11.5% higher than the combined shock. This is consistent with the results of other models and arises because a constrained model always delivers less than optimized results due to the constraint.

7.4 SUMMARY

The reported soil carbon losses appear to be high and could not be duplicated or reconciled with the information that is reported.

The above ground biomass loss makes no provision for natural mortality of the forests and thus overstates the above ground carbon losses.

The peatland impacts are new to the 2011 report and are a major reason why the biodiesel emissions are as high as they are. Depending on the feedstock, these emissions account for 20% to 60% of the total emissions. There is a great deal of uncertainty in these emissions both due to the emission rate and the area impacted. Several recent papers indicate that the emission rate used in the IFPRI report is overstated and could be reduced between 30% and 60%. Furthermore, the area of palm on peat is based on estimates for Indonesia and Malaysia but these two countries are only expected to contribute about half of the growth in palm area.

The 20 year amortization period chosen for the calculation of the emissions is arbitrary. A 30 year (also arbitrary) period has been used both by the US EPA and CARB. One problem with both the 20 and 30 year time periods is that all of the rest of the GHG emissions are calculated based on 100 year GWPs. If they were calculated using 20 or 30 year GWPs, the baseline emissions for petroleum fuels would all be higher.

Finally, the individual ILUC factors deliver results that are 11.5% higher than the result from the combined shock.

8. GHG EMISSIONS FROM CHANGES IN AGRICULTURE

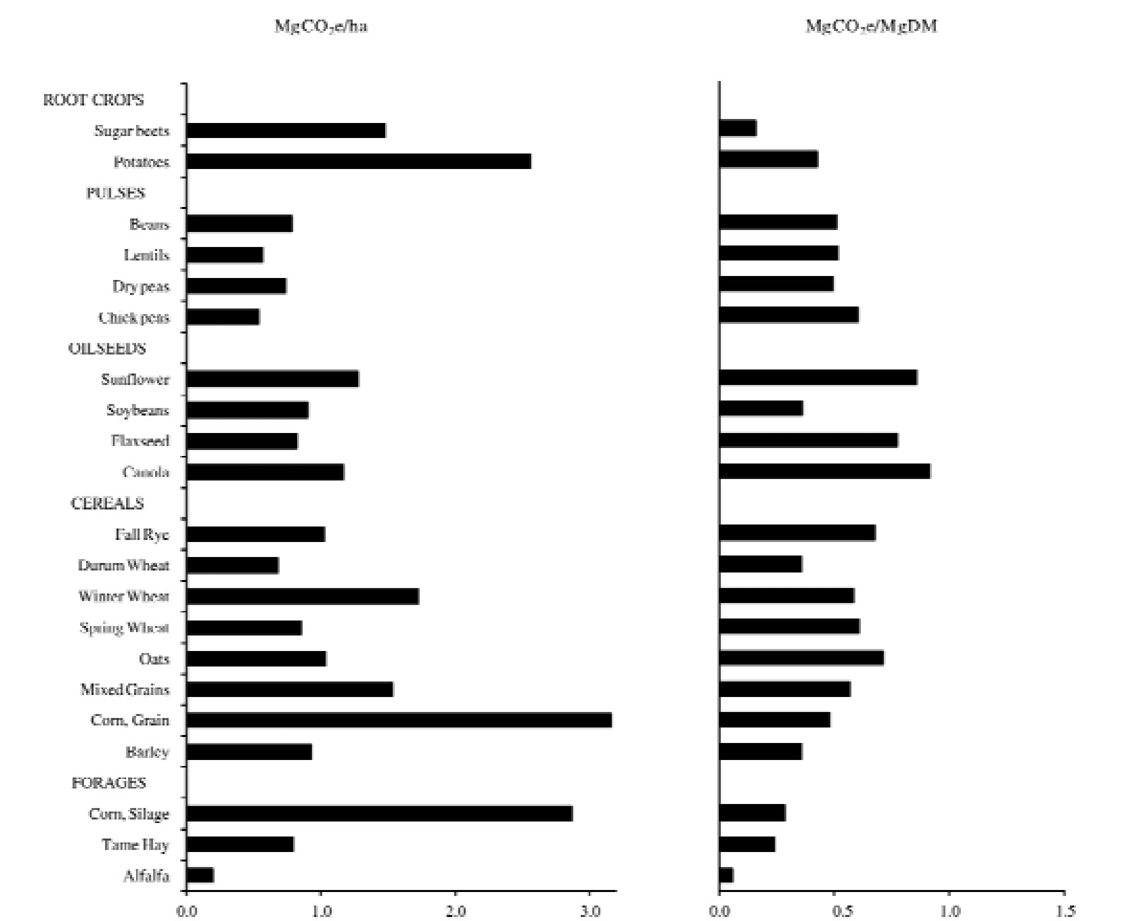
The modelling effort has focussed solely on the land use effects of an increased demand for biofuel feedstocks but there are other indirect impacts that can effect the GHG emissions from an increase in demand that are not considered. Some of these are discussed below.

8.1 CROPPING PATTERN CHANGES

The GHG emissions per tonne of biomass and per hectare of crop production varies between crops. Fertilizer requirements are different, energy used to plant and harvest a crop can change and, of coarse, the yield changes.

A recent paper (Dyer et al, 2010) examined this issue for Canada and the results are shown in the following figure. It is expected that similar results (at least directionally) would apply to other locations.

Figure 8-1 GHG Emission Variation Between Crops



GHG emission intensities per unit area and per unit of dry matter (DM) for the 21 most important field crops in Canada during 2006.

The total GHG emissions from cropland therefore depend on the crop mix and field management practices. The assumption that has effectively been made in the IFPRI reports, that there are no GHG impacts of cropland remaining cropland, is obviously not correct. The issue is that some of the crop shifting is driven by the availability of co-products, whereas other crop shifting is caused by demand changes resulting from changes in prices. In the direct GHG analysis, one generally already attempts to put a GHG values on those co-products, so there is some overlap between the GHG change from crop shifting and the GHG benefits from the direct analysis of co-products. In the EU case, where there is just an energy allocation for the co-products, this is not the case and all of the emissions resulting from changing crop patterns could be considered an indirect impact.

8.2 CHANGES IN LIVESTOCK

Agricultural emissions account for about 32% of total anthropogenic emissions. Livestock emissions account for about 42% of these emissions in two major categories:

- Enteric fermentation (~34% of total ag emissions)
- Manure (~8% of total ag emissions) and indirect emissions from manure management are highly variable and substantial.

Changes in livestock population will directly impact both of these livestock emission sources.

It would appear that the livestock population decreases with the increase in biofuel production. This would result in a reduction in livestock emissions, which are an indirect impact, the same way that new land requirements are an indirect impact.

8.3 CHANGES IN RICE PRODUCTION

Rice production also drops in the expanded biofuels scenario. Methane emissions from rice production account for 11% of agricultural emissions (US EPA, 2006). They amount to about 1.05 tonnes of CO_2 eq/tonne of rice. The model calculates a reduction in rice production of 102,000 tonnes of rice. This would be equivalent to a reduction in the ILUC factor of 0.1 g CO_2eq/MJ.

8.4 SUMMARY

None of these indirect effects are included in the IFPRI modelling effort. The only modelling effort that has included these effects is the FASOM modelling done for the United States as part of the EPA RFS2 work. There were livestock and rice benefits in that work and there appears to have been a crop shifting benefit as well, although it was included in the overall co-product credit and it is not possible to isolate the impact of the shifting crops. In that work the benefits for soybean biodiesel amounted to 13.5 g CO_2eq/MJ, not an insignificant amount. The reductions from the corm ethanol were lower.

9. CONCLUSIONS

The indirect land use modelling undertaken by IFPRI has a large number of problems and the result is that the ILUC emissions are greatly overestimated. While the MIRAGE modelling effort has a number of unique factors and could be considered an improvement over other similar models, such as GTAP, not all of these unique features are utilized in the work undertaken for the European Commission. In addition, the model has a significant number of shortcomings that seriously impact the reported results.

9.1 LAND INVENTORY

The land inventory database that has been added to the MIRAGE model is missing all of the cropland that is used to produce forages for livestock feed and all of the cropland that is temporarily idle. These two sub categories of cropland amount to about 400 to 500 million hectares. This land is available for increased crop production and some of it is currently creating GHG emissions without producing a crop. The land demand that is calculated by MIRAGE for the EU biofuel demand ranges from 1.74 to 1.87 million hectares, a small fraction (less than one half of one percent) of the land that is available.

Addressing the missing land issue is more than just adding new data to the model, as it needs to be added as a new land category with its own CET function. It is most likely that if this was done and the appropriate CET function used (in conjunction with fixing the other issues with the CET function), the ILUC emissions for the EU biofuels mandate would drop to very close to zero.

In addition, the land data that is in the model appears to significantly underestimate the land devoted to the major biofuels crops. This will underestimate the impact of intensification. Finally, the model currently has no way of modelling double cropping, an important management practice in many parts of the world. 150 million hectares of cropland are double cropped and there is evidence that this area is very responsive to price signals, at least in some parts of the world.

9.2 OILSEED CRUSHING SECTOR

There are important issues with the way that the model deals with the oilseed crushing sector and the livestock industry. It is not clear how the livestock sector can be modelled without including the production of forages in crops produced. Replacing forages with oilseed meals would be one possible response to an increase in meal availability. Secondly, the description of the crushing sector implies that it is considered as part of the biodiesel sector, yet it existed as a very large part of the ag value added sector long before biodiesel existed. The change in the price of oilseeds and the crush products, oil and meal, indicate that the profitability of this sector disappears as demand for the products increase. This scenario is not possible in the real world. It is believed that oilseed meals can't be traded on their own, just through the livestock sector and this is partially the reason for the incorrect results for the crushing industry. The net result of all of this is that the meals probably don't receive the proper credit in terms of displacing other agricultural crops and this leads to higher demands for additional land.

9.3 ELASTICITY VALUES

There are other issues with the model and the assumptions that have been made and these lead to either higher estimates of land converted to cropland or higher emissions from the converted land.

There are significant issues with the elasticity factors used in the MIRAGE model. The elasticity factors related to crop displacement and substitution should be the strongest of the elasticity factors used in the model, since they are at the core of how a CGE model has been traditionally used. While this is probably still the case for the response of consumers to different meat prices and vegetable oil prices, the appropriate response of the livestock sector to different feedstock availability and prices is not clear.

It appears that the livestock model is not modelled adequately. Forages, an important component in the diets, are not specifically included in the model or the land database created. Thus co-products can substitute for these feed components. The oilseed crushing industry does not appear to be modelled independently of the biodiesel producers as oilseed meals are identified as a co-product of the biodiesel sector. This creates major problems for the model and the sector response.

Being an econometric model, there is no way for the model to balance diets for protein and energy, it just balances for lowest cost based on the elasticity factors between different co-products that are chosen by the modellers.

Less than 1% of the new supply for biodiesel feedstock are produced through intensification efforts on existing land. A relatively low elasticity factor has been applied to these effects. Higher elasticity factors were recommended by the EWG in California.

The elasticity factor for the yield of crops on expanded land is an assumption chosen by the modellers. Based on the data that is available and the results of other more sophisticated models the values chosen are too low by 25% to 50%. This directly impacts the GHG emissions attributed to the biofuels, so this one assumption alone increase the ILUC factors by 25% to 50% over what they should be.

An even larger issue are the assumptions made with respect to the CET function values. The modellers have used the same value for pasture land and managed forests, whereas in reality the available data indicates that there should be a difference of 20 to 30 times between the values. This error increases the quantity of forest land converted by more than an order of magnitude and this increases the ILUC factor by 30% in the case of the scenarios modelled by IFPRI.

These errors are additive. The combined impact of just the improper elasticity with respect to land expansion and the CET function, is that the real values should be 35% to 50% of the values reported in the report. The improvement of the modelling of co-products would be expected to provide additional reductions in the reported values.

9.4 GHG EMISSIONS FROM CONVERTED LAND

The reported soil carbon losses appear to be high and could not be duplicated or reconciled with the information that is reported.

The above ground biomass loss makes no provision for natural mortality of the forests and thus overstates the above ground carbon losses.

The peatland impacts are new to the 2011 report and are a major reason why the biodiesel emissions are as high as they are. Depending on the feedstock, these emissions account for

20% to 60% of the total emissions. There is a great deal of uncertainty in these emissions, both due to the emission rate and the area impacted. Several recent papers indicate that the emission rate used in the IFPRI report is overstated and could be reduced between 30% and 60%.

The 20 year amortization period chosen for the calculation of the emissions is arbitrary. A 30 year (also arbitrary) period has been used both by the US EPA and CARB. One problem with both the 20 and 30 year time periods is that all of the rest of the GHG emissions are calculated based on 100 year GWPs. If they were calculated using 20 or 30 year GWPs the baseline emissions for petroleum fuels would all be higher.

9.5 INDIVIDUAL CROP RESULTS

The individual ILUC factors deliver results that are 11.5% higher than the results from the combined shock. This finding is consistent with the analysis of other work in this area undertaken by the US EPA and CARB. Artificially constraining the response to a single commodity limits the ability to choose the best options.

9.6 SUMMARY

The IFPRI modellers acknowledge the limitations of the MIRAGE model and state;

> *First, the model has tested the limits of the CES/CET framework. Both for co-products and for land use allocation, this conventional modeling approach leads to too many simplifications. For co-products, the two-level CES approach has helped to reinforce the substitution of the protein contents between meals and DDGS. Unfortunately, it has also forced simplify simplification of the representation of substitution between proteins and carbohydrates. Similarly for land use, even if our multi-nested CET has helped to capture substitution between crops, it is not flexible enough to provide the right full substitution matrix across crops and their yield consequences. More importantly from a long-term perspective, it is not designed to capture issues such as multi-cropping and crop rotation, both important issues for land use considerations in a dynamic approach.*

The challenges with the model go beyond just these limitations.

1. There appear to be errors in the fundamental assumptions about how much oil and meal is extracted from each feedstock.
2. There are concerns about how the oilseed crushing sector is modelled and the negative impact this has on co-product displacement for the oilseed meals.
3. The land database is missing idle land and the model has no way to directly access this land with the current structure.
4. A very low assumption has been made with respect to the intensification potential of existing land. An elasticity factor an order of magnitude lower than the CARB EWG recommended is used. The higher value would allow double cropping to be included in the modelled, which the modellers acknowledge should be included.
5. The assumptions regarding the CET values, which determines how much of which kind of new managed land is brought into production, and not aligned with the limit data that is available on this subject. The modellers use the same value for pasture and forest, whereas the data suggests that pasture is 20 to 30 times more likely to be converted than forest. This has a huge impact on the final calculations since forests are more carbon intense than pasture. If idle land were

included as a new land category, then the CET function should be very high compared to the values used for pasture and forests.

6. The reports have little transparency with respect to the carbon calculations but the soil carbon losses could be not reconciled.
7. There is a great deal of uncertainty with respect to emissions from peat soils and the growth of palm plantations onto peat lands. New findings in the past 12 months suggest that peat loss emissions used in the 2011 report may be overstated.
8. The choice of a 20 year amortization period is purely arbitrary and 30 years has been used by both the EPA and CARB in their work.
9. Finally, the individual ILUC factors are inconsistent with the result from the total shock and overstate ILUC emissions by 11.5%.

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11. APPENDIX A CET FUNCTION

There is very little real world evidence to indicate what the CET values should be. This issue was also one identified by the CARB EWG as one of the areas that needed improvement. A paper by Babcock and Carriquiry (2010) that looked at the GTAP modelling of biodiesel explains the issue in some detail. Portions of this paper are shown below.

> *The way that GTAP allocates land between crops, pasture, and forest is to use a function called the constant elasticity of transformation (CET) supply function. This is a function that allocates land based on a function that depends on the share of revenue from each type of land cover and the transformation elasticity σ. This function is used because of it parsimony and because it gives the necessary convexity so that a solution to the maximization problem can be obtained. However, the convenience of this function imposes some restrictions that are quite important in predicting how much pasture land relative to forest land is converted in response crop price increases related to biofuels expansion.*
>
> *Following the notation on page 4 of Ahmed, Hertel, and Lubowski, the cross price elasticity of the supply of forest land in response to a crop price increase equals* $\varepsilon_{forest,crop} = \theta_{crop}\sigma$ *where* θ_{crop} *is the share of revenue from crops. The cross price elasticity of pasture land in response to a crop price increase is* $\varepsilon_{pasture,crop} = \theta_{crop}\sigma = \varepsilon_{forest,crop}$. *This means that a 10% increase in crop prices will result in the same percent change in pasture and forest land.*[1] *Homogeneity of supply means that the own price elasticity equals (in absolute value) the sum of the cross price elasticities so that the own price elasticity of pasture, forest and crop in GTAP differ only by the share of revenue:*
>
> $$\varepsilon_{pasture,pasture} = -\sigma(1-\theta_{pasture})$$
>
> $$\varepsilon_{forest,forest} = -\sigma(1-\theta_{forest})$$
>
> $$\varepsilon_{crop,crop} = -\sigma(1-\theta_{crop}) .$$
>
> *The central value of σ in CARB's biodiesel analysis is -0.2, which is equal to the revenue-share-weighted average of the estimated individual land cover CET parameters (discussed below) after five years. Page 5 of Ahmed, Hertel, and Lubowski report revenue share values of 0.7489 for crops, 0.0975 for pasture, and 0.1023 for forest. This means that the GTAP own return elasticities of supply are 0.05, 0.18 and 0.18 for crops, pasture, and forest respectively.*
>
> *One cost of using the CET function to allocate land is that the own return elasticities for pasture and forest are significantly different than what Ahmed, Hertel, and Lubowski estimate them to be. Their estimates are derived from analysis of plot-level National Resources Inventory data from 1982 to 1996 conducted by Lubowski and Lubowski, Plantinga, and Stavins. Their own estimates of the own price elasticities at five years are approximately 0.045, 0.22, and 0.005 for crops, pasture, and forest*

[1] The equilibrium solution will not typically be exactly the same percent change because the own supply elasticities of forest and pasture may differ and the demand elasticities for forest products may differ from pasture products.

respectively[2]. Thus the GTAP own price elasticities for crops and pasture are roughly equal to the empirically based own price elasticities. ***But the forest elasticity in GTAP is 36 times higher than the estimated value.*** *This difference in forest is particularly important when considering the response of forest land to higher crop prices.*

As stated above, GTAP imposes the homogeneity condition that the own price elasticity equals the absolute value of the sum of the cross price elasticities. Because both cross price elasticities are negative (a higher price of crops leads to less forest land) we know that their value must be between zero and the value of the own price elasticity. Using a forest own price elasticity of 0.18 allows the cross price elasticities to be between 0 and -0.18. For example, if the cross price elasticity of forest with respect to pasture equals -0.08, then the cross price elasticity of forest with respect to crops equals -0.1.[3] If GTAP had instead used 0.005 as the own price elasticity of forests, then this implies that the cross price elasticity of forest land with respect to crop prices would be limited to between 0 and -0.005.

The most important factor affecting the magnitude of the change in greenhouse gas emissions from land use changes is the response of forest land to an increase in crop prices. Thus use of the GTAP own price elasticity of 0.18 instead of the empirically-estimated own price elasticity of forests of 0.005 results in dramatically higher greenhouse gas emissions. The GTAP cross price elasticity of forest with respect to crop price equals

$$\varepsilon_{forest,\, crop} = \theta_{crop}\sigma = -0.7489 * 0.2 = -0.15$$

This elasticity is 30 times higher than the maximum cross price elasticity that would be possible if the empirically-estimated forest own price elasticity was used in the analysis.

The GTAP cross price elasticity of crops with respect to crops is also equal to -0.15, which may be close to the value that is consistent with the empirical estimates. ***This suggests that a model that used empirically based own and cross price elasticities for forest, pasture, and crops would have pasture land being at least 30 times more responsive to crop prices than forest land in a five year horizon.***

[2] These estimates were obtained from Figure 2 of Ahmed, Hertel, and Lubowski. The approximation of the forest elasticity was difficult because the five year value was so close to zero.

[3] The share of revenue in Ahmed, Hertel, and Lubowski do not sum to one, which implies that "other" land use must be equal to one minus the sum of share to forest, crops, and pasture. The other land use is ignored in this explanation.