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Biofuels: Global Trade and Environmental Impact Study

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Executive summary

The key objectives of this report are to study the impacts of an EU biofuels mandate under several trade policy options. Included in these impacts are the global agricultural production effects; the global environmental impact; the likelihood and extent of substitution effects between different crops, and between different outputs (agricultural products for food, fuel and petrochemical products, and the effects on trade. Many of these impacts are interlinked. This report in particular seeks to address the key question of the impact of direct and indirect land use change effects induced by global (not only EU) demand for biofuels and their impact on the carbon emissions attributed to biofuels.

The study firstly considers the policy context. Initially biofuels were seen as a potentially important tool in the fight against global warming. In 2003 a first EU target of 5.75% of biofuel use in all transport by the end of 2010 was set and a Renewable Energy Roadmap adopted in 2006. However, the attitude to biofuels both amongst scientists and politicians has changed over time. In particular the environmental basis of favouring biofuels over other fuels has come to be increasingly questioned, while the impact of the policy on agricultural markets in general, and their potential role in the food crisis in 2007-08 in particular, raised significant questions about the unforeseen consequences of the push for biofuels. It is against this background that the report seeks to clarify the interactions between different policy scenarios and the potential impacts on markets and the environment.

In order to ensure that all key factors and interactions are taken into account, the report undertakes a review of the increasingly extensive literature on the impacts of biofuel support policies. It presents the main conclusions of numerous studies ranging from 'back of the envelope' calculations, to extensive modeling exercises. Many studies focus on the extent to which the increase in food prices can be attributed to the development of biofuels. Depending on methodology and data used the findings vary from very small impacts to rather large. Other studies use general equilibrium analysis to evaluate the broader impact of European and US mandates on agricultural markets. Finally the review of literature emphasizes three key aspects of biofuels production and interactions which contribute significantly to the results of the analysis: the land use effects of increased production of biofuels, the impact on crop yields and the use of biofuel by-products. Analysis has shown that the way in which these aspects are taken into account can make an important difference to the results and even modify the conclusions. With the exception of the latter factor, which unfortunately could not be incorporated for reasons of complexity, they are integrated as far as possible into this analysis.

A key objective of the study is to establish the global agricultural production effects of the EU objective to secure 10% of its transport energy needs from renewable resources – hereafter referred to for simplicity as 'the EU mandate'. To do this effectively requires a general equilibrium (CGE) approach and therefore the study relies on MIRAGE, a model of the global economy developed at CEPII. After presenting the main characteristics of this model, the study highlights the new methodological developments that are addressed to adapt the model to the biofuels sector. Firstly it extends databases on which multi-country multi-sector CGE models are grounded, by developing the new sectors of key importance for the study: ethanol, biodiesel, fossil fuel, maize, oilseeds for biodiesel and fertilizers. Secondly a new modeling of energy demand has been introduced into the MIRAGE model in which different degrees of substitutability between sources of energy and the extent to which investment in capital can reduce demand for energy have been introduced. Thirdly, it revisits the land use and land allocation issues by taking into account differences in land type and substitutability by introducing eighteen agro-ecological zones (AEZs) as well as different degrees of "land mobility": forest/ pasture/ crops. This change is vital to effectively assessing the direct and indirect land use impacts of biofuel support.

The overall objective of the analysis is to explore how EU agricultural trade policies (and the design of the sustainability criteria) could be adapted to maximize the environmental and economic benefits of biofuels policies. In order to do so the report evaluates the economic and environmental impact of two policy scenarios: firstly an interpretation of the mandate such that the share of biofuels in fuel consumption for transportation rises to 5% in 2010 and 10% in 2020; secondly, the removal of tariffs on European imports of biodiesel and ethanol.

The two scenarios are evaluated according to two key parameters of the model: the elasticity of land supply and the degree of substitutability between land and fertilizers. This sensitivity analysis looks high priority as economists do not have today precise information about these key parameters.

Then we study how marginal changes in the use of specific feedstocks needed to produce biofuels modify the economic and environmental impact of these policies. In particular it is important to test the potential presence of non-linearities.

In the central scenario, the model shows that:

i) The mandate should have a very substantial impact on production of ethanol and its feedstocks in the European Union. It is forecast to increase ethanol production by 690%, stimulating demand for wheat sugar beet and corn;

ii) European biodiesel production should also be stimulated by a mandate (+ 144% in 2020) but less so than ethanol as initial consumption of this biofuel is already high;

iii) In order to reach the consumption targets defined by the European Commission, the full removal of tariffs on European imports of ethanol and biodiesel would not be sufficient. It would have to be complemented by new domestic tax exemptions;

iv) While foreign production (in particular in Brazil) of oilseeds for biodiesel (rapeseeds, soya…) is significantly increased by all policy tools, only the trade liberalization scenario has a stimulating impact on the foreign production of sugar cane. Such a policy should increase Brazilian production of this crop by 9.7% in 2020 while the mandate and the trade liberalization scenarios both imply an increase by about 14% of oilseeds in the same country;

v) European support for biofuel production will in all cases imply a significant reallocation of land in favor of sugar cane/sugar beet and oilseeds for biodiesel sectors, in Europe and/or in South America. In the European Union, land allocated to the cultivation of sugar beet would be increased by 16% under an EU mandate in 2020, while in Brazil land for sugar cane would be increased by 4.2% under an EU trade liberalization scenario;

vi) European policies supporting biofuels have a positive and substantial positive impact on agricultural value-added, in particular in the European Union and in Brazil. While the impact on European agricultural value-added is stronger in case of a mandate (+7.1% in 2020), it is stronger in case of a trade liberalization on Brazilian agricultural activity (+5.75% in 2020);

vii) In terms of environmental impacts, the direct effects of biofuels policies in terms of CO2 emissions are usually positive while indirect effects are negative. The indirect land use effects of these various policies are usually greater than the direct emissions reduction effects.

viii) If the direct and indirect CO2 emissions changes are combined, the mandate is forecast to result in an overall increase in CO2 emissions of 14.5 million tons of CO2eq in 2015 and 10.6 million in 2020 while globally the trade liberalization scenario is forecast to increase the emission of CO2 by 12.0 million tons in 2015 and 5.4 million in 2020. The trade liberalization scenario is more efficient in terms of the impact on direct emission reduction as it stimulates more ethanol production from more efficient sources, especially sugar cane.

ix) Sensitivity analysis using alternative assumptions on the elasticity of land supply and the substitution between land and fertilizers indicate that the magnitude of changes, but not their direction, are impacted by our assumptions. The elasticity of land supply in developing countries on which we do not have today consensual information is critical as far as the assessment of environmental impacts of biofuel policies are concerned. This means that the results of this study have to be considered with the highest prudence.

1. Introduction and objectives of the study

This study has been commissioned by DG Trade of the European Commission in order to contribute to the debate on the increased use of biofuels for transport in the EU. The key research questions of the study have been identified in the terms of reference as:

- What are the global agricultural production effects of an EU biofuels mandate?
- What is the global environmental impact? A distinction is made between direct (in the production process) and indirect (due to land use changes) greenhouse gas emission effects.
- What is the likelihood and extent of substitution effects between different crops, and between different outputs (agricultural products for food, fuel and petrochemical products) as a result of the biofuels mandate?
- What are the effects on trade?
- What are the impacts of a variety of policy scenarios in terms of environmental impacts and socio-economic effects?
- Finally, and perhaps most importantly, the study will address one of the key issues identified in the recent debates on biofuels, both in Council/Parliament and in wider public opinion and research reports (especially Searchinger, 2008), namely the impact of direct and indirect land use change effects induced by global (not only EU) demand for biofuels and their impact on the carbon emissions attributed to biofuels.

The study is being conducted at a time when biofuels production has become increasingly controversial. Recent food price increases in particular have led to concerns that the production of biofuels may be threatening food security (Sheeran, 2008). However there are also several researchers who question the fundamental tenet of their use – the concept that biofuels are intrinsically less damaging to the environment than fossil fuels.

Concerns about the potential for biofuels to contribute to carbon savings have been raised for some time. The EEA pointed out in 2004 that there was a danger that encroaching onto long term fallow land to grow biofuels could result in the emission of CO2 at a rate which would take many years of biofuel use to negate (EEA, 2004). Fargione et al (2008) highlighted the importance of the source of raw materials for biofuels and the major differences in the efficiency of different sources depending on the 'carbon debt' from land use. The Joint Research Centre undertook a series of studies on the issue which culminated in a report in early 2008 which cast serious doubt on whether the large scale use of biofuels would contribute to reducing GHG emissions (De Santi, 2008).

Several key points have been made in more recent studies which need to be addressed if a comprehensive analysis of biofuel impacts is to be made. These are:

- Indirect land use effects – taking land that had been in use for food out of the market to produce biofuels almost inevitably results in new land being converted elsewhere to feed the population. This indirect effect has to be factored into the impact assessment.
- Yield effects – in general an increase in prices would encourage an increase in productivity, lowering the potential increased demand for land.
- By-products – several assessments of the impacts of biofuels neglected to take account of the role of by-products. Farrell et al (2006) concluded that the failure to include by-products was the key reason for discrepancies in assessments of biofuel energy balance, but they are equally important to questions of land use. The fact that the by-products of both ethanol and biodiesel can be used as animal feed means that less land will be required to grow animal feed directly. This key aspect is not included in this analysis, which means that the findings are likely to be biased upwards, in that

incorporation of by-products in the model would result in substantially lower demand for land for animal feed, reducing overall pressure on land.

2. The context

2.1. What are biofuels?

Biofuels are fuels produced from biomass. For the purposes of this work the two key types of biofuel of importance are ethanol and biodiesel. Ethanol is produced from the fermentation of sugars. Virtually any source of carbohydrates can be used, but most fuel ethanol is produced from corn, sugar cane, sugar beet or wheat. In the EU the latter two crops are the main source. In the US fuel ethanol comes overwhelmingly from corn, while in Brazil it is produced from sugar cane. Ethanol can also be produced from cellulose, which first needs to be broken down. This makes it expensive and energy intensive using present technologies. The so called 'second generation' biofuels which emerge from this process would be able to use a wider range of raw materials with lower impacts on agricultural food markets, but at present they are still in the development stages (Edwards et al, 2007).

Cars can run on a blend of up to 10% ethanol with conventional petrol without any special adaptation (OECD, 2006, De Santi et al, 2008). This is the level of blending that has historically been allowed in the EU Fuel Quality Directive. Higher levels of blending require engine modifications. In countries where high ethanol blends are the norm, fuel flex vehicles (FFVs) which can run on any blend of petrol and ethanol have a high market penetration. This is true for Brazil, where 80% of new cars are FFVs. It is much less the case in the EU.

Biodiesel is produced from oilcrops by reacting vegetable oils with an alcohol, usually methanol, in a process known as esterification. The resulting diesel can be blended with conventional diesel at levels of up to 5% without any engine modifications. The main source in the EU is rapeseed in the north and sunflower seed, to a lesser extent, in the south (Edwards et al, 2007).

In the EU the majority of biofuel production is made up of biodiesel – over 6.1 bn litres in 2007 with 2.25 bn litres of ethanol (FO Licht data quoted in OECD (2008)). This is certainly related to the fact that the relatively high penetration of diesel vehicles in the EU means that it is increasingly short of diesel and it is expensive for refineries to increase its relative production from conventional sources (De Santi, 2008). Biodiesel thus provides a welcome alternative.

2.2. The policy context

The EU has long been a major driver of action on climate change and an innovator on concrete action to address environmental issues. The adoption of firm targets on the use of biofuels in transport was a key part of the EU's response to achieving its Kyoto targets of GHG reductions. The initial target of 5.75% of biofuels in all transport by the end of 2010 was set in 2003 (CEC, 2003). Progress has been slower than expected and the level now forecast for 2010 is 4.2% (CEC, 2008). The proposal to adopt a 10% target for biofuels in transport by 2020 was made in the Renewable Energy Roadmap (CEC, 2006) as part of the other binding target for renewable sources to represent 20% of the EU energy mix by the same date.

The European Parliament as a whole was initially supportive of the proposal, even indicating that a 12.5% target would be 'realistic and desirable' in their resolution on the proposal (EP, 2007). However concerns about the sustainability of biofuels were already clear in its early resolution. It called on the Commission to introduce a certification scheme to ensure the sustainability of EU and imported biofuels. The following month the European Council endorsed the 10% target as part of the Energy Policy for Europe (EPE) Action Plan, with the proviso '*The binding character of this target is appropriate subject to production being* *sustainable, second-generation biofuels becoming commercially available and the Fuel Quality Directive being amended accordingly to allow for adequate levels of blending.*' (European Council, 2007).

The feasibility of both of the first two conditions was soon questioned, in particular the condition on sustainable production. The Commission adopted a proposal for a Renewable Energy Directive in January 2008, which included the 10% target, but proposed 'sustainability criteria' to ensure that biofuel in the EU respected key criteria including securing at least a 35% level of GHG emissions savings and not being produced on land with high biodiversity value or high carbon stock (CEC, 2008). Although an analysis for the Commission indicated that the development and implementation of sustainability criteria was feasible (BTG, 2008), in the responses to the public consultation on Biofuels which preceded the proposal, several NGOs expressed serious doubts that the 10% target could be achieved sustainably (Friends of the Earth, 2007, Greenpeace, 2008). In addition, the UN called for caution in implementing such a binding target because of the potential negative direct and indirect effects (UN, 2007).

The significant food price increases experienced in 2008 further fueled concern on biofuels. The potential for biofuel production to contribute to social upheaval and increase food insecurity was highlighted by a number of NGOs (e.g. Oxfam, 2007). In their testimony to the European Parliament in March 2008, the World Food Programme highlighted biofuels as one of four drivers of the higher food prices which were threatening food security around the world (Sheeran, 2008). Although clearly not the only, or even the most important, factor, biofuels were the only one of the four which could potentially be significantly impacted by policy (the others were increased growth in China and India, climatic shocks and high oil prices). There was not universal agreement that biofuels contributed to food price increases. For example, a Brazilian report found that the main driving factor was speculation on commodities markets (Fundacao Getulio Vargas, 2008), however in the light of increasing concerns about possible unintended and unwelcome side effects, calls increased to reassess the EU's mandate. The UN's rapporteur on food security was so concerned about the potential impacts on food prices that he called for a five year moratorium on the conversion of arable land to biofuel production (UNPDI, 2007).

Increasing criticism of the EU biofuels mandate has also come from within the EU institutions themselves. The Joint Research Centre (JRC) published a report early in 2008 which brought together several research strands on the issue and reached what can only be considered to be fairly damning conclusions. They undertook a cost-benefit analysis of biofuels including the benefits in terms of GHG savings, security of supply and employment and concluded that '*It is obvious that the cost disadvantage of biofuels is so great with respect to conventional fuels … that even in the best of cases, they exceed the value of the external benefits that can be achieved*.' De Santi (2008, p.20). The key point of the report was that the underlying objectives of the biofuels mandate, in terms the above supposed benefits, could be better achieved by other means. In particular they consider that using biomass for transport use is not the best way to use this resource to reduce GHG emissions.

In April 2008, the European Environment Agency's (EEA) scientific advisory body issued an opinion on the environmental impact of biofuels in Europe which recommended the suspension of the 10% target pending a comprehensive scientific study. Their key points echoed the JRC study – biofuels are not the best use of biomass, the land requirements for the 10% target exceed the available EU land and imports to reach the target cannot be guaranteed to be sustainable (EEA, 2008). Refuel, an EU sponsored EU-wide project to encourage greater market penetration for biofuels issued a report which concluded that reaching the 2020 target with a primarily 1st generation mix of biofuels '*leads to only modest reductions of greenhouse gases, creates minor opportunities for innovation and a competitive industry, and is not very efficient in terms of land use.* (Refuel, 2008). They called for a more consistent policy effort to stimulate 2nd generation biofuels.

Finally the Economic and Social Committee's opinion on the Commission proposal was very critical of support for biofuels: '*The strategic requirement for the substitution of diesel or petrol by agrofuels is one of the least effective and most expensive climate protection measures, and it represents an extreme misallocation of financial resources*' (EESC, 2008). They called instead for more support for electric traction fueled by renewable energy. This conclusion mirrors to some extent that of the International Energy Agency which, in their work on the potential to achieve significant CO2 savings in the transport sector concluded that electric batteries and hydrogen cells were the most promising alternatives for cars. Biofuels were however seen to have a key role in aircraft, trucks and shipping (IEA, 2008).

Member state institutions also began to voice concern at the EU mandate. In a November 2007 recommendation on the use of biomass for energy production, the scientific advisory council of the German Federal Agriculture Ministry indicated that, in the long term, solar and wind energy have considerably higher potential than biomass. The key reasons given were the higher energy yields, the shortage of arable land and resulting impacts of biofuels production on agricultural prices and the potential GHG emissions from use of previously fallow or forested land (quoted in EESC, 2008). The Dutch Environmental Assessment Agency reviewed the potential impact and feasibility of the EU mandate and called for the obligatory target to be reconsidered because 'The presently proposed target and the sustainability criteria cannot prevent important negative impacts on greenhouse gas emissions and global biodiversity' (Eickhout et al, 2008).

A comprehensive review of the indirect effects of biofuel production was commissioned by the UK's Department of transport and reported in July 2008. The 'Gallagher Review', as it was known, reviewed the evidence and concluded that, although a sustainable biofuels industry is possible, more caution and discrimination in policy making is needed (RFA, 2008). The Royal Society, a British scientific institution, issued a report from leading experts that concluded that, although biofuels did have important potential for positive environmental and social impacts, current policies risked missing out on these opportunities (Royal Society, 2008). Several other reports raised concerns. The OECD's analysis indicated that biofuels support policies were having impacts on global food prices, although in the case of sugar and oilseed meals the effect was to reduce prices. The report also raised concerns about the extent of real GHG savings and land use effects as a result of support for biofuels (OECD, 2008).

The increasing evidence that the target could have undesirable direct and indirect consequences and may even ultimately have negative impacts on sustainable development clearly influenced the political debate in the Parliament. In May 2008, Turmes, the rapporteur on the Directive from the European Parliament's Committee on Research Industry and Energy issued a draft report which called for the 10% target to be dropped. The justification given was that '*The latest scientific and political evidence have shown that imposing a binding target on fuels for the transport sector coming from biomass of 10% cannot be achieved in a sustainable way*' (EP, 2008a). The Environment Committee's draft report called for a reduction of the target to 8%, while the final opinion called for a 4% target by 2015 and a review of the 2020 target at that stage (EP, 2008b). EU Environment and Energy ministers meeting in informal session in Paris in July underlined that the 10% objective was for 'renewable energy sources' not just biofuels.[1] This echoed the position of the Commission. Finally, at the end of 2008, both the Council and Parliament agreed to the 10% target for renewable energy sources in transport[2], however the debate had raised many questions about how best to achieve this goal, and particularly on the role of biofuels.

In this context, the current report seeks to elucidate some of the key questions surrounding the EU's policy to promote biofuels in terms of both the potential positive environmental impacts of the biofuels mandate and the potential negative impacts of this mandate on non-energy markets, particularly for food.

2.3. Implications of the EU mandate on the market

In order to achieve the objective of increased use of biofuels the Community has utilized a series of different, but complementary, measures. Farmers are encouraged to produce energy crops by the Energy Crop Aid (ECA) subsidy which provides an incentive of €45 per hectare to produce crops for non-food or industrial use. In addition, farmers can use set-aside land, which would otherwise be left idle, for energy

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[1] See: http://www.ue2008.fr/PFUE/lang/en/accueil/PFUE-07_2008/PFUE-05.07.2008/pid/3487

[2] http://ec.europa.eu/energy/strategies/2008/2008_01_climate_change_en.htm

crops. This second measure has particular implications for the question of land use effects of biofuels, as we shall see below.

Several member states have mandatory targets supported by legislative measures. For example in the UK, the Renewable Fuels Transport Obligation (RFTO) requires 2.5% of transport fuels to be delivered from renewable sources by 2008/9 rising to 5% by 2010/11. Fuel suppliers who fail to reach this target must pay a penalty (RFA, 2008).

Another key tool is the reduction in the price of biofuels through excise tax exemptions or reductions. Although these vary by Member State the OECD estimates that taxes in the EU on biofuels are on average 50% lower than on fossil fuels (OECD, 2008). Finally, the EU protects its domestic industry through import tariffs on ethanol. There is no tariff code for ethanol for use as fuel, so tariff rates are the same as for generic ethanol. The fixed duties on denaturated and undenaturated ethanol imports are respectively €10.20/hl and €19.20/hl, which the OECD has estimated to represent 33.2% and 62.4% in ad valorem terms at 2007 prices. Imports of biodiesel are taxed at 6.5%.

2.4. Biofuels support in other countries

The EU is by no means the only region to support the development and use of biofuels. Historically, the most successful supporter of biofuel use has been Brazil, where a combination of low production costs and government support has resulted in a market share in transport of over 20%. Other countries are well below this level, but the production and use of biofuels has nevertheless expanded significantly. The US, like the EU, has a variety of support measures, but probably the most significant is the excise tax credit provided to biofuel blenders. This is $0.51 per gallon ($0.135 per litre) for ethanol blended into fossil gasoline, and $1 per gallon ($0.264 per litre) for biodiesel blended into fossil diesel (OECD, 2008). Although support for biofuels in the US dates from the 1970s it is only in recent years that the increasing price of fossil fuels has made its production competitive. The recent surge in petrol prices has increased US production from 3.4 billion gallons in 2004 to an estimated 13 billion gallons in 2008, overtaking Brazil as the world's primary biofuel producer (Hertel et al, 2008).

Support also comes in the form of a government mandate to secure a certain level of consumption – in gallon terms rather than in percentage terms as in the EU. Most recently, the Energy Independence and Security Act of 2007 established a 36 billion gallon (136 billion litres) Renewable Fuel Standard (RFS) by 2022. The US currently mainly uses corn-based ethanol. Although, the Act stipulates an increase in the latter's production to 15 billion gallons by 2015, other biofuels are explicitly mentioned and the mandate addresses consumption – not production. Thus imported biofuels could supply part or even all of this consumption (OECD, 2008).

For the moment, however, imports supply only a small percentage of the US's biofuel needs, mainly due to relatively high trade barriers. Ethanol imports from outside NAFTA face a tariff of 1.9-2.5% as well as the far more significant 'secondary ethanol tariff', of $14.27 per hl. The OECD estimates that this represented an ad valorem tariff of between 34.6% and 36.4% for Brazilian ethanol in 2007. As in the EU the 4.6%.tariff applied for biodiesel is substantially lower than that for ethanol.

Other countries, including Canada, Japan and China support the production and use of biofuels however they are currently marginal in global terms. Over three quarters of global production of biofuels was concentrated in the US and Brazil in 2007. The percentage rises to 90% if the EU is included (OECD, 2008).

2.5. Biofuels and trade

The exact level of trade in ethanol for fuel is difficult to establish as there is no specific customs code to differentiate it from ethanol for other uses, however it is estimated that global trade in ethanol for fuel was 3 billion litres per year in 2006-7, up from 1 billion in 2000. Brazil is by far the biggest exporter of ethanol representing 70% of world exports, while trade represents 9% of world production. In the case of biodiesel the main exporting countries to the global market are the United States, Malaysia and Indonesia, while the EU is the main importing region. About 12% of global production is traded (OECD, 2008).

The level of trade is certainly impacted by the tariffs applied to biofuels on many key markets. These tariffs have come in for increasing criticism in the context of the broader debate on the sustainability of biofuels production. In particular the fact that Brazilian ethanol is much more efficient than either US or EU production in terms of the balance of greenhouse gas emissions, makes it a more logical source of biofuels if a key objective is the reduction of such emissions. Recent analysis by the OECD which looked at the implications of tariff elimination on GHG emissions suggested significant potential savings from the restructuring of global production which would result from a free trading environment (OECD, 2008).

3. Literature review

Several researchers have sought to explore the impact of policies to promote biofuels on agriculture and other sectors of the economy. Although it is a relatively new area of study, research has been particularly intense in recent years, as the political debate has increased. The key studies will be considered in this section looking firstly at the outcomes of these studies in relation to the key questions of commodity prices, trade and outputs. The specific issue of land use and the key factors which affect it will then be considered in more depth as well as the key issue at the heart of the environmental debate – the actual impact of biofuels on greenhouse gas emissions.

3.1. Impacts on prices, trade and output

The impact of biofuels on food prices has become a hotly debated issue as the latter have increased rapidly in recent years and in particular in 2008. As indicated above, there is broad agreement that these increases are due to several factors including, but by no means restricted to biofuels (Sheeran, 2008, Von Braun, 2008). Several researchers have sought to quantify the impacts of past and, in particular, future policies on prices. Results are varied, but in general there is agreement that the impacts are likely to be significant, although they vary by sector, may be negative (in the case of sugar) and are highest in maize and vegetable oils.

Studies range from 'back of the envelope' calculations, such as those from the JRC (de Santi, 2008) and the World Bank (Mitchell, 2008) to extensive modeling exercises. The key difference between most of the studies is whether they were based on partial or general equilibrium models. As the Gallagher review points out, although the latter provides a better global assessment, taking interlinkages in the economy into account, the outcomes predicted are more representative of medium and long term impacts (where markets work efficiently), while partial equilibrium (PE) models may give better indications of short term reactions to shocks, in the absence of rapid adjustment (RTA ,2008).

The JRC sought to give some ballpark figures of the potential impact of the EU biofuel mandate on prices by simply looking at the percentage of production of key crops which will be used for biofuels in 2020 and combining these with the elasticity of supply figures. They predicted price changes of 4% in cereals and 24% in vegetable oils (de Santi, 2008). There is broad agreement in the more sophisticated studies cited below that the lion's share of the impact will indeed be on oilseed prices.

The World Bank recently sought to assess the relative importance of different factors contributing to the increase in fuel prices in an ad-hoc manner on the basis of figures on exchange rates, energy costs, and production, trade and consumption figures on grains. The report concluded that higher energy costs and exchange rate changes contributed between 25-30% of the rise in food prices, while the other 70-75% was due to biofuels *'and the related consequences of low grain stocks, large land use shifts, speculative activity and export bans'* (Mitchell, 2008, p. 17).

The Fondacao Getulio Vargas in Brazil analysed the relationship between prices and biofuel production, market speculation, demand and stocks using dynamic linear regression models. They concluded that biofuel production was not a key factor in the price rises, which were mainly correlated with speculation, demand and low stocks (FGV, 2008).

Schmidhuber (2006) sought to explore the link between food prices and biofuels in a largely theoretical paper, where he argues that, although the use of crops for biofuel undoubtedly had an impact on prices, this impact was naturally 'capped' by the fact that, in order to remain competitive in energy markets, agricultural feedstock prices cannot rise faster than energy prices. Thus increases will be limited by the market.

Rosegrant (2008) used IFPRI's PE 'IMPACT' model to address the question of the extent to which biofuel production has contributed to current high food prices. He simulated market developments between 2000-2007 without the sudden increase in biofuel production which was witnessed and compared them to actual evolutions. He estimated on this basis that biofuel growth accounted for 30% of the food price increases seen in the period. The level varied from 39% for maize to 21% for rice (Rosegrant, 2008). In this work he also simulated the future impact of freezing biofuel production at 2007 levels. This is projected to reduce maize prices by 6% in 2020 and 14% in 2015.

One of the earlier in depth PE studies on the future impacts of increased production of biofuels was undertaken by the OECD (2006). In this study, which was based on the AgLink partial equilibrium model, the authors explored three scenarios – a 'status quo' scenario, where biofuel production remained constant, a 'policy-target' scenario where all stated policy targets for biofuel use are met and a high oil price scenario – where an oil price of $60 per barrel was fixed.[3]

The policy target scenario indicated that if the EU met its targets wheat and coarse grain use for ethanol would reach 9% of projected grain use over the period to 2014, with sugar beet for ethanol reaching 17% of projected EU production. Most striking was the projection that 49% of expected consumption of vegetable oils in the EU would be for Biodiesel. Thus, increased demand in the EU for vegetable oils was projected to increase world prices by 15%, while increased demand for sugar was projected to increase prices by 60%. The impact on wheat prices is projected to be lower – 4%. Meat and dairy markets are impacted only marginally, except butter with a projected price increase of 3%.

The 'high-oil price' scenario resulted in higher production of biofuels with an 8% increase in ethanol production by 2014 and a 16% increase in bio-diesel. The impacts on prices are most significant in sugar and vegetable oils which see increases of just over 4% compared to the standard scenario. The paper points out that these projections indicate that biofuel mandates have the potential to boost vegetable oil prices in particular to levels not seen in the past two decades. Although the impact on sugar prices may seem more significant, they need to be seen in the light of a general downward trend in sugar prices which is projected to continue in the absence of the biofuel mandates.

More recent work, based on the same AgLink model, looked at the impact of maintaining biofuel production at 2007 levels, rather than the doubling of production implied by the mandates, used as the baseline scenario. The impact on prices was a fall of 12% compared to the projected prices for coarse grain and 15% for the projected prices for vegetable oil (OECD/FAO, 2008). Other recent work looking at the impact of the abolition of biofuel support policies showed similar price changes for vegetable oils – 16%, but lower impacts for coarse grains (7%) and wheat (5%) (OECD, 2008). The difference in the latter figures compared to the scenario of maintaining 2007 production is due to the fact that ethanol production would continue to rise even without public support. This is because of its more competitive production costs compared to biodiesel, which, on the contrary, would be substantially effected by the removal of support. The study indicated that without support policies global production of ethanol and biodiesel would reduce by 14% and 60% respectively on average over the period 2013-17. DEFRA in the UK found similar price impacts in their work

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[3] Relative to prices of $120-40 barrel prevalent during much of mid 2008, this 'high price' scenario seems rather conservative.

using the same model (Pfunderer and del Castillo, 2008). Their work included an exhaustive literature review which identified several other key factors contributing to higher prices including weather, speculation, trade policies, oil prices and emerging market demand.

The European Commission's own impact assessment of the long term (2020) impact of the biofuels 10% target was carried out by DG Agriculture based on the ESIM PE model. It predicts fairly minor impacts from ethanol production of 3-6% on cereals prices, but higher impacts from biodiesel on oilseeds prices. These are highest on sunflower seeds (15%) due to its limited global production potential. Lower, but still significant, impacts are predicted in rapeseed (8-10%) as there is significant potential to increase production, in Russia and the Ukraine.

Several recent studies have used general equilibrium (CGE) models to analyse the impact of biofuels production more broadly. A study by the Overseas Development Institute (ODI), undertaken as part of the Gallagher review, looked at the potential impact on world prices assuming that the EU and NAFTA replace 10% of their vehicle fuels with biofuel (ODI, 2008). They found significant price increases, especially in the 'grains' sector (mainly related to maize) where export price increases were between 4-21% and in oilseeds where they were 24-72%. The higher percentages are for the EU/NAFTA markets which are clearly the most affected, but all regions experience price rises, because of the increased demand in both the EU and NAFTA. Trade is also significantly impacted - the EU is projected to increase imports of grains and oil seeds by 11% and 16% respectively and NAFTA by 11% and 93% respectively.

Banse et al (2008) used a model based on GTAP-E to look at the impact of the EU's mandate compared to a baseline scenario with no mandate on the one hand and global mandates (where the US, Japan, Brazil also adopt targets for biofuel consumption) on the other. They find significant impacts from a 'global' scenario, less so for an 'EU only' scenario. The latter projects reductions by 2020 in world cereal prices of 7% compared to increases of over 5% in a global biofuel scenario and only small positive impacts on oilseed prices. Overall the difference between the baseline scenario (where food prices fall) and the global biofuel scenario is significant – 18% in cereals and 26% in oilseeds. As for cereals, most of this increase is related to the global scenario rather than EU only. Their model predicts large increases in the agricultural trade deficit of the EU, up to almost $40 billion by 2020 under an EU only scenario, as the required levels of biofuels cannot be met without substantial imports. Other high income countries increase their trade surplus, except under a global biofuels scenario where they would have a substantial deficit of about $14bn.

Hertel et al (2008) use the GTAP-E model as a base for an analysis of the impact of the EU and US biofuels mandates. In their model they incorporate the growing recognition that the EU's 10% objective for 2020 is unlikely to be reached and model instead a 6.25% level for 2015. They do not report price impacts but concentrate on impacts on output and land use (see next section). They find increases of 16% in coarse grain outputs in the US and 50% increases in oilseeds output in the EU. Most impacts in both regions are due to their domestic policies. The exception is a projected increase of 7% in US oilseeds production with EU policies compared to a 6% fall without.

Impacts on trade are substantial. US exports of coarse grain reduce by $1bn at constant prices, while the EU sharply reduces its exports of coarse grains, oilseeds and other food products. Substantial increases in exports of oilseeds to the EU are projected, from Brazil, the US and most other regions.

Boeters et al (2008) assessed the impacts of the 10% target (fully exempted from fuel taxes) compared to a baseline freezing biofuels shares at 2004 levels using the WorldScan CGE model. They found negligible impacts on aggregate food prices (0.1% in most countries). Meeting the target would involve an increase in current global arable acreage from 1% to 3.5%. The projected land price increases due to heightened demand for land vary. The average in the EU was 2.2%, with the highest impacts (6.1%) in the UK. The same study looked at the impact of eliminating tariffs on ethanol. They found that the share of domestic production in EU consumption would fall from almost 100% to about 50% in the absence of tariffs. In biodiesel, tariffs are lower and imports already account for 68% of consumption. This figure increases marginally to 75% under a trade liberalization scenario.

A key issue related to the impact of liberalising trade in biofuels is the wider issue of the very varied level of greenhouse gas emissions from different raw materials used as sources of biofuels. Depending on the type of crop, cultivation techniques, previous land use and a host of other factors the GHG balance can be very different. Given that most studies indicate that the most efficient source of biofuel in GHG terms seems to be Brazilian ethanol and EU and US production from wheat and corn tends towards significantly lower levels of savings (OECD, 2008), trade barriers can be seen as resulting in lower reductions in GHGs because of the failure to maximize the GHG reducing capacity of biofuels by concentrating production in the 'best' areas and crops.

Work in the OECD has suggested that eliminating tariffs on biofuel trade could have significant effects on the amount of GHG avoided via biofuels. Such liberalisation, which would mainly impact on ethanol trade, would result in the substitution of more efficient sugar cane based ethanol for other sources, with the result that total GHG avoidance would increase by between 3.5 and 6 Mt of CO2-equivalent (CO2eq) per year. This represents about 20% of the whole GHG savings expected to result from existing support policies. Crucially these figures do not take into account land use change, which has the potential to change the calculation significantly, as the following section explores.

3.2. Land use issues

It is clear that increased demand for biofuels will have impacts on the demand for land and will result in land use changes which could be significant. The increased demand for land for biofuels is estimated to be lower than the increased demand for land for food, however estimates vary. Kampman et al (2008) have reviewed the literature and estimate that land for food and feed will expand between 200-500 Mha by 2020, whereas increased demand for biofuels could result in total demand of between 73-276 Mha (up from 13.8 Mha today). Eickhout et al (2008) estimated the land requirements of the EU's mandate alone as being between 20-30 Mha. There are high levels of uncertainty in these estimates as much depends on development of demand, but also on the extent to which high yield crops (such as sugar cane) are used, the share of second generation biofuels (land demand is 30-40% less in scenarios with 2G biofuels) and the yield of the crops. The FAO reported estimates of the difference between the land required for different sources of first generation biofuels if they were to replace 25% of global transport needs. This varies from 17% of available land (estimated at 2.5 bn ha) if the source were sugar cane to 200% for soybean (FAO, 2008a). Clearly the choice of crop makes a major difference to the land use impacts of biofuels.

Several researchers have attempted to quantify the expected impacts on land use of the biofuels mandates through modeling exercises. In the early work by OECD it was estimated that the EU biofuels mandate would require two-thirds of the land area currently harvested for oilseeds, cereals and sugar, in part because of the high relative land requirement of biodiesel compared to ethanol (OECD, 2006). The study acknowledges however that this estimate is inflated by the failure to take account of trade, fallow land and technological improvements. The most recent OECD report looks at the issue from another perspective and estimates the impact of the removal of biofuel support policies. The analysis indicates that this would result in some 6.2m hectares reduction in global crop area. Although this represents a sizeable 23% of the projected increase in crop area requirements over the coming decade it is only about 0.7% of total global agricultural land. Even in the EU, where impacts are the most significant, total crop area is projected to fall by less than 1.5%, or 2.2m hectares, if support policies were abolished (OECD, 2008). The report concludes that *'…growth in land use is for a larger part independent from biofuel support policies.'* (p.60).

The Commissions' own PE estimates indicate relatively modest increases in land use due to biofuel production, with biofuel production taking up 15% of arable land or 17.5 mio ha in 2020. The main source of additional land is predicted to be obligatory set aside which currently represents about 3.9 mio ha in the EU-27 with further increases over the period of 1.5m ha from new member states (CEC, 2007). The large shortfall between available set aside land and predicted acreage is not addressed in the study which concludes '*…the additional land use requirements [of the mandate] would not overly draw on the land* *resources of the EU-27'*. (CEC, 2007, p. 8). The impact assessment was analysed by Ecofys as part of the Gallagher Review and criticized for several shortcomings, notably the failure to consider both land use impacts outside the EU and GHG impacts of land use change (Dehue et al, 2008).

The European Energy Agency has sought to analyse whether the EU could produce adequate biomass in an environmentally sustainable manner. They concluded that the available arable land which can be used for dedicated bioenergy production could increase from 13 million ha in 2010 to 19.3 million ha in 2030, in particular as a result of the liberalization of agricultural markets and the resulting reduction of EU food crop production (EEA, 2006). However these assumptions are rather heroic given the historic pace of agricultural trade negotiations.

Gurgel et al (2007) used the EPPA CGE model from MIT to model the long term global impact of both a Business as Usual (BAU) scenario where biofuel demand reacts only to price effects and a scenario (the 'policy case') where all actors make serious efforts to address GHG emissions by adopting biofuels. They modeled only 'second generation' cellulosic ethanol production. Even under the BAU scenario biofuel acreage increases much more significantly than the above estimates - by 1.44-1.74 Gha and from 2.24-2.52 Gha in the policy case. This compares with only 1.6 Gha currently in use as cropland. They conclude that '*Biofuels production at this level thus has major consequences for land use on a global scale*'. They use two different versions of the model, which feature different scenarios for the conversion of different types of land to explore how land use will be affected. Their research indicates that if conversion of land were based purely on the relative costs, forest cover would reduce by 40% by 2100 in the 'policy case' to make way for biofuels. The version of the model which models land conversion in reference to historical precedent sees much more expansion onto pastureland. Much of the expansion of production in their model, which features free trade in biofuels, comes from Latin America (between 45-60% of global production), followed by Africa.

Analysis by Banse et al (2008) indicates important land use impacts from implementing biofuels mandates on a global scale. Compared to a reference scenario of trade liberalization, the EU's land use falls by less under both an EU and global biofuel scenario. All other key regions expand land use under a global biofuels scenario, in particular Central and South America which increases agricultural land use by almost 10 percentage points compared to the reference scenario. The study also makes clear, however, that the majority of the expansion in land use in most regions is due to the liberalization of trade and other projected changes in the world economy. These are modeled under the reference scenario, where global agricultural land increases by18% compared to 21% under the global biofuels scenario. Although biofuels contributes to greater land cultivation it is not, therefore, projected to be the major driver.

Tokgoz et al (2007) used a PE model to estimate the impacts on the US of current government policy to support biofuels on US production. This baseline scenario would require an additional 94 million corn acres in the US alone. This rises to 112 million under a high oil price scenario of just $10 above the baseline, provided that adequate FFVs are adopted. Reductions are seen in soy and wheat acreage.

Hertel et al (2008) use a GTAP-E model adapted to include Agro-Ecological Zones (AEZs). In other words they take account of the fact that land types differ and substitutability is only possible within limited zones. They find substantial impacts on land use from the EU and US mandates. In the US, coarse grains acreage increases by 10% at the expense of other cropland, as well as pasture land and forests. The biggest global impacts are however seen as a result of the boom in oilseeds production due to EU demand for biodiesel. Here increases range from 11-16% in Latin America, 14% in SE Asia and Africa and 40% in the EU itself. The model restricts the potential land sources of increased biomass production to pastureland or forests as it does not take into account idle land. This tends to over-estimate the impacts. The largest impacts are for pastureland in Brazil where the acreage is estimated to reduce by 11%, of which 8% is due to the EU mandate. Reductions in forestry cover are highest for the EU (-7%), Canada (-6%) and Africa (-3%). The model (like that used in this study) does not take account of the potential impact of biofuel byproducts which the authors acknowledge to be an important limitation which overestimates the impact of the mandates on corn and livestock markets.

Two issues which have emerged as key in the recent debate on the impact of biofuels are the question of the impact of changes in yields on potential increased land use demand and the impact of incorporating the by-products of biofuels in the analysis. These shall be discussed in turn.

3.3 Yields

On the issue of yields, one likely impact of increased crop prices is an increase in yields. Even without substantial increases in prices in recent decades (rather the reverse) crop yields have increased substantially. Corn yields in the US doubled between 1975 and 2005 and this increase seems to be accelerating (Fernandez-Cornejo et al, 2008). Clearly if yields continue to increase at levels close to historical precedent, then the amount of land required to produce the increased amount of feedstock used for biofuels will be correspondingly lower. On the other hand pressure for land is likely to lead to increased use of more marginal land hitherto considered unsuitable for agriculture, which could be expected to reduce average yields thus increasing acreage required. Whether changes in yields will lead to more intensive or extensive production is a key question with major implications for the land use impacts of biofuels. Researchers have often side-stepped this question. In his work on biofuels, for example, Searchinger (2008) assumed that the positive and negative impacts of these differing effects on yields would cancel each other out.

Fernandez-Cornejo et al (2008) incorporated the potential increase in yields into their GTAP-based analysis by running two scenarios, one with baseline projection increases in yields and one with additional productivity gains. The increases in yields did not have major impacts on land use. Corn acreage in the US increased by 18% in the baseline scenario compared to 16% in the increased yields scenario, while sugar acreage in Brazil increased by 52% and 51% respectively.

There are two key elements to the debate on yields – in the first place the possibilities for increases in the future and in the second the drivers of such increases. The extent to which changes in relative prices foster increases in productivity in agriculture has been subject to extensive debate. One recent analysis concluded that relative price changes have not encouraged innovation in US agriculture in the last 40 years. The paper concludes '*This finding cautions against the efficacy of policies based on the premise that price signals alone induce efficient technical change*' (Lui and Shumway, 2007, p.28).

3.4. Biofuels byproducts

The production of biofuels results in several byproducts which have potential or existing markets. Producing ethanol from corn results in a byproduct – Dried Distillers Grains with Solubles (DDGS) which is used as animal feed. Its sale represents 16% of ethanol revenues in the US (Hertel at al, 2008). Biodiesel production from vegetable oil produces seed meals which can be used as animal feed. Farrell et al (2006) was one of the first papers to point out the importance of integrating by-products in assessments of the energy balance of biofuels. In particular they found that studies which didn't take by-products into account concluded that biofuels had a negative energy balance because they failed to take account of the energy use which the by-products offset.

The increased availability of these by-products will have beneficial side effects in other areas of agriculture. The Commission's impact assessment of the biofuels mandate has pointed out the positive impacts on livestock production in terms of reduced prices for animal feed, with soymeal prices predicted to fall by 25% and rapemeal by 40% by 2020 (CEC, 2007).

Taheripour et al (2008) analysed the impact of including biofuel byproducts in an analysis based on a general equilibrium model. They found quite significant differences in feedstock output and prices depending on whether the existence of by-products is taken into account. In their other study on agricultural land availability, Kampman et al (2008) estimated that incorporating by-products into the calculations for land requirements of biofuels reduced the land demand by 10-25%. Thus the integration of by-products is key to properly estimating changes in prices and land use, as well as energy balance.

The model used in this analysis does not include by-products. This is clearly a source of bias and will tend to over-estimate the impacts of the mandate in terms of increased demand for land. However given the impact of including by-products estimated in Taheripour et al (2008), the effect will be to mitigate the size of the impacts, but not their overall direction.

An important aspect of the potential move to second generation biofuels is that the byproducts of these processes tend to be much more limited, certainly in terms of offset land use. Thus in their analysis of the impacts of byproducts on land use, Croezen and Brouwer (2008) found that those scenarios which included 2G biofuels resulted in substantial reductions of almost half in the amount of avoided land use. For example in the scenarios based on volume targets for 2020 the avoided land use was calculated to be 16.7 m hectares with 2G and 31 m without. However this fact needs to be seen in context – in general 2G biofuels require less land for their production (30-40% less according to Kampmann et al (2008)).

3.5. Greenhouse Gas (GHG) emissions

Much of the reasoning behind the adoption of biofuels is based on the assumption that they are a more environmentally friendly fuel source, as the GHG emissions associated with their production and use are lower than those associated with traditional fossil fuels. This assumption is not based on the GHGs impacts from the use of biofuels, as the GHGs emitted from burning them are not noticeably different to those of other fuels. There is a reduction in certain pollutants, with a possible increase in others (Worldwatch institute, 2006). Rather their advantage over fossil fuels is based on the idea that the production of biofuels absorbs CO2 and therefore offsets large percentages of the future emissions from using them.

This assumption is far from being universally accepted. Early estimates from the International Energy Agency indicated that the use of biofuels resulted in net GHG savings – between 20-90% for ethanol from crops (with most crops in the lower levels. The higher figures are for cellulosic ethanol) and around 50% for biodiesel from oilseeds (IEA, 2004).

Although the logic for these figures is intuitively attractive, several researchers have pointed out that such estimates are incomplete as several aspects of the lifecycle and indirect effects of biofuels are not properly taken into account. Even early, positive analysis of biofuels' potential, such as that from the Worldwatch institute warned that there were limits to its potential benefits. In particular, biofuels that are produced from low yielding crops, or grown on previous forested or grasslands or produced using large inputs of fossil fuel, could easily have a negative GHG balance (Worldwatch institute, 2006). The fact that biofuel's GHG balance varies widely depending on these factors is increasingly taken into account in analyses.

One key issue is that producing biofuels requires energy and the assumptions on where that energy comes from can make a large difference to the calculated relative efficiency of different biofuel sources. Mortimer et al (2008) note the large difference between the CO2 emissions in the production of corn based ethanol in the US and France (0.108 kg eq/MJ compared to 0.049 kg eq/MJ respectively), which is largely due to the assumption that coal is used for ethanol processing in the US compared to natural gas in France. Biofuels which use the plant waste to fuel their processing, such as those based on switchgrass and sugarcane are clearly the most efficient.

In their research for the Gallagher Review, Mortimer et al (2008) provide estimates of the percentage of GHGs emissions by various sources of biofuels compared to standard fossil fuels. Their results are fairly consistent with other sources in highlighting the relative efficiency of Brazilian sugar cane (which generally uses bagasse as the fuel source) and the relative inefficiency of maize which this study found to be more intensive in GHG emissions than the fuels it seeks to replace (see Table 1).

Table 1. Current biofuels emissions as a percentage of GHGs for fossil fuels

Fuel type	Feedstock	Processing	Percentage of GHG Emissions of Fossil Fuels	
			Low value	High value
Biodiesel	Oil Palm	Esterification	54	54
Biodiesel	Oilseed Rape	Esterification	53	83
Biodiesel	Soybean	Esterification	55	93
Bioethanol	Maize	Fermentation	127	127
Bioethanol	Molasses	Fermentation	47	103
Bioethanol	Sugar Beet	Fermentation	59	59
Bioethanol	Sugar Cane	Fermentation	29	136
Bioethanol	Wheat	Fermentation	70	121

Source: Adapted from Mortimer et al (2008). See original for methodological notes

The above results take into account the 'credit' represented by the by-products of the various processes and the N2O emissions from the soil where the crops are grown. This latter issue is one of the most contentious and difficult to integrate in relation to the biofuels debate. N2O is a greenhouse gas which is far more detrimental to global warming than CO2 (296 times according to Mortimer at al (2008)). For this reason, although emissions are far lower by weight than CO2, they are potentially very damaging.

A key input to the debate on NO2 emissions and biofuels is a paper by Crutzen et al (2007). This paper claims that the manner in which the UN's Inter-governmental Panel on Climate Change (IPCC) integrates N2O emissions into its assessments underestimates N2O emissions from crops by a factor of 3 to 5. The paper has been criticized and its accuracy called into question[4]. Mortimer et al. have undertaken an exhaustive review of the paper and conclude that while it raises an important issue '*…it cannot be regarded as resolving the problems and assisting the objective evaluation of biofuels.*' (Mortimer et al, 2008, p. 29). For the moment, as their review makes clear, it is impossible to accurately measure the extent of N2O emissions related to a given biofuel from a given source. For this reason and due to the complexities of seeking to integrate it in the model, this research does not seek to access the effects of biofuels on GHGs other than CO2.

The other key issue which has emerged as controversial in recent months is the question of the 'credit' attributable to biofuels from the 'carbon uptake' of the crops used to produce them. A key paper in this debate is that by Searchinger et al (2008). His main point is that earlier assessments of the carbon impacts of biofuels have been biased because they have not taken account of the land use impacts. In short they have counted the carbon benefits of using land for biofuels but not the carbon costs – the carbon storage and sequestration which is sacrificed when the land is diverted from its former use (direct GHG effects) or when land is cleared for growing food to replace land which has been diverted into biofuel production (indirect GHG effects). As he notes '*Because existing land uses already provide carbon benefits in storage and sequestration … dedicating land to biofuels can potentially reduce greenhouse gases only if doing so increases the carbon benefit of land*.' (Searchinger et al., 2008) p. 1

Searchinger used the Greenhouse gases, regulated emission and energy use in transportation (GREET) model to calculate the total GHG emissions from various biofuel sources. The model indicates that, without taking into account land use changes, replacing gasoline by corn-based ethanol reduces GHG emissions by 20% by 2015. Once they account for land use change, however, the picture changes significantly and they find that corn based ethanol more than doubles GHG emissions over a 30 year timescale and increases GHGs for 167 years. On the other end of the spectrum, Brazilian sugarcane production is estimated by their model to

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[4] http://www.cosis.net/members/journals/df/article.php?paper=acpd-7-11191

provide GHG savings of 86%. If this sugarcane production converts only tropical grassland, the payback for GHG emissions would be only 4 years, although this would rise to 45 years if displaced ranches were to convert forest to grazing land.

Mortimer et al (2008) have reviewed the Searchinger paper and the GREET model to assess its applicability to the EU/UK context. They have concluded that the model is too US specific to be readily useable outside that context. The US Department of Energy has itself issued a rebuke criticizing many aspects of the study, which it considers to also misrepresent the US case, by overestimating corn ethanol production and making several invalid assumptions (DOE, 2008). Nevertheless the key point which Searchinger makes – that land use changes and their impacts on GHG emissions are key to assessing the true impacts of biofuels - is a valid one which needs to be taken into account in analysis. The Gallagher review acknowledges this, particularly in its recommendation that policies should seek to direct biofuels production towards suitable idle land or appropriate wastes and non-food products.

This recommendation is based on a series of calculations on the net impact of the conversion of various types of land on GHG emissions which concur with the broad conclusions of Searchinger's paper (Mortimer, 2008). The analysis finds that, apart from the lowest estimate of ethanol from sugar beet, all current biofuel production on converted UK grasslands would be negative in terms of GHG emissions, in some cases emitting twice the level of fossil fuels. The figures calculated for biofuels from overseas sources are even worse. Of all sources analysed - oil palm in Malaysia, soy biodiesel in Brazil, maize ethanol in the US and sugar cane ethanol in Brazil - only the latter showed a net saving and the others showed large net losses, topping 30,000% for biodiesel from soy converted from Brazilian rainforest.

The calculation for the impact of using fallow land is slightly different, as it assumes that the N2O emissions which would have been emitted by this land are avoided by its cultivation, thus adding an additional 'credit' to the calculation. The results are generally positive i.e. the production of biofuels in the UK from fallow land is calculated to emit less GHG than fossil fuels, although the percentage varies from 88-55%. The figures are similar for biodiesel and ethanol, although they tend to be lower for the former, especially in the long term and when rotational set-aside land is used.

The JRC report has also looked at the issue of land use change and its impacts on GHG emissions (de Santi, 2008). They have made the point that looking at direct effects alone was probably legitimate when rates of substitution by biofuel were low and most biofuel feedstock could come from set-aside or other unused arable land. However the 10% target means that most of the EU biofuel feedstock will be removed from the world commodity markets either by reduced EU exports or increased EU imports.

They have looked at the alternative sources of these extra biofuels and in most cases found significant negative effects. For example using EU permanent grassland would result in an initial emission of carbon which would take 20 to 110 (+/- 50%) years to recover through biofuel production. The carbon losses from drained peat forest, which is used for palm oil production in South East Asia, are so high that if even 2.4% of the EU's biodiesel needs are met directly or indirectly by palm oil grown in peatland all GHG savings from EU biodiesel would be cancelled out. Palm oil is a key alternative to rapeseed for the food industry, so EU imports are likely to increase once the latter is diverted to biofuel production. The calculations in the report indicate that the level of EU imports of palm oil produced on peatland is likely to be considerably higher than 2.4%. Although local regulations could be set in place to avoid such negative indirect effects, the report is dubious about the potential of certification schemes to assure sustainability. The report concludes '*Indirect land use change could potentially release enough greenhouse gas to negate the savings from conventional EU biofuels*.' (De Santi, 2008).

Finally a key question which is frequently ignored in the biofuels debate is whether the use of biomass for biofuels is the most efficient means to use the limited biomass resources at our disposal to reduce GHGs. A recent JRC report has pointed out that while the efficiency of fuel burners for heating and electricity is almost as high as that of fossil fuels, the energy efficiency of converting biomass to liquid fuels is only 30-40% (de Santi et al, 2008). Their cost benefit analysis indicates that the decision to specifically target GHG reductions in the transport sector reduces the benefits that could be achieved in other ways. The European Energy Agency has furthermore expressed concern that diversion of biomass to biofuel will make it difficult for the EU to meet its objectives for renewable energy sources in energy production (EEA, 2004).

A related point is that support for biofuels is a very expensive means of reducing CO2 emissions. The OECD has estimated that policy support to biofuels would cost taxpayers and consumers between $960 and $1 700 per ton of CO2 emissions avoided (OECD, 2008). The exact figures can be debated as they are based on a series of assumptions and indeed are far higher than the figures used in the Commission's impact assessment of the Renewable Energy Directive[5] or even the high end estimates (over €300/ton) refered to in the Economic and Social Committee's report (EESC, 2008). However the fundamental point of the OECD work – that reducing CO2 emissions through measures in support of biofuel production is an expensive option – is a valid one, reiterated both in that report (EESC, 2008) and in the work of the JRC (2007).

4. Approach of this study

A key objective of the study is to establish the global agricultural production effects of this biofuels policy mandate. To do this effectively requires a CGE approach. The demand shock for biofuels generated by the mandate will induce effects on quantities, prices, substitution between fuels and inputs and incomes. Once all these effects have been estimated it is possible to calculate the global environmental impact of these changes. A distinction has to be made between direct (in the production process) and indirect (due to land use changes) greenhouse gas emission effects.

The effects on trade of the changes in demand for biofuels depend on wider changes in production/consumption patterns in countries and regions. Agricultural markets worldwide are constrained by a variety of price and quantity restrictions as well as subsidies. These constraints are taken into account in the model.

The overall objective of the analysis is to explore how EU agricultural trade policies (and the design of the sustainability criteria) could be adapted to maximize the environmental and economic benefits of biofuels policies.

4.1. The model

The work relies extensively on MIRAGE, a model developed at CEPII. MIRAGE is a multisector, multiregion Computable General Equilibrium Model devoted to trade policy analysis. The model operates in a sequential dynamic recursive set-up: it is solved for one period, and then all variable values, determined at the end of a period, are used as the initial values of the next one. Macroeconomic data and social accounting matrixes, in particular, come from the GTAP 7 database (see Narayanan, 2008), which describes the world economy in 2004. Tariff averages have been recalculated using the MacMap methodology (see Bouët et al. 2006, 2008).

From the supply side in each sector, the production function is a Leontief function of value-added and intermediate inputs: one output unit needs for its production *x* percent of an aggregate of productive factors (labor, unskilled and skilled; capital; land and natural resources) and (1 – *x*) percent of intermediate inputs.[6] The intermediate inputs function is an aggregate CES function of all goods: it means that substitutability exists between two intermediate goods, depending on the relative prices of these goods. This substitutability is constant and at the same level for any pair of intermediate goods. Similarly, in the generic version of the model, value-added is a constant elasticity of substitution (CES) function of unskilled labor, land, natural

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[5] These were €20-160/tCO2 eq.

[6] The fixed-proportion assumption for intermediate inputs and primary factor inputs is especially pertinent to developed economies, but for some developing economies that are undergoing dramatic economic growth and structural change, such as China, the substitution between intermediate inputs and primary factor inputs may be significant.

resources, and of a CES bundle of skilled labor and capital. This nesting allows the modeler to introduce less substitutability between capital and skilled labor than between these two and other factors. In other words, when the relative price of unskilled labor is increased, this factor is replaced by a combination of capital and skilled labor, which are more complementary.[7]

Factor endowments are fully employed. The only factor whose supply is constant is natural resources. Capital supply is modified each year because of depreciation and investment. Growth rates of labor supply are fixed exogenously. Land supply is endogenous; it depends on the real remuneration of land. In some countries land is a scarce factor (for example, Japan and the EU), such that elasticity of supply is low. In others (such as Argentina, Australia, and Brazil), land is abundant and elasticity is high.[8]

Skilled labor is the only factor that is perfectly mobile. Installed capital and natural resources are sector specific. New capital is allocated among sectors according to an investment function. Unskilled labor is imperfectly mobile between agricultural and nonagricultural sectors according to a constant elasticity of transformation (CET) function: unskilled labor's remuneration in agricultural activities is different to that in nonagricultural activities. This factor is distributed between these two series of sectors according to the ratio of remunerations. Land is also imperfectly mobile between agricultural sectors.

In the MIRAGE model there is full employment of labor; more precisely, there is a constant aggregate employment in all countries (wage flexibility). It is quite possible to suppose that total aggregate employment is variable and that there is unemployment; but this choice greatly increases the complexity of the model, so that simplifying assumptions have to be made in other areas (such as the number of countries or sectors). This assumption could amplify the benefits of trade liberalization for developing countries (see Diao et al. 2005): in full-employment models, increased demand for labor (from increased activity and exports) leads to higher real wages, such that the origin of comparative advantage is progressively eroded; but in models with unemployment, real wages are constant and exports increase much more.

Capital in a given region, whatever its origin, domestic or foreign, is assumed to be obtained by assembling intermediate inputs according to a specific combination. The capital good is the same whatever the sector. MIRAGE describes imperfect, as well as perfect, competition. In sectors under perfect competition, there is no fixed cost, and price equals marginal cost. Imperfect competition is modeled according to a monopolistic competition framework. It accounts for horizontal product differentiation linked to product variety. Each firm in sectors under imperfect competition produces its own unique variety, with a fixed cost expressed as a fixed quantity of output. According to the Cournot hypothesis, each firm supposes that its decision of production will not affect the production of other firms. Furthermore, the firms do not expect that their decision of production will affect the level of domestic demand (which would be what modelers call a "Ford effect").

The monopolistic competition framework implies that each year, firms exert their market power by applying a markup to their marginal costs. This markup depends negatively on the price elasticity of demand according to the Lerner formula. This price elasticity, as perceived by firms, depends positively on the elasticity of substitution between the goods produced domestically and abroad, and negatively on the number of competitors and the market share of the firm in the demand region.[9] In the long term, the number of firms is endogenous, as it increases when profits are positive. An implication of this hypothetical structure is that international trade has pro-competitive effects and reduces mark-ups and prices.

The number of firms may adjust progressively, either quickly (2 years in fragmented sectors) or slowly (5 years in segmented sectors). This classification is based on the seminal work of Sutton (1991) and has been

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[7] In the generic version, substitution elasticity between unskilled labor, land, natural resources, and the bundle of capital and skilled labor is 1.1, whereas it is only 0.6 between capital and skilled labor. This structure has been modified for the present exercise (see 4.2).

[8] This assumption is modified in the version of MIRAGE designed to address the biofuel issue.

[9] This specification is very close to the one used by Harrison, Rutherford, and Tarr (1997).

confirmed by Oliveira-Martins (1994) and Oliveira-Martins, Scarpetta, and Pilat (1996). The taxonomy used by MIRAGE to distinguish fragmented and segmented sectors is based on this earlier work.

The demand side is modeled in each region through a representative agent whose propensity to save is constant. The rest of the national income is used to purchase final consumption. Preferences between sectors are represented by a linear expenditure system–constant elasticity of substitution (LES-CES) function. This implies that consumption has a non-unitary income elasticity; when the consumer's income is augmented by *x* percent, the consumption of each good is not systematically raised by *x* percent, other things being equal.

When competition is imperfect, products are horizontally differentiated (so-called "product variety"), and consumers have increased utility with more variety; this hypothesis is a traditional one (the Spence-Dixit-Stiglitz function). But MIRAGE introduces here two specific features. Firstly, in some sectors (such as industry), products coming from developed countries and those from developing countries are assumed to belong to different quality ranges. Their substitutability, therefore, is assumed to be lower than the substitutability among products coming from the same quality range. Secondly, domestic products benefit from a specific status for consumers - they are less substitutable with foreign products than foreign products are amongst one another, within a given quality range.

The sector sub-utility function used in MIRAGE is a nesting of four CES functions. In this study, Armington elasticities are drawn from the GTAP 6 database and are assumed to be the same across regions. The other elasticities used in the nesting for a given sector are linked to the Armington elasticity by a simple rule (see Bchir et al. 2002 for more details). Macroeconomic closure is obtained by assuming that the sum of the balance of goods and services and foreign direct investments (FDIs) is constant and equal to its initial value.

4.2. Adaptations to the model

MIRAGE was developed primarily to assess the impact of traditional trade liberalization. There were therefore several adaptations which needed to be made to the model in order to address some of the key questions of the study, especially those related to environmental impacts.

The sector decomposition focuses on biofuels, on the commodities needed for their production and on the commodities directly related to them. The geographic decomposition of the model focuses on the main countries that play an active role in the development of the production and trade of biofuels.

Some key model issues had to be addressed in order to adequately examine the questions in this study. The MIRAGE model had to be improved in terms of the modeling of energy demand, the modeling of land use (land availability, conversion between uses), the modeling of household demand and the elasticity estimates used, and also in terms of sectoral coverage to introduce the ethanol and biodiesel sectors and separately identify corn, oilseeds used in biodiesel production, fertilizers and transport fuels.

The model has been expanded to address these shortcomings and thus better adapt it to the needs of the study. Specifically, four significant changes have been made to the existing version:

a) <u>The integration of two biofuel sectors</u> in the GTAP database. Ethanol produced from different feedstock crops (varying by region) and biodiesel were introduced as new sector in the global database (see the description of procedure and assumptions in Annex 1). The is already a separate sugarcane\sugarbeets sector but maize and oilseeds used for biodiesel production had to be separated from larger sectors. The petroleum products sector was split into two subsectors: fuel for transportation and other petroleum products. A fertilizer sector was also separately identified in the social accounting matrix of the world economy.

b) <u>The modeling of the energy sector has been improved</u> following a methodology determined as more suitable by modellers, following a literature review described in Annex 2.

c) The decomposition of land use and allocation has been improved, since a key element of the interdependence between biofuels and energy sectors is the demand for this primary factor. Land resources has been differentiated between different agro-environmental zones and best suitable substitution and extension mechanisms have been chosen by modelers following a literature review (see Annex 3).

d) Projections have been made on domestic support for biofuels programs, population growth, and price of fossil oils in order to evaluate how economic scenarios impact on the world demand for agricultural and food products. Demand functions take into account income increases leading to shifts in consumption behaviour.

e) A differentiation of the evolution of Global Factor Productivity has been made between sectors of production (Agriculture/Industry/Services) and agricultural sectors (Crops, Livestock).

The environmental impacts of increased biofuel production are assessed through:

- The emissions of CO2 calculated from energy consumption using a vector of emission per type of fossil energy input.
- The emissions of CO2 linked to direct and indirect land use change, which is calculated using a vector of emission per type of land type, which is subject to sufficient consensus in the scientific community.
- Estimates of deforestation per region and their environmental impact are endogenous to the model. The estimation of parameters of this specific function has been developed based on the historical record.

Non-CO2 gases are not considered in this study. It is acknowledged that because of this fact the model may underestimate the emissions of total GHGs, especially NO2, from certain production processes and land use changes, however the technical difficulty and additional data requirements of incorporating other gases was simply too great.

4.3. Scenarios

The terms of reference require that a variety of policy scenarios should be explored to study not only the environmental impact of the biofuels mandate but also any negative socio-economic effects. It is also required to explore the impact of any variations in the sustainability criteria, incentive schemes, trade restrictions and the overall quantitative target.

Using the baseline scenario incorporating the main existing biofuels policies applied in the EU27, the USA and Brazil, we run the following two scenarios to test the impact of alternative EU policies. They are both based on the target that has been defined by the European Commission i.e. reaching a share of biofuels in total fuel consumption of 5.75% in 2010 and 10% in 2020.

Two scenarios are investigated:

- EU mandate - The policy is implemented as a legal element, a mandate. This implies that fuel distribution will have to support the cost of non efficient blending, a cost which will be transmitted to the consumer price.
- Trade liberalisation - The reduction or removal of import tariffs on ethanol and biodiesel reduces domestic consumption prices and favors the consumption of biofuels.

Scenario 1: EU Biofuels mandate

In order to model the consequences of a European obligation to incorporate biofuels into fossil fuels for transport, we simulate a blend share of 5% for 2010 and 10% for 2020 with a gradual increase between 2008 and 2010 and between 2011 and 2020 (under a linear scheme). The official objective is 5.75% for 2010. Nevertheless since the share of biofuels to be incorporated into fuels differs from one European country to another (e.g. the French mandate is for a 7% biofuel blending in 2010, while the United Kingdom aims for only 3.5% by the same date), even if the EU27 imposes a mandate of 5.75% by 2010, the real mandate applied at this date will be 5%. This is the shared objective that we modeled in the simulation. According to our mandate modeling, the blend obligation is applied to both final household and intermediate consumption in the road and transport sector. Note that the target is fixed for each type of biofuel such that ethanol should represent 5% of petrol in 2010 (10% in 2020) and biodiesel 5% of diesel in 2010 (10% in 2020). In other words there is no possible substitution, so one biofuel cannot reach more than the target blending ratio to compensate for the fact that the other biofuel has not reached the target.

Scenario 2: Biofuels trade liberalization

The second scenario models a policy which seeks to fulfill the 2020 biofuels mandate by liberalizing trade in order to reduce EU consumer prices. This scenario will particularly affect ethanol imports, which are currently inhibited by high tariffs in the European market. In implementing this scenario we reduce tariffs on imports of ethanol and biodiesel by the same percentage until consumption of both is equal to 5% of total fuel consumption over the 2008-2010 period, 10% in the 2010-2020 period. In case consumption is still below the target but tariffs are completely eliminated, we increase consumption subsidies on both ethanol and biodiesel by the same percentage until the mandate targets are attained.

5. Results

We first focus on the assessment of the impacts of a European Mandate and of trade liberalization. In subsection 5.4 we proceed to a sensitivity analysis.

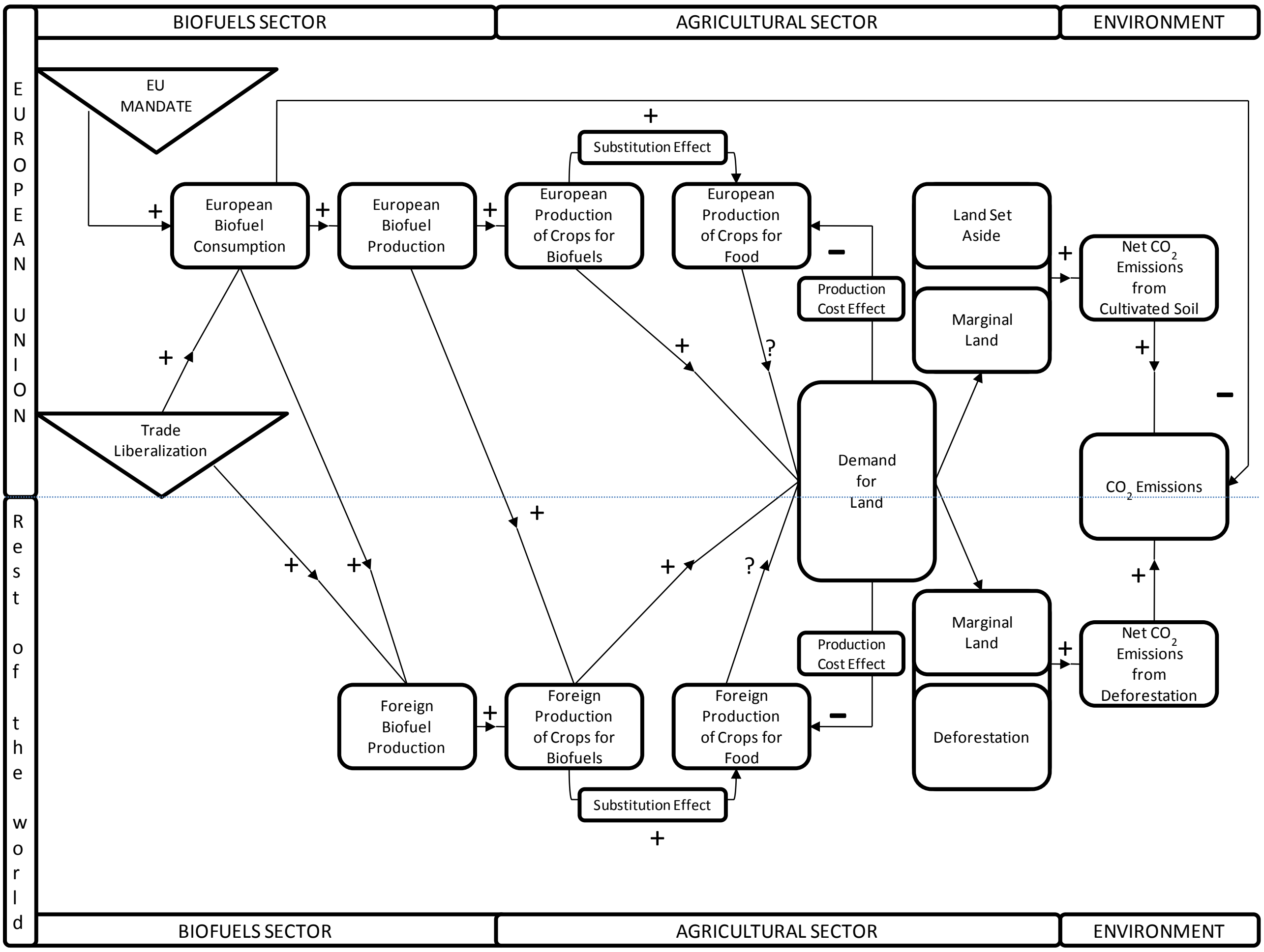
The economic mechanisms that we expect to play in this modeling exercise are illustrated on 0.

These (direct or indirect) policies supporting the consumption of biofuels in Europe should stimulate the production of biofuels in Europe, but also elsewhere via European imports of biofuels (in particular ethanol that should be much more stimulated by the trade liberalization scenario). Augmenting the production of biofuels in both Europe and the Rest of the World should encourage the production of crops for biofuels (maize, wheat, sugar cane/sugar beet, oilseeds for biodiesel) and/or in the case of Europe the imports of these crops (we think in particular to vegetable oils). What is the impact of an expansion of the production of crops for biofuels on the production of crops for food?

Two effects are in play in an opposite direction. From one side as the demand for food is inelastic, more crops are needed: this is what we call a substitution effect (between different crops – more demand for maize and wheat increases their prices and consumers substitute other cereals to these crops - ; of in general between crops for food and crops for non-food use). This effect tends to increase the production of crops for food.

The second effect plays through the increased demand for land implied by augmented production of crops. This should translate in a higher remuneration of this primary factor which should have a negative effect on agricultural production: this is what we call a production cost effect.

Figure 1. Economic mechanisms in play under scenarios 1 and 3



Anyway the effect of these policies on land use should be positive and more land should mean marginal land put into cultivation and less set aside land in the European Union while it should translate in marginal land cultivated and deforestation in the Rest of the World. This model has been designed to capture these effects. At the end of the process, the net impact of these European policies on CO2 emission will depend on the strength of two forces: from one side the consumption of biofuels instead of fossil fuels should reduce the emission of CO2. From the other side new land put into cultivation should contribute to supplementary emission.

Of course all the economic mechanisms in play under this new version of the MIRAGE model are not represented on 0: for example another effect that should contribute to new CO2 emission is the “leakage effect” under which less demand for fossil fuel by the European Union should reduce the world price of oil which should contribute to more CO2 emission. This effect will be evaluated by MIRAGE even of not accounted for by 0.

5.1 Baseline

Although the model is based on 2004 data, the initial year from which the policy scenario is evaluated is 2007. Production of biofuels in the baseline is considered as driven only by the prolongation of existing subsidies without any mandate constraint and the consumption of biofuel is simply driven by substitution for fossil fuels on the basis of relative prices.

Oil prices follow trends proposed by IEA in its last World Energy Outlook (2008) with an oil price reaching $100 a barrel by 2010 and remaining at this high level with a slight increase up to $110 in 2020. Oil production is forecast to experience constraints with an increase of only 46% on the period 2010-2020, whereas GDP growth between 2007 and 2020 reaches 59% thanks to productivity gains. Demand for all crops remains high with an increase of 57% in total world production on the same period. The highest increases in demand are in the wheat (66%) and oilseeds (+60%) sectors. Maize and rice demand see more limited increases (around 53% and 45% respectively). Crop production benefits from technological improvements bringing productivity gains that are exogenously represented in the baseline. Other gains come from reallocation of factors and inputs, which are endogenously driven by substitutions mechanisms. The evolution of the technological component of total factor productivity (TFP) is reproduced from Ludena et al. (2006) which conclude on large expected increases of total factor productivity in meat, dairy and animal products sectors as well as fishing, vegetable oil and sugar.

Given these forecast changes, cropland expansion is expected to be 1.13 Mha between 2007 and 2020 (+7.1%), with substantial expansion in Sub-Saharan Africa (South Africa excluded), Indonesia, Brazil and other net food exporting countries of Latin America. This forecast is based on the assumption that no major changes in the diet of the world populations occur. The shares of crops and animal products in the food budget respond only to the mixed effects of food price evolution and a shift related to modified consumptions following an income increase. For developing countries, this latter income effect is more apparent and consumers shift 1 to 2% of their food budget to animal products over the period.

High oil prices are beneficial to the development of biofuels in the baseline. The production of ethanol reaches 107.9 Mtoe and biodiesel 11.4 Mtoe in 2020 against 40 Mtoe and 7.4 Mtoe respectively in 2007 because of the sustained change in the relative price between fossil fuel and biofuels. In the present baseline, the USA are also considered to reach a level of 10% of biofuel incorporation in 2020 and Brazil retain its incorporation rate of 25% ethanol in gasoline, which considerably helps the development of the ethanol sector in these countries.

Last, no specific additional programs to curb greenhouse gases emissions by industry are considered. Emissions rise from 23.6 Gt CO2 in 2007 to 33.3 Gt in 2020, with the share from developing countries increasing from 51% in 2007 to 62% in 2020. China alone sees his share growing up from 18% to 26%, while the European and US shares go down from 15.4% to 12.8% and from 23% to 18.1% respectively.

5.2 The economic and environmental impacts of the Mandate and Tariff Liberalisation scenarios

In this section we examine the impact of two policy scenarios:

First, the European mandate scenario seeks to achieve the EU policy objective of at least 5% biofuels consumption in transport fuels in 2010, and at least 10% in 2020, by imposing that bio/fossil fuel mix on all fuels sold in the EU. In that case, the consumer bears the cost of any fuel price increases at the pump. It is compared to the baseline situation where no mandate is implemented. The mandate is implemented progressively and in a linear fashion from 2008 to 2010 and from 2010 to 2020. It is applied on each type of biofuel and no blending over 10% is allowed for biofuels in either gasoline or diesel.

Second, the trade liberalization scenario consists of reaching the same objective through a more market-based approach, by lowering the consumer price of biofuels in order to stimulate consumption. This is achieved, in a first step, by the removal of European import tariffs on ethanol and biodiesel in 2010. When the removal of tariffs is not sufficient to achieve the consumption target, it is complemented by subsidies to further reduce the consumer price. The incorporation of biofuels in domestic consumption (5% in 2010; 10% in 2020) can then be reached at a lower cost for the consumer under this scenario.

We evaluate the effects of these policy scenarios on several key elements - biofuel production, biofuel imports, crop production, agricultural value-added, variation of land use by sector, variation of total land use, variation of the intensification index for cultivation ($ of fertilizer used by ha), direct emission reduction related to biofuels and indirect emission related to indirect land use effect. We adopt a 33*18 (33 sectors by 18 regions) decomposition. It is detailed in Annex 5.

Table 2 and 3 illustrate the impact of the two policies on biofuel production. The first column in Table 2 provides the level of ethanol production in 2015 in the baseline (without policy shocks – column Ref). The next columns give the variation of production implied by the mandate (column Mandate) and by trade liberalization (column Trade Lib'n) as compared to the baseline in 2015 and 2020 (so it is a comparison between a policy scenario and a "business-as-usual" situation, at the same year).

Table 2. Level and variation of ethanol production (Mio toe and %)

	2015	2015	2015	2015	2015	2020	2020	2020	2020	2020
	Ref	Mandate	Mandate	TradeLib'n	TradeLib'n	Ref	Mandate	Mandate	TradeLib'n	TradeLib'n
	Lev	Lev	Var	Lev	Var	Lev	Lev	Var	Lev	Var
Oceania	0.55	0.55	*-0.3%*	0.55	*0.7%*	0.79	0.79	*-0.2%*	0.80	*1.0%*
China	8.09	7.98	*-1.4%*	7.98	*-1.3%*	6.57	6.43	*-2.2%*	6.43	*-2.1%*
RoOECD	0.73	0.77	*5.2%*	0.93	*27.8%*	0.96	1.06	*10.2%*	1.39	*44.5%*
RoAsia	1.22	1.21	*-0.9%*	1.22	*-0.4%*	1.34	1.32	*-1.4%*	1.33	*-0.7%*
Indonesia	0.87	0.86	*-1.5%*	0.86	*-1.3%*	1.01	0.99	*-2.1%*	0.99	*-1.9%*
Malaysia	0.09	0.09	*-1.8%*	0.09	*-1.2%*	0.21	0.20	*-2.4%*	0.21	*-1.4%*
SouthAsia	6.65	6.66	*0.3%*	6.68	*0.5%*	9.81	9.84	*0.3%*	9.87	*0.6%*
Canada	0.70	0.69	*-2.0%*	0.69	*-1.6%*	0.79	0.77	*-2.7%*	0.77	*-2.2%*
USA	31.55	31.80	*0.8%*	32.29	*2.3%*	47.25	47.86	*1.3%*	48.88	*3.4%*
Mexico	0.24	0.24	*-0.3%*	0.25	*0.6%*	0.33	0.33	*-0.5%*	0.33	*0.6%*
EU27	1.50	7.95	*430.5%*	4.46	*197.8%*	1.84	14.49	*689.5%*	7.92	*331.3%*
LACExp	0.16	0.15	*-2.0%*	0.15	*-1.4%*	0.20	0.20	*-2.7%*	0.20	*-2.0%*
LACImp	2.51	2.64	*4.9%*	2.57	*2.2%*	3.56	3.92	*10.1%*	3.70	*3.8%*
Brazil	18.26	18.47	*1.1%*	21.66	*18.6%*	22.04	22.62	*2.6%*	28.99	*31.6%*
EEurCIS	4.50	4.44	*-1.3%*	4.66	*3.6%*	5.92	5.80	*-2.0%*	6.15	*3.9%*
MENA	1.85	1.81	*-1.9%*	1.84	*-0.4%*	2.60	2.52	*-3.2%*	2.57	*-1.2%*
RoAfrica	0.53	0.54	*3.1%*	0.54	*1.6%*	0.86	0.91	*5.8%*	0.88	*2.5%*
SAF	1.26	1.28	*1.4%*	1.43	*13.9%*	1.81	1.86	*2.6%*	2.17	*20.0%*
World	81.24	88.12	*8.5%*	88.84	*9.4%*	107.88	121.90	*13.0%*	123.58	*14.5%*

The mandate scenarios and trade liberalization scenario have very contrasting effects on biofuel production in the European Union. In 2015 ethanol production increases by 431% in the EU under an EU mandate scenario (690% in 2020), while the competition coming from increased imports in a trade liberalization scenario would mean that this increase is much smaller: +198% in 2015; 331% in 2020. The removal of tariffs on ethanol would be followed by a surge in European imports of this product (they are multiplied by 95 by 2020). However increased imports are not sufficient to reach the domestic consumption target and an increase in the consumption subsidy has to be put in place. The trade liberalization scenario increases European imports of ethanol by 9.9 Mtoe in 2020, 63% of these supplementary imports coming from Brazil, 10% from the US (see 0).

Table 3. Level and variation of EU biofuel imports by origin (Mio toe and %)

		2015 Ref Lev	2015 Mandate Lev	2015 Mandate Var	2015 TradeLib'n Lev	2015 TradeLib'n Var	2020 Ref Lev	2020 Mandate Lev	2020 Mandate Var	2020 TradeLib'n Lev	2020 TradeLib'n Var
Ethanol	**RoOECD**	0.01	0.07	*809.04%*	0.25	*3244.20%*	0.01	0.15	*1698.51%*	0.49	*5773.19%*
Ethanol	**USA**	0.01	0.13	*819.50%*	0.42	*2962.73%*	0.02	0.33	*1702.00%*	0.95	*5089.44%*
Ethanol	**EU27**	0.33	2.13	*549.47%*	0.58	*75.49%*	0.35	3.83	*980.31%*	0.98	*175.53%*
Ethanol	**LACImp**	0.02	0.20	*806.02%*	0.05	*138.67%*	0.03	0.53	*1662.79%*	0.12	*305.46%*
Ethanol	**Brazil**	0.04	0.35	*771.13%*	3.07	*7615.14%*	0.05	0.84	*1582.28%*	6.17	*12310.86%*
	World	0.44	3.11	*712.04%*	5.05	*1153.60%*	0.49	6.15	*1262.59%*	9.87	*2027.15%*
Biodiesel	**Malaysia**	0.34	0.89	*159.19%*	0.83	*143.44%*	0.50	1.51	*204.34%*	1.43	*188.04%*
Biodiesel	**SouthAsia**	0.19	0.49	*159.36%*	0.47	*146.57%*	0.25	0.78	*207.09%*	0.75	*194.06%*
Biodiesel	**USA**	0.48	1.17	*142.32%*	1.47	*204.57%*	0.48	1.32	*175.47%*	1.67	*248.79%*
Biodiesel	**EU27**	0.27	0.57	*106.56%*	0.54	*95.84%*	0.28	0.65	*127.15%*	0.62	*117.41%*
	World	1.29	3.12	*241.70%*	3.31	*256.69%*	1.51	4.25	*281.18%*	4.46	*294.97%*

Rather intuitively, the European mandate increases overseas production of ethanol by less than trade liberalization. The greatest impacts are seen in the two largest producers, the US and Brazil and in Eastern Europe. In particular, Brazilian ethanol production is increased by 18.6% in 2015 and 31.6% in 2020 under European liberalization of biofuels imports, while it is only increased by 1.1% and 2.6% under a European mandate. The mandate has such an impact on import demand on world market that the imports of all other countries are reduced. This effect comes through a price effect on the world market: as Europe increases its demand, the world price of ethanol goes up and the demand for imports in all other countries/regions go down. Europe is clearly a price-maker.

Table 4. Level and variation of biodiesel production (Mio toe)

	2015 Ref Lev	2015 Mandate Lev	2015 Mandate Var	2015 TradeLib'n Lev	2015 TradeLib'n Var	2020 Ref Lev	2020 Mandate Lev	2020 Mandate Var	2020 TradeLib'n Lev	2020 TradeLib'n Var
Malaysia	0.32	0.59	*82.79%*	0.56	*74.81%*	0.52	1.02	*95.47%*	0.99	*88.13%*
SouthAsia	0.16	0.35	*115.61%*	0.33	*106.42%*	0.23	0.56	*141.24%*	0.54	*132.48%*
USA	2.72	3.25	*19.33%*	3.50	*28.54%*	3.65	4.26	*16.64%*	4.56	*24.69%*
EU27	6.31	13.73	*117.41%*	13.58	*115.12%*	6.84	16.66	*143.62%*	16.53	*141.70%*
World	9.52	17.92	*85.71%*	17.98	*86.39%*	11.25	22.51	*96.97%*	22.61	*97.88%*

As far as biodiesel is concerned, the mandate also has a substantial impact on European production since it increases by 117% in 2015 and 144% in 2020 (see Table 4). The growth of European biodiesel production is much less than for ethanol. This is due to differences in the initial conditions. Today the rate of blending of biodiesel in diesel is much higher than the equivalent rate in ethanol. Consequently in order to catch up the European rate of growth of ethanol production has to be much larger. The European mandate has a very substantial percentage increase on foreign production of biodiesel only in Malaysia and South Asia, but these variations are from very small base levels. Indeed international trade in this product is still limited. If tariff liberalization is implemented, the European production of biodiesel is increased by 115% in 2015 as compared to the reference situation (absence of policy shocks), but this augmentation is slightly less than the one implied by the mandate. Because of the low level of international trade, supplementary imports of biodiesel are not sufficient to enable Europe to reach its consumption target. Tax exemption has to be increased (this is equivalent to a new subsidy), even in a trade liberalization scenario and as a consequence the increases in European biodiesel production are quite similar in both policy shocks.

The expansion of the biofuel sectors, either by a mandate or trade liberalization reduces European demand for fossil fuel. As Europe is a large region, this decrease in demand reduces world demand and world oil prices go down slightly, by less than 1%. This is an important mechanism, referred as "carbon leakage" in the biofuels policy. If world oil prices decrease, that will stimulate oil consumption outside the EU and thereby undo part of the fossil fuel reduction effect inside the EU. Table 5 gives variation of CO2 emissions in the total economy (MtCO2eq) thanks to either the EU mandate or the trade liberalization scenario.

Table 5. Variation of CO2 emissions in the total economy (MtCO2eq)

	2015	2015	2015	2015	2015	2020	2020	2020	2020	2020
	Ref	Mandate	Mandate	TradeLib'n	TradeLib'n	Ref	Mandate	Mandate	TradeLib'n	TradeLib'n
	Lev	Lev	Var	Lev	Var	Lev	Lev	Var	Lev	Var
Oceania	376	376	*0.06%*	376	*0.05%*	412	412	*0.09%*	412	*0.08%*
China	6351	6356	*0.08%*	6356	*0.07%*	8525	8536	*0.13%*	8536	*0.12%*
RoOECD	1723	1726	*0.15%*	1726	*0.15%*	1851	1855	*0.23%*	1855	*0.22%*
RoAsia	782	783	*0.22%*	783	*0.22%*	919	922	*0.33%*	922	*0.32%*
Indonesia	405	405	*0.16%*	405	*0.16%*	496	497	*0.25%*	497	*0.24%*
Malaysia	157	158	*0.43%*	158	*0.40%*	196	197	*0.60%*	197	*0.56%*
SouthAsia	1607	1610	*0.19%*	1610	*0.19%*	2019	2026	*0.34%*	2025	*0.33%*
Canada	508	509	*0.16%*	509	*0.15%*	540	541	*0.23%*	541	*0.22%*
USA	5566	5571	*0.10%*	5571	*0.09%*	6045	6054	*0.15%*	6053	*0.14%*
Mexico	408	408	*0.10%*	408	*0.09%*	445	446	*0.13%*	446	*0.13%*
EU27	3912	3880	*-0.81%*	3881	*-0.79%*	4249	4196	*-1.26%*	4197	*-1.23%*
LACExp	201	201	*0.21%*	202	*0.21%*	222	222	*0.34%*	222	*0.35%*
LACImp	605	606	*0.17%*	606	*0.17%*	690	691	*0.26%*	691	*0.24%*
Brazil	308	308	*0.17%*	308	*0.11%*	342	343	*0.28%*	343	*0.23%*
EEurCIS	2994	2995	*0.04%*	2996	*0.05%*	3633	3634	*0.04%*	3634	*0.05%*
MENA	1856	1858	*0.08%*	1858	*0.08%*	2218	2220	*0.08%*	2220	*0.07%*
RoAfrica	200	200	*0.27%*	200	*0.30%*	231	231	*0.39%*	232	*0.43%*
SAF	261	261	*0.06%*	261	*0.09%*	278	278	*0.10%*	279	*0.14%*
World	28218	28213	*-0.02%*	28213	*-0.02%*	33310	33303	*-0.02%*	33303	*-0.02%*

This evaluation is based on the MIRAGE representation of the world production process and coefficients of CO2 emissions related to sectoral use of energy inputs. It is important to note that variations in CO2 emissions related to indirect land use effects are not taken into account by this table. Globally it shows that the EU mandate reduces total CO2 emission by a mere 0.02%: it reduces CO2 emissions in Europe by 0.81 % in 2015, 1.26% in 2020, thanks to the consumption of biofuels instead of fossil fuels. But this policy has an adverse effect on other countries/regions in the world as in particular it increases oil consumption (quantity) outside the EU through this effect on world oil price. Therefore there is displacement of CO2 emissions from the EU to other regions: for example the EU mandate increases CO2 emissions in Malaysia in 2020 by 0.6%, in the Rest of Africa zone by 0.39%.

Table 6 shows crop production impacts, reporting only the feedstock crops and countries that are significantly affected by the various policy scenarios. The European mandate has a substantial impact on the

European production of agricultural crops. As a result of the development of ethanol, the European production of sugar crops (mostly sugar beet in this case) is increased by 16.8% in 2015 and 24% in 2020. Production of wheat and maize are also increased, but not so significantly. In 2020, production of wheat is increased by 14.6% and maize by 12.8%. Increased European production of biodiesel leads to increased production of oilseeds for biodiesel by 21.3% in 2020.

The European mandate also stimulates production of oilseeds for biodiesel in all foreign countries, particularly in Brazil (+14.3% in 2015; +14.4% in 2020) and in the US (+9.7% in 2015; +10.4% in 2020). The impact on foreign production of feedstocks for ethanol (wheat, maize, sugar cane-sugar beet) is much more limited. Brazil's production of sugar crops (mostly sugar cane in this case) is increased thanks to the European mandate by a mere 0.5% in 2020, with negligible impact in 2015.

Thus while the European mandate mainly stimulates domestic production of ethanol and sugar beets, it substantially increases foreign production and trade of feedstock for biodiesel (oilseeds).

Table 6. Level and variation in production of key crops in key countries (Mio $)

		2015	2015	2015	2015	2015	2020	2020	2020	2020	2020
		Ref	**Mandate**	**Mandate**	**TradeLib'n**	**TradeLib'n**	**Ref**	**Mandate**	**Mandate**	**TradeLib'n**	**TradeLib'n**
		Lev	**Lev**	**Var**	**Lev**	**Var**	**Lev**	**Lev**	**Var**	**Lev**	**Var**
Wheat	**China**	14186	14209	0.16%	14202	0.11%	15948	15978	*0.18%*	15966	*0.11%*
Wheat	**SouthAsia**	39042	39087	0.12%	39076	0.09%	48689	48786	*0.20%*	48759	*0.14%*
Wheat	**USA**	14359	14402	0.30%	14348	-0.08%	19498	19602	*0.53%*	19484	*-0.08%*
Wheat	**EU27**	29036	31442	8.29%	30200	4.01%	34287	39292	*14.60%*	36754	*7.19%*
Wheat	**Brazil**	743	723	-2.78%	715	-3.75%	937	911	*-2.79%*	894	*-4.63%*
Wheat	**EEurCIS**	12677	12702	0.19%	12764	0.68%	14221	14276	*0.39%*	14344	*0.86%*
Wheat	**MENA**	15299	15373	0.49%	15348	0.32%	17192	17312	*0.70%*	17258	*0.38%*
	World	154393	157074	1.74%	155741	0.87%	187393	192993	*2.99%*	190189	*1.49%*
Maize	**China**	18053	18013	-0.22%	18015	-0.21%	20688	20645	*-0.21%*	20647	*-0.20%*
Maize	**USA**	35426	35478	0.14%	35619	0.54%	42233	42384	*0.36%*	42677	*1.05%*
Maize	**Mexico**	10256	10265	0.09%	10267	0.11%	11663	11676	*0.11%*	11681	*0.15%*
Maize	**EU27**	14059	14982	6.57%	14490	3.07%	15041	16960	*12.76%*	15951	*6.05%*
Maize	**Brazil**	4757	4721	-0.75%	4709	-0.99%	5592	5556	*-0.65%*	5530	*-1.10%*
Maize	**RoAfrica**	13613	13599	-0.10%	13602	-0.09%	16375	16350	*-0.15%*	16353	*-0.14%*
	World	128440	129365	0.72%	129083	0.50%	148934	150989	*1.38%*	150402	*0.99%*
OilseedBio	**SouthAsia**	23884	23976	0.38%	23975	0.38%	29066	29196	*0.45%*	29194	*0.44%*
OilseedBio	**USA**	31556	34616	9.70%	34597	9.64%	41439	45754	*10.41%*	45726	*10.34%*
OilseedBio	**EU27**	22147	26420	19.29%	26457	19.46%	23494	28500	*21.31%*	28644	*21.92%*
OilseedBio	**LACExp**	11006	11607	5.46%	11595	5.34%	13424	14222	*5.94%*	14213	*5.87%*
OilseedBio	**Brazil**	20033	22916	14.39%	22761	13.62%	25526	29213	*14.44%*	28984	*13.55%*
	World	132666	144462	8.89%	144300	8.77%	159936	175059	*9.46%*	174926	*9.37%*
Sugar_cb	**SouthAsia**	20138	20159	0.11%	20170	0.16%	24610	24648	*0.15%*	24673	*0.25%*
Sugar_cb	**USA**	2472	2472	-0.01%	2472	0.00%	2674	2675	*0.04%*	2675	*0.06%*
Sugar_cb	**EU27**	9334	10902	16.79%	10132	8.55%	10022	12428	*24.01%*	11387	*13.62%*
Sugar_cb	**Brazil**	6293	6291	-0.04%	6645	5.59%	7377	7415	*0.52%*	8093	*9.70%*
	World	63283	64982	2.68%	64583	2.05%	74159	76924	*3.73%*	76558	*3.23%*

As noted earlier, tariff liberalization in Europe on biofuels has a very substantial impact on the European production of biodiesel as a subsidy has to be added in order to reach the target. This scenario requires a large amount of feedstocks and production of oilseeds for biodiesel is positively affected in the European Union (19.5% in 2015; 21.9% in 2020) and in foreign countries, in particular Brazil (+13.6% in 2020), the US (+12.3% in 2020), the region Oceania (+14.9% in 2020), Mexico (+8.5% in 2020). Indeed at the world level, this is the crop which is the most positively affected by both policy shocks: under the trade liberalisation scenario world production of oilseeds for biodiesel is augmented by 8.8% in 2015, while sugar cane/beet's one is only increased by 2.1% (0.7% for maize; 0.9% for wheat).

Table 7. Level and variation in EU imports of feedstocks (Mio $ - volume)

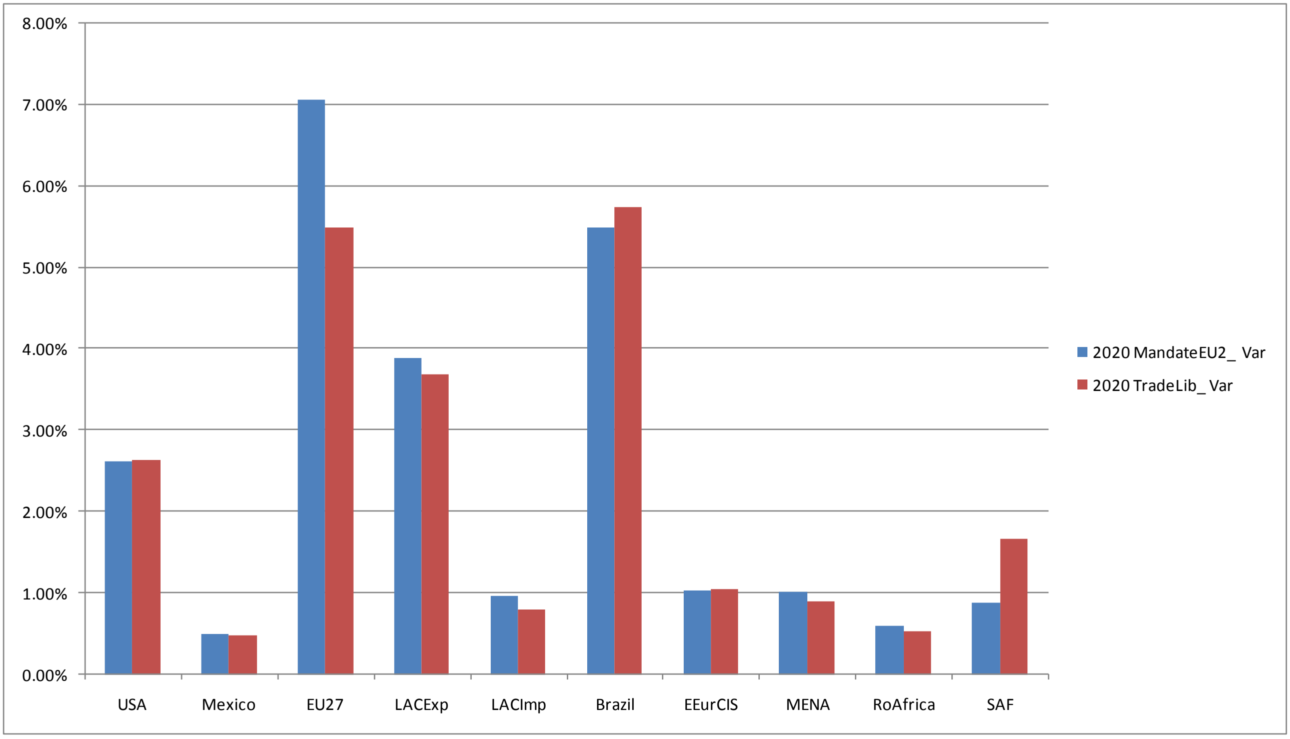
		2015 Ref Lev	2015 Mandate Lev	2015 Mandate Var	2015 TradeLib'n Lev	2015 TradeLib'n Var	2020 Ref Lev	2020 Mandate Lev	2020 Mandate Var	2020 TradeLib'n Lev	2020 TradeLib'n Var
Wheat	**Oceania**	86.10	101.19	*17.53%*	91.86	*6.70%*	60.66	81.85	*34.93%*	68.82	*13.44%*
Wheat	**Canada**	247.27	283.45	*14.63%*	258.87	*4.69%*	127.12	166.77	*31.20%*	141.10	*11.00%*
Wheat	**USA**	308.94	360.70	*16.76%*	327.42	*5.98%*	232.31	311.13	*33.93%*	261.46	*12.55%*
Wheat	**Mexico**	5.27	6.28	*19.34%*	5.69	*8.11%*	6.16	8.51	*38.12%*	7.13	*15.78%*
Wheat	**LACExp**	11.88	13.37	*12.54%*	12.10	*1.90%*	13.00	16.72	*28.59%*	14.01	*7.76%*
Wheat	**LACImp**	10.89	12.93	*18.80%*	11.71	*7.57%*	11.57	15.88	*37.17%*	13.30	*14.88%*
Wheat	**Brazil**	47.87	52.69	*10.06%*	47.63	*-0.52%*	49.72	61.89	*24.48%*	51.79	*4.16%*
Wheat	**EEurCIS**	71.53	85.62	*19.71%*	75.55	*5.63%*	49.68	68.83	*38.56%*	55.90	*12.52%*
Wheat	**World**	856.03	995.28	*16.27%*	902.48	*5.43%*	610.59	814.59	*33.41%*	683.22	*11.90%*
Maize	**USA**	142.25	155.61	*9.39%*	147.38	*3.61%*	150.86	178.47	*18.30%*	161.77	*7.23%*
Maize	**LACExp**	184.23	197.65	*7.28%*	187.75	*1.91%*	187.78	216.51	*15.30%*	197.27	*5.05%*
Maize	**LACImp**	57.14	62.89	*10.06%*	59.72	*4.52%*	63.81	76.09	*19.25%*	69.32	*8.63%*
Maize	**Brazil**	258.84	274.52	*6.06%*	259.59	*0.29%*	280.97	320.35	*14.02%*	289.70	*3.11%*
Maize	**EEurCIS**	81.86	90.46	*10.51%*	85.85	*4.87%*	79.85	95.88	*20.08%*	87.26	*9.28%*
Maize	**World**	776.80	838.90	*7.99%*	795.05	*2.35%*	819.90	954.94	*16.47%*	866.75	*5.71%*
OilseedBio	**Oceania**	116.97	232.84	*99.06%*	230.01	*96.64%*	125.75	289.64	*130.33%*	286.54	*127.87%*
OilseedBio	**China**	42.22	86.19	*104.13%*	84.96	*101.21%*	24.73	58.64	*137.10%*	57.82	*133.81%*
OilseedBio	**RoOECD**	81.91	167.30	*104.24%*	164.98	*101.41%*	99.04	236.15	*138.44%*	233.03	*135.29%*
OilseedBio	**SouthAsia**	13.02	28.00	*114.96%*	27.60	*111.90%*	11.85	30.25	*155.20%*	29.85	*151.83%*
OilseedBio	**Canada**	231.81	443.12	*91.16%*	437.54	*88.75%*	231.17	503.68	*117.88%*	497.67	*115.28%*
OilseedBio	**USA**	2768.41	5497.88	*98.59%*	5416.39	*95.65%*	2950.51	6761.39	*129.16%*	6662.66	*125.81%*
OilseedBio	**LACExp**	879.22	1719.29	*95.55%*	1697.40	*93.06%*	944.13	2116.28	*124.15%*	2091.11	*121.49%*
OilseedBio	**LACImp**	16.75	35.39	*111.26%*	34.91	*108.39%*	21.07	52.37	*148.62%*	51.75	*145.68%*
OilseedBio	**Brazil**	4382.13	7946.21	*81.33%*	7822.20	*78.50%*	4869.23	9902.83	*103.38%*	9735.29	*99.93%*
OilseedBio	**EEurCIS**	222.62	406.09	*82.41%*	401.27	*80.24%*	199.84	419.30	*109.81%*	414.51	*107.42%*
OilseedBio	**MENA**	31.53	65.60	*108.02%*	64.69	*105.16%*	32.10	77.72	*142.14%*	76.75	*139.09%*
OilseedBio	**RoAfrica**	19.10	40.69	*113.06%*	40.13	*110.12%*	28.41	71.16	*150.47%*	70.27	*147.33%*
OilseedBio	**World**	8689.93	16438.27	*89.16%*	16194.53	*86.36%*	9413.35	20232.95	*114.94%*	19923.83	*111.65%*

The production of various agricultural crops competes for common scarce productive resources (like land). On the one hand the production of agricultural commodities for non-food purposes can have negative consequences on other agricultural commodities through increased price of this common resource. On the other, demand for food is inelastic and there should be some substitution effects in demand that could positively affect the production of other agricultural crops. It is therefore important to assess the impact of these policies on the production of other crops. In the European Union, for both policy shocks, production of crops not used as feedstock for biofuel production is very stable and increases do not exceed 1% of absolute value. The negative impacts are more pronounced in the case of Brazil where the demand for agricultural commodities is less inelastic. Here trade liberalization which implies, as we noted earlier an increased specialization for Brazil in oilseeds for biodiesel and sugar cane/sugar beet, also results in a reduction in Brazil's wheat production by 4.6% in 2010, of maize by 1.1%, of "Other crops" by 1.5%.

Both policy shocks have a significant impact on European imports of agricultural feedstocks. The mandate raises European production of ethanol and biodiesel. Since increased biofuels productions raises demand for feedstocks (sugar beet, wheat and oilseeds) thus competing with the use of these crops for food, the mandate results in increased production or imports of agricultural feedstock. As shown in 0, the impact on European imports of oilseeds for biodiesel is particularly significant with imports of oilseeds for biodiesel from the US increasing by 99% through the mandate in 2015 and by 96% through the trade liberalization. European imports from Brazil (another substantial supplier) are increased by 81% through the mandate in 2015, and by 79% through trade liberalization. Imports of wheat and maize are also augmented but by much less. The mandate and trade liberalization scenarios do not result in pronounced differences regarding production and trade of feedstocks,

Figure 2 illustrates how agricultural value-added could be affected by these different scenarios. The potential impact of both policies on agricultural value-added is positive in all countries/regions throughout the world, in particular in the ten countries/regions shown (they have been selected as their agricultural value-added will be augmented by at least 1% under at least one scenario) and especially in the EU and in Brazil, but also the net food exporters from Latin America and the US. These policies create more activity in the agricultural sector and the impact is worldwide. The increase in agricultural value-added is systematically close to 2.6% in the US. But while the mandate is substantially positive for European agricultural value-added (more than 7%) and slightly less so for that of Brazil (+5.5%), the impact is larger in Brazil in the case of trade liberalization (5.75% vs. 5.5%). The impact of the trade liberalization scenario is positive for value-added in the Brazilian sectors of oilseeds for biodiesel (+23.4% in 2020) and of sugar cane/sugar beet (+17.9% in 2020), while it is only significant for the oilseeds for biodiesel sector in case of a mandate (+25.1%in 2025).

Figure 2. Variation of agricultural value-added in 2025 (%)



These gains in agricultural value-added have to be compared with the cost to consumers (consumers are negatively affected in the EU) in order to derive a net economic benefit. This is done through the calculation of welfare effects of European policies and this is done not only for the EU but also for other countries/regions on Table 8. It indicates the welfare effects of European policies in 2015 and in 2020. Both policies have marginal effect on countries/regions welfare, except for Brazil and the Net Food Exporting Countries of Latin America which benefit from significant improvement in their terms of trade thanks to their exporting status of wheat, oilseeds for biodiesel and sugar cane. The impact is also positive for the US, as it is a net exporter of oilseeds for biodiesel. As far as the European Union is concerned both policies are identically detrimental: in that sense the increase in agricultural added value observed on Figure 2, is more than offset by negative impact of both policies on consumers' surplus and public receipts.

Table 8. Welfare impact of European biofuel policies (Variation / Baseline)

	2015	2015	2020	2020
	Mandate	TradeLib'n	Mandate	TradeLib'n
	Var	Var	Var	Var
Oceania	*0.03%*	*0.02%*	*0.04%*	*0.04%*
China	*0.00%*	*0.00%*	*0.00%*	*0.00%*
RoOECD	*0.00%*	*0.00%*	*0.00%*	*0.00%*
RoAsia	*0.03%*	*0.03%*	*0.05%*	*0.05%*
Indonesia	*-0.01%*	*0.00%*	*-0.02%*	*-0.02%*
Malaysia	*-0.03%*	*-0.02%*	*-0.05%*	*-0.03%*
SouthAsia	*0.05%*	*0.04%*	*0.09%*	*0.07%*
Canada	*0.00%*	*0.00%*	*-0.01%*	*-0.01%*
USA	*0.02%*	*0.02%*	*0.03%*	*0.03%*
Mexico	*-0.08%*	*-0.08%*	*-0.14%*	*-0.13%*
EU27	*-0.17%*	*-0.16%*	*-0.23%*	*-0.22%*
LACExp	*0.27%*	*0.26%*	*0.43%*	*0.42%*
LACImp	*-0.06%*	*-0.06%*	*-0.08%*	*-0.08%*
Brazil	*0.27%*	*0.35%*	*0.43%*	*0.58%*
EEurCIS	*-0.20%*	*-0.19%*	*-0.31%*	*-0.28%*
MENA	*-0.30%*	*-0.28%*	*-0.45%*	*-0.41%*
RoAfrica	*-0.20%*	*-0.19%*	*-0.28%*	*-0.26%*
SAF	*0.01%*	*0.03%*	*0.03%*	*0.05%*

Changes in crop production, particularly due to the increased demand for feedstock crops used as inputs in biofuels, has different implications on the expected patterns of land use under the mandates and trade liberalization scenarios. Table 9 and Table 10 indicate the variation in land use by sector which would be expected from these policy scenarios (Table 9 for Europe; Table 10 for other key countries), while Table 10 shows how the intensification of production – specifically the use of fertilizers - is affected.

The amount of land used for oilseeds and sugar beet in Europe is significantly increased by the mandate: +14.2% in 2015 for oilseeds for biodiesel; +10% for sugar beet (given that the European production of oilseeds for biodiesel is increased by 19.3% against 16.8% for sugar beet, the increase in yields appears to be more pronounced in the latter sector). The effect on land used for maize and wheat is positive, but limited. The increase in land planted to biofuel feedstocks in Europe comes at the expense of land planted to rice, other crops and vegetable and fruits, i.e. crops that are not used as feedstock for biofuels. As expected, in the case of tariff liberalization the impact on land allocated to oilseeds for biodiesel is similar (+14.4% in 2015; +16.5% in 2020), while it is reduced for land allocated to the cultivation of sugar beet (+4.5% in 2015; +8.4% in 2020). Globally the mandate increases land use by 1,2% in 2015, 1,9% in 2020 while under the trade liberalization scenario these augmentations are less: 1,03% and 1,53%.

Table 9. Level and variation of land use by sector in Europe (thousand ha)

		2015	2015	2015	2015	2015	2020	2020	2020	2020	2020
		Ref	Mandate	Mandate	TradeLib'n	TradeLib'n	Ref	Mandate	Mandate	TradeLib'n	TradeLib'n
		Lev	Lev	Var	Lev	Var	Lev	Lev	Var	Lev	Var
Rice	**EU27**	446	442	*-0.85%*	442	*-0.83%*	442	437	*-1.04%*	438	*-0.98%*
Wheat	**EU27**	25508	26114	*2.38%*	25966	*1.80%*	25084	26062	*3.90%*	25775	*2.75%*
Maize	**EU27**	9123	9324	*2.21%*	9269	*1.60%*	8811	9139	*3.73%*	9034	*2.53%*
OthCrop	**EU27**	54578	53749	*-1.52%*	53817	*-1.39%*	52552	51672	*-1.67%*	51745	*-1.53%*
VegFruits	**EU27**	13472	13277	*-1.45%*	13294	*-1.32%*	12973	12754	*-1.68%*	12777	*-1.51%*
OilseedBio	**EU27**	9846	11242	*14.17%*	11263	*14.39%*	9700	11239	*15.88%*	11304	*16.54%*
Sugar_cb	**EU27**	2495	2743	*9.96%*	2606	*4.45%*	2459	2850	*15.88%*	2665	*8.36%*
Total	**EU27**	115467	116890	*1.23%*	116658	*1.03%*	112020	114154	*1.90%*	113738	*1.53%*

Table 10. Level and variation of land use by sector in non European countries (thousand ha)

		2015	2015	2015	2015	2015	2020	2020	2020	2020	2020
		Ref	Mandate	Mandate	TradeLib'n	TradeLib'n	Ref	Mandate	Mandate	TradeLib'n	TradeLib'n
		Lev	Lev	Var	Lev	Var	Lev	Lev	Var	Lev	Var
Rice	**Brazil**	4093	4083	*-0.24%*	4080	*-0.32%*	4127	4114	*-0.33%*	4108	*-0.46%*
Wheat	**Brazil**	2425	2314	*-4.56%*	2300	*-5.14%*	2627	2505	*-4.65%*	2474	*-5.83%*
Maize	**Brazil**	17026	16564	*-2.71%*	16545	*-2.82%*	17548	17078	*-2.67%*	17030	*-2.95%*
OthCrop	**Brazil**	8169	8074	*-1.17%*	8050	*-1.47%*	8597	8483	*-1.33%*	8437	*-1.86%*
VegFruits	**Brazil**	12284	12194	*-0.73%*	12177	*-0.87%*	12600	12502	*-0.78%*	12471	*-1.03%*
Sugar_cb	**Brazil**	9117	9063	*-0.59%*	9316	*2.19%*	9526	9493	*-0.35%*	9923	*4.16%*
Total	**Brazil**	53113	52291	*-1.55%*	52467	*-1.22%*	55026	54174	*-1.55%*	54443	*-1.06%*
Rice	**USA**	1789	1782	*-0.41%*	1782	*-0.41%*	1790	1781	*-0.49%*	1781	*-0.49%*
Wheat	**USA**	31332	31092	*-0.77%*	31034	*-0.95%*	32713	32445	*-0.82%*	32344	*-1.13%*
Maize	**USA**	39566	39047	*-1.31%*	39133	*-1.09%*	38616	38061	*-1.44%*	38205	*-1.06%*
OthCrop	**USA**	58475	57950	*-0.90%*	57951	*-0.90%*	59458	58782	*-1.14%*	58786	*-1.13%*
VegFruits	**USA**	5679	5653	*-0.46%*	5652	*-0.47%*	5818	5785	*-0.57%*	5785	*-0.57%*
Sugar_cb	**USA**	1219	1209	*-0.85%*	1209	*-0.84%*	1147	1135	*-1.05%*	1135	*-1.03%*
Total	**USA**	138061	136732	*-0.96%*	136761	*-0.94%*	139542	137990	*-1.11%*	138037	*-1.08%*
OilseedBio	**Oceania**	1793	1918	*6.97%*	1917	*6.90%*	1773	1915	*7.96%*	1914	*7.95%*
OilseedBio	**China**	14569	14661	*0.63%*	14661	*0.63%*	14068	14168	*0.72%*	14171	*0.73%*
OilseedBio	**RoOECD**	995	1007	*1.29%*	1007	*1.27%*	1000	1018	*1.79%*	1017	*1.77%*
OilseedBio	**RoAsia**	1321	1332	*0.78%*	1332	*0.78%*	1327	1341	*1.02%*	1341	*1.02%*
OilseedBio	**Indonesia**	4654	4688	*0.73%*	4688	*0.73%*	4979	5025	*0.91%*	5024	*0.91%*
OilseedBio	**Malaysia**	4031	4031	*0.00%*	4031	*0.00%*	3975	3975	*0.00%*	3975	*0.00%*
OilseedBio	**SouthAsia**	13385	13407	*0.17%*	13407	*0.17%*	13317	13342	*0.19%*	13343	*0.19%*
OilseedBio	**Canada**	8912	9288	*4.23%*	9290	*4.24%*	8877	9290	*4.66%*	9294	*4.69%*
OilseedBio	**USA**	46846	48714	*3.99%*	48691	*3.94%*	48566	50685	*4.36%*	50650	*4.29%*
OilseedBio	**Mexico**	147	151	*2.84%*	152	*2.89%*	159	165	*3.94%*	166	*4.02%*
OilseedBio	**EU27**	9846	11242	*14.17%*	11263	*14.39%*	9700	11239	*15.88%*	11304	*16.54%*
OilseedBio	**LACExp**	15811	16344	*3.38%*	16337	*3.33%*	17313	17960	*3.74%*	17962	*3.75%*
OilseedBio	**LACImp**	1878	1903	*1.35%*	1904	*1.36%*	1893	1926	*1.74%*	1927	*1.78%*
OilseedBio	**Brazil**	22873	24637	*7.71%*	24524	*7.22%*	25319	27321	*7.91%*	27162	*7.28%*
OilseedBio	**EEurCIS**	12258	12638	*3.10%*	12626	*3.01%*	12206	12613	*3.33%*	12602	*3.24%*
OilseedBio	**MENA**	*420*	428	*1.80%*	428	*1.83%*	*417*	426	*2.01%*	426	*2.10%*
OilseedBio	**RoAfrica**	7983	8109	*1.57%*	8106	*1.54%*	8715	8929	*2.46%*	8927	*2.42%*
OilseedBio	**SAF**	1483	1491	*0.52%*	1484	*0.09%*	1466	1474	*0.54%*	1464	*-0.15%*
OilseedBio	**Total**	169205	175990	*4.01%*	175849	*3.93%*	175072	182813	*4.42%*	182668	*4.34%*

Both scenarios also affect the allocation of land abroad (see Table 10 which illustrates level and variation of land use by all sectors in Brazil and in the US and in all countries/regions in the case of the oilseeds for biodiesel sector). Land is increasingly allocated to the cultivation of oilseeds for biodiesel in almost all countries under both policy scenarios; the reallocation can be substantial with over 7.7% increase in Brazil in 2015 and at the world level land use for oilseeds is increased by about 4% in 2015 and 4.4% in 2020 under both scenarios. As far as feedstocks for ethanol are concerned, changes in land use are more limited, except for sugar cane in Brazil. In this case the liberalization of tariffs on ethanol in Europe creates a substantial expansion of ethanol production in Brazil which requires more land: +4.2% in 2020.

As a central aspect of this report is the impact on indirect land use change, these tables are a first key finding. They show that: (a) there is very little global increase in land use implied by both scenarios, around 0.25% in 2015, 0.3% in 2020, (b) the trade liberalization scenario has overall slightly lower land use effects than the mandate scenario, (c) behind this unsubstantial augmentation of world total land use, the one for oilseeds for biodiesel is significantly increased (4% in 2015, 4.4% in 2020) while this process is detrimental to land allocated to the production of wheat, maize and other crops.

Table 11 shows the variation in the use of fertilizers per hectare, as implied by the various policy shocks. Again we focus on the main crops and the main countries. The use of fertilizers is substantially increased, in particular in the production of oilseeds for biodiesel in all countries (this is the sector where the pressure on demand is highest) and in the sugar crops and wheat sectors in Europe where the use of fertilizers is increased by over 7% for sugar beets and over 9% for wheat under the European mandate. This findings need to be seen in the context of the above indication that land yields are improved.[10]

Table 11. Level and variation of intensification index for cultivation (volume of fertilizer in $ per ha)

		2015	2015	2015	2015	2015	2020	2020	2020	2020	2020
		Ref	Mandate	Mandate	TradeLib'n	TradeLib'n	Ref	Mandate	Mandate	TradeLib'n	TradeLib'n
		Lev	Lev	Var	Lev	Var	Lev	Lev	Var	Lev	Var
Wheat	**USA**	5.38	5.49	*1.95%*	5.47	*1.62%*	8.11	8.32	*2.55%*	8.28	*2.04%*
Wheat	**EU27**	12.29	13.44	*9.36%*	12.72	*3.49%*	16.12	18.85	*16.93%*	17.24	*6.96%*
Wheat	**Brazil**	6.88	7.01	*1.95%*	6.99	*1.57%*	7.94	8.11	*2.15%*	8.06	*1.49%*
Maize	**USA**	16.80	17.21	*2.47%*	17.27	*2.81%*	22.52	23.23	*3.15%*	23.37	*3.75%*
Maize	**EU27**	21.30	22.81	*7.10%*	21.81	*2.38%*	24.73	28.32	*14.50%*	26.12	*5.61%*
Maize	**Brazil**	5.75	5.88	*2.26%*	5.87	*2.15%*	6.54	6.70	*2.44%*	6.69	*2.29%*
OilseedBio	**USA**	8.46	9.29	*9.85%*	9.29	*9.84%*	12.23	13.57	*10.94%*	13.58	*10.97%*
OilseedBio	**EU27**	20.75	21.96	*5.86%*	21.94	*5.77%*	22.46	23.89	*6.36%*	23.86	*6.24%*
OilseedBio	**Brazil**	18.45	19.44	*5.39%*	19.41	*5.23%*	20.77	21.93	*5.55%*	21.90	*5.42%*
Sugar_cb	**USA**	16.42	16.65	*1.40%*	16.65	*1.40%*	19.81	20.17	*1.84%*	20.17	*1.84%*
Sugar_cb	**EU27**	38.92	41.90	*7.66%*	40.73	*4.66%*	42.66	46.64	*9.33%*	45.27	*6.12%*
Sugar_cb	**Brazil**	14.11	14.22	*0.80%*	14.67	*3.99%*	15.85	16.04	*1.22%*	16.87	*6.46%*
Total	**World**	3612.53	3633.24	*0.57%*	3630.82	*0.51%*	4160.37	4194.12	*0.81%*	4190.04	*0.71%*

The land use changes under the two policy scenarios have implications on CO2 emissions as shown in Table 12 and Table 14. Table 12 shows the expected direct effects, i.e the CO2 emissions reduction from the production and consumption of specific crops. Table 14 includes the indirect effects which occur due to the impact of land use changes (the fall in food crop production occasioned by the mandates requires new land to be brought into production, implying further emissions).

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[10] Another important aspect in this study is NOx emissions linked to use of fertilizers. We cannot proceed to this evaluation in this report as we do not have emissions linked to fertilizers at initial year. But this evaluation will be done in the next research stage.

Table 12. World cumulative direct emissions reduction related to biofuels (Mios tCO2eq - extra emissions are positive values)

		2015 Ref Level (1)	**2015 MandateEU2 Level (2)**	**2015 MandateEU2_ Var from EU emissions**	**2015 TradeLib_ Level (3)**	**2015 TradeLib_ Var from EU emissions**	**2020 Ref Level (4)**	**2020 MandateEU2 Level (5)**	**2020 MandateEU2_ Var from EU emissions**	**2020 TradeLib_ Level (6)**	**2020 TradeLib_ Var from EU emissions**
World	**Ethanol - Wheat**	-4.19	-7.88	-0.20%	-5.93	-0.15%	-5.49	-13.53	-0.32%	-9.28	-0.22%
World	**Ethanol - Maize**	-17.36	-18.89	-0.48%	-18.38	-0.47%	-21.39	-24.77	-0.58%	-23.67	-0.56%
World	**Ethanol - Sugar Beet**	-1.95	-5.94	-0.15%	-4.03	-0.10%	-2.52	-9.30	-0.22%	-6.42	-0.15%
World	**Ethanol - Sugar Cane**	-63.72	-64.55	-1.65%	-70.73	-1.81%	-81.86	-84.10	-1.98%	-96.13	-2.26%
World	**Ethanol - Other Crops**	-0.13	-0.14	0.00%	-0.15	0.00%	-0.17	-0.18	0.00%	-0.21	0.00%
World	**Biodiesel - Soya**	-5.40	-9.95	-0.25%	-10.14	-0.26%	-6.72	-13.02	-0.31%	-13.22	-0.31%
World	**Biodiesel - Palm Oil**	-0.13	-0.21	-0.01%	-0.21	-0.01%	-0.21	-0.33	-0.01%	-0.34	-0.01%
World	**Biodiesel - Rapeseed**	-6	-12	-0.31%	-12	-0.31%	-7	-14	-0.34%	-14	-0.34%
World	**Total**	Sum(2) -Sum(1)	**-20.48**	Sum(3) -Sum(1)	**-22.45**		Sum(5) -Sum(4)	**-34.13**	Sum(6) -Sum(4)	**-38.20**	

The first column in Table 12 indicates the cumulative CO2 emissions likely to result from the use of a given crop for biofuels regardless of policy intervention. The following columns indicate the decline in CO2 emissions linked to the EU mandate and trade liberalization, in 2015 and 2020. For example, in the absence of any policy intervention, ethanol production from sugar beet would enable an annual reduction of 1.95 million tons in CO2 emissions in 2015. The EU mandate would increase that figure to 5.94 million tons – an increase of 3.99 million tons. Trade liberalization would result in an increased reduction of only 2.08 million tons.

Table 13. Variations in land occupation across countries (in million km^2)

	2015 Ref Lev	**2015 Mandate Lev**	**2015 Mandate Var**	**2015 Trade Lib'n Lev**	**2015 Trade Lib'n Var**	**2020 Ref Lev**	**2020 Mandate Lev**	**2020 Mandate Var**	**2020 Trade Lib'n Lev**	**2020 Trade Lib'n Var**
Brazil Cropland	0.76	0.77	*1.24%*	0.77	*1.32%*	0.8	0.81	*1.43%*	0.82	*1.57%*
Brazil Forest_managed	0.19	0.19	*0.17%*	0.19	*0.14%*	0.19	0.19	*0.21%*	0.19	*0.19%*
Brazil Forest_primary	4.3	4.29	*-0.09%*	4.29	*-0.09%*	4.13	4.12	*-0.11%*	4.12	*-0.12%*
Brazil Other	1.3	1.3	*-0.24%*	1.3	*-0.26%*	1.44	1.44	*-0.27%*	1.44	*-0.29%*
Brazil Pasture	1.96	1.96	*-0.15%*	1.96	*-0.16%*	1.95	1.94	*-0.18%*	1.94	*-0.20%*
EU27 Cropland	1.15	1.17	*1.23%*	1.17	*1.03%*	1.12	1.14	*1.90%*	1.14	*1.53%*
EU27 Forest_managed	1.48	1.48	*-0.20%*	1.48	*-0.17%*	1.48	1.48	*-0.25%*	1.48	*-0.22%*
EU27 Forest_primary	0.07	0.07	*0.00%*	0.07	*0.00%*	0.07	0.07	*0.00%*	0.07	*0.00%*
EU27 Other	1.17	1.16	*-0.42%*	1.17	*-0.35%*	1.19	1.18	*-0.61%*	1.19	*-0.49%*
EU27 Pasture	0.72	0.71	*-0.89%*	0.71	*-0.73%*	0.73	0.72	*-1.41%*	0.72	*-1.10%*
USA Cropland	1.85	1.85	*0.29%*	1.85	*0.30%*	1.88	1.89	*0.30%*	1.89	*0.31%*
USA Forest_managed	3	2.99	*-0.12%*	2.99	*-0.12%*	2.99	2.98	*-0.13%*	2.98	*-0.13%*
USA Other	1.91	1.91	*-0.07%*	1.91	*-0.07%*	1.89	1.89	*-0.07%*	1.89	*-0.07%*
USA Pasture	2.4	2.4	*-0.02%*	2.4	*-0.02%*	2.41	2.41	*-0.02%*	2.41	*-0.03%*
World Pasture	33.9	33.88	*-0.05%*	33.88	*-0.05%*	33.76	33.73	*-0.07%*	33.73	*-0.07%*
World Cropland	16.53	16.57	*0.25%*	16.57	*0.24%*	16.97	17.03	*0.31%*	17.02	*0.30%*
World Other	41.35	41.34	*-0.03%*	41.34	*-0.03%*	41.59	41.58	*-0.04%*	41.58	*-0.03%*
World Managed forests	13.12	13.12	*-0.05%*	13.12	*-0.05%*	13.16	13.16	*-0.07%*	13.16	*-0.06%*
World Primary forests	24.82	24.82	*-0.02%*	24.82	*-0.02%*	24.24	24.23	*-0.02%*	24.23	*-0.02%*

The sum of direct emissions reductions implied by the European mandate is 20.5 million tons of CO2 equivalent in 2015, 34.1 million tons of CO2 equivalent in 2020. The sum of direct emissions reductions implied by a European liberalization of trade in ethanol and biodiesel is 22.5 million tons of CO2 equivalent in 2015, 38.2 million tons of CO2 equivalent in 2025. The most efficient feedstock in terms of emission reduction is sugar cane. It explains why the trade liberalization is more efficient than the mandate for reducing directly CO2 emissions. The supplementary reduction in CO2 emission is not that large: less than 10% in 2015, less than 12% in 2020.

However, as several researchers have pointed out, the production of agricultural products for non-food use in a context where demand for agricultural products is largely inelastic, implies an increase in agricultural production elsewhere (Searchinger et al, 2008, Fargione et al, 2008). This production comes from substitution with areas used for non biofuel crops or from expansion of cropland by converting new land to cultivation. The substitution effect between crops is considered neutral in terms of CO_2 emissions. However, the use of new land not cultivated before (pasture, grassland, etc)[11] generates emissions from the release of mineral carbon contained in soil. More dramatic effects occur with destruction of forests which emit larger quantities of carbon in the atmosphere. Changes in total areas which are used to compute the emissions are displayed in Table 13.

The resulting expansion of production into new land has negative impacts in terms of C02 emissions. In almost all countries, save those where production falls, this effect is found to increase CO2 emissions overall. Table 14 distinguishes between new emissions linked to the conversion of land that was previously forest (emission corresponding to deforested biomass) and those from land that had been newly cultivated (emission from mineral carbon in soil release).[12]

In terms of annual flows, these cumulative indirect effects result in increased CO2 emissions of 35 million tons per year in the case of an EU mandate in 2015, 44.7 million tons per year in 2020; 34.5 million tons per year in the case of trade liberalization in 2015 and 43.6 million in 2025.

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[11] Here we consider as new cultivated land any surface registered as non arabe land under FAO nomenclature and that is converted to cropland.

[12] The methodology for emission computation is presented in details in Annex 3.

Table 14. Indirect emissions flow related to land use (Mios tCO2eq - extra emissions are positive values)

		2015 MandateEU2_	2015 TradeLib_	2020 MandateEU	2020 TradeLib_
Net CO2 Emission from forest	**Oceania**	0.059	0.039	0.151	0.105
Net CO2 Emission from forest	**China**	0.123	0.080	0.491	0.363
Net CO2 Emission from forest	**RoOECD**	0.087	0.089	0.141	0.143
Net CO2 Emission from forest	**RoAsia**	0.066	0.062	0.094	0.087
Net CO2 Emission from forest	**Indonesia**	0.209	0.205	0.179	0.175
Net CO2 Emission from forest	**SouthAsia**	0.012	0.012	0.016	0.016
Net CO2 Emission from forest	**Canada**	0.323	0.304	0.327	0.305
Net CO2 Emission from forest	**USA**	2.734	2.726	3.092	3.081
Net CO2 Emission from forest	**Mexico**	0.068	0.063	0.110	0.101
Net CO2 Emission from forest	**EU27**	2.495	2.165	3.212	2.751
Net CO2 Emission from forest	**LACExp**	0.441	0.427	0.480	0.443
Net CO2 Emission from forest	**LACImp**	0.424	0.372	0.742	0.614
Net CO2 Emission from forest	**Brazil**	10.335	10.925	12.632	13.587
Net CO2 Emission from forest	**EEurCIS**	-0.151	-0.142	-0.182	-0.163
Net CO2 Emission from forest	**MENA**	-0.013	-0.006	0.007	0.017
Net CO2 Emission from forest	**RoAfrica**	0.846	0.757	1.322	1.184
Net CO2 Emission from forest	**SAF**	-0.002	-0.017	-0.002	-0.026
Net CO2 Emission from forest	**World**	18.055	18.061	22.811	22.783
Net CO2 Emission from cultivated soil	**Oceania**	0.288	0.267	0.308	0.285
Net CO2 Emission from cultivated soil	**China**	0.074	0.072	0.066	0.066
Net CO2 Emission from cultivated soil	**RoOECD**	0.060	0.065	0.091	0.100
Net CO2 Emission from cultivated soil	**RoAsia**	0.053	0.054	0.063	0.066
Net CO2 Emission from cultivated soil	**Indonesia**	0.095	0.095	0.098	0.098
Net CO2 Emission from cultivated soil	**SouthAsia**	0.011	0.009	0.014	0.009
Net CO2 Emission from cultivated soil	**Canada**	0.613	0.582	0.606	0.577
Net CO2 Emission from cultivated soil	**USA**	2.115	2.145	2.226	2.273
Net CO2 Emission from cultivated soil	**Mexico**	0.033	0.033	0.046	0.044
Net CO2 Emission from cultivated soil	**EU27**	6.216	5.212	9.297	7.504
Net CO2 Emission from cultivated soil	**LACExp**	1.276	1.229	1.461	1.407
Net CO2 Emission from cultivated soil	**LACImp**	0.171	0.142	0.257	0.198
Net CO2 Emission from cultivated soil	**Brazil**	4.235	4.547	5.179	5.717
Net CO2 Emission from cultivated soil	**EEurCIS**	1.278	1.419	1.493	1.604
Net CO2 Emission from cultivated soil	**MENA**	0.100	0.084	0.101	0.077
Net CO2 Emission from cultivated soil	**RoAfrica**	0.294	0.265	0.465	0.419
Net CO2 Emission from cultivated soil	**SAF**	0.053	0.234	0.079	0.350
Net CO2 Emission from cultivated soil	**World**	16.965	16.452	21.852	20.795
Total	**World**	35.021	34.513	44.663	43.579

Globally, based on total impact on CO2 emissions, the mandate is projected to have a negative impact on the environment (see Table 15). If we combine the positive direct and negative indirect effects we find that overall it results in an increase in CO2 emissions of 14.5 million tons of CO2eq per year in 2015 and 10.6 in 2020. The trade liberalization scenario is also projected to have an aggregate negative impact as the indirect land use effect tends to dominate the direct effect: +12.0 million tons of CO2eq per year in 2015, and only +5.4 million tons of CO2eq in 2020. However, the trade liberalization scenario generates less additional CO2 emissions because it shifts emphasis to a more emission-efficient feedstock, sugarcane.

Table 15. Direct emissions effect of biofuel use and Indirect emissions related to land use implied by various European policies (Mios tCO2eq - extra emissions are positive values)

	2015 Mandate	2015 TradeLib'n	2020 Mandate	2020 TradeLib'n
Direct effect	-20.48	-22.45	-34.13	-38.20
Indirect effect	35.02	34.51	44.66	43.58
Total	14.54	12.06	10.53	5.38

5.3 Promotion of different feedstocks for the production of ethanol.

This part is aimed at differentiating the effects of ethanol feedstocks and illustrating the impacts of policies discriminating between these crops.[13] These effects are evaluated as marginal shocks applied on the mandate scenario presented in previous subsections. The consumption of a specific feedstock for biofuel production is subsidized by a small extra amount (5% of additional tax cut or subsidy), which increases the use of this feedstock in the mandate scenario. The marginal effect of each feedstock is then computed as the additional impact generated by 1 extra Mtoe of ethanol generated through this type of extra subsidy (adjusted marginal effect).[14]

We therefore consider the marginal effect of subsidizing wheat, maize and sugar beet in the EU domestic ethanol production.

The results illustrate how different crop effects are on the different economic and environmental variables. We compare the impact of this extra subsidy to a full mandate reference situation in 2020. In this reference situation, feedstocks are used in the following proportions in 2020: 46% for wheat, 37% for sugar and 15% for maize. The total quantity of ethanol produced is assumed to be 14.5 Mtoe for the EU.

The first interesting fact concerning marginal effect is that a same subsidy shock leads to different variation of domestic production of ethanol. Indeed, as illustrated by 0, production increases by 1.6% when wheat is subsidized, whereas it augments by 1.1% for corn and by 0.7% for sugar beet. It is therefore necessary to adjust the marginal variation in order to get an effect amounting to one Mtoe extra ethanol produced through subsidization of the selected crop.

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[13] We only address the case of ethanol because oilseeds and vegetable oil types are not explicitly represented for biodiesel in this version of the model.

[14] Because no precise data is available concerning the elasticity of substitution between different ethanol feedstocks, we do not present in this part the additional level of subsidy that should be used to generate this extra Mtoe of ethanol with the selected crop. We rather focus on the effect of using an additional share of crop for biofuel use and the associated impacts of this change. The substitution here is assumed with an elasticity of 2, which allows for a surge in the marginally subsidized crop without reducing too dramatically the aggregated biodiesel price.

Table 16. **Marginal change in ethanol production corresponding to subsidisation of a specific crop (Mtoe)**

		2020 Mandate Lev	2020 Wheat Subs Lev	2020 Wheat Subs Real var	2020 Wheat Subs Marginal adj. var	2020 Maize Subs Lev	2020 Maize Subs Real var	2020 Maize Subs Marginal adj. var	2020 Sugar Subs Lev	2020 Sugar Subs Real var	2020 Sugar Subs Marginal adj. var
Ethanol	**Oceania**	0.79	0.79	*-0.25%*	*-1.06%*	0.79	*-0.15%*	*-1.01%*	0.79	*-0.11%*	*-1.03%*
Ethanol	**China**	6.43	6.42	*-0.03%*	*-0.14%*	6.43	*-0.02%*	*-0.12%*	6.43	*-0.01%*	*-0.14%*
Ethanol	**RoOECD**	1.06	1.05	*-1.17%*	*-5.00%*	1.05	*-0.76%*	*-5.01%*	1.06	*-0.52%*	*-5.12%*
Ethanol	**RoAsia**	1.32	1.32	*-0.02%*	*-0.08%*	1.32	*-0.01%*	*-0.08%*	1.32	*-0.02%*	*-0.20%*
Ethanol	**Indonesia**	0.99	0.99	*0.00%*	*0.00%*	0.99	*0.00%*	*0.00%*	0.99	*-0.01%*	*-0.14%*
Ethanol	**Malaysia**	0.20	0.20	*-0.03%*	*-0.11%*	0.20	*-0.02%*	*-0.12%*	0.20	*-0.01%*	*-0.06%*
Ethanol	**SouthAsia**	9.84	9.82	*-0.12%*	*-0.51%*	9.83	*-0.08%*	*-0.51%*	9.83	*-0.05%*	*-0.53%*
Ethanol	**Canada**	0.77	0.77	*-0.01%*	*-0.03%*	0.77	*-0.01%*	*-0.05%*	0.77	*0.00%*	*-0.02%*
Ethanol	**USA**	47.86	47.82	*-0.08%*	*-0.36%*	47.83	*-0.06%*	*-0.37%*	47.84	*-0.04%*	*-0.35%*
Ethanol	**Mexico**	0.33	0.33	*-0.15%*	*-0.62%*	0.33	*-0.09%*	*-0.61%*	0.33	*-0.06%*	*-0.57%*
Ethanol	**EU27**	14.49	14.73	*1.62%*	*6.90%*	14.65	*1.05%*	*6.90%*	14.60	*0.71%*	*6.90%*
Ethanol	**LACExp**	0.20	0.20	*-0.06%*	*-0.26%*	0.20	*-0.04%*	*-0.26%*	0.20	*-0.03%*	*-0.27%*
Ethanol	**LACImp**	3.92	3.88	*-0.99%*	*-4.23%*	3.90	*-0.65%*	*-4.25%*	3.90	*-0.46%*	*-4.49%*
Ethanol	**Brazil**	22.62	22.53	*-0.38%*	*-1.62%*	22.56	*-0.25%*	*-1.63%*	22.58	*-0.17%*	*-1.69%*
Ethanol	**EEurCIS**	5.80	5.79	*-0.18%*	*-0.79%*	5.80	*-0.07%*	*-0.49%*	5.80	*-0.05%*	*-0.52%*
Ethanol	**MENA**	2.52	2.51	*-0.21%*	*-0.90%*	2.52	*-0.07%*	*-0.44%*	2.52	*-0.05%*	*-0.47%*
Ethanol	**RoAfrica**	0.91	0.90	*-0.84%*	*-3.58%*	0.90	*-0.54%*	*-3.57%*	0.90	*-0.39%*	*-3.81%*
Ethanol	**SAF**	1.86	1.85	*-0.50%*	*-2.12%*	1.85	*-0.33%*	*-2.17%*	1.85	*-0.22%*	*-2.14%*

Note: "Real var" designates real variation resulting from the 5% shock of subsidy. "Marginal adj var" designates the marginal variation after being adjusted to correspond to a 1 Mtoe increase under a specific crop subsidy.

This marginal increase in one feedstock induces different direct and indirect effects for CO2 emissions. 0 indicates the direct marginal emissions related to the additional use of a specific feedstock in 2020 while 0 gives the indirect marginal emissions.

The direct effect of using additional feedstock clearly appears in 0 which also shows that the consumption of extra domestic subsidized feedstock generates less consumption of other type of feedstocks. Indeed, the subsidization makes other domestic feedstocks less attractive but also diminishes the imports of ethanol produced abroad. This relaxes the demand for foreign feedstocks. This makes the total direct effect more ambiguous than if it was driven only by the additional consumption of a single feedstock. The environmental effectiveness of each crop is related to the reduction coefficient used and to the substitution with other feedstocks in response to relative price changes. As we used reduction coefficient from the EU directive, the hierarchy of feedstock is not surprising. Maize is the most efficient crop (-56% of savings according to the Directive), then comes sugar beet (-48% of savings) and last is wheat (-45%).

Table 17. Direct marginal emissions related to the use of a specific feedstock (tCO2eq)

		2020 Mandate Lev	2020 Wheat Subs Lev var	2020 Wheat Subs Marginal adj. Var	2020 Maize Subs Lev var	2020 Maize Subs Marginal adj. Var	2020 Sugar Subs Lev var	2020 Sugar Subs Marginal adj. Var
World	**Ethanol - Wheat**	-13527824	-596375	18.80%	68748	-3.35%	161717	-11.66%
World	**Ethanol - Maize**	-46382759	165011	-1.52%	-317025	4.50%	81077	-1.71%
World	**Ethanol - Sugar Beet**	-9007240	207654	-9.83%	15779	-1.15%	-363827	39.41%
World	**Ethanol - Sugar Cane**	-35404559	129398	-1.56%	79100	-1.47%	37444	-1.03%
World	**Ethanol - Other Crops**	-182485	1020	-2.38%	504	-1.82%	466	-2.49%
World	**Ethanol - Total**	-104504867	-93293	0.38%	-152895	0.96%	-83123	0.78%
World	**Biodiesel - Soya**	-11381128	-5611	0.21%	-3815	0.22%	-1437	0.12%
World	**Biodiesel - Palm Oil**	-1173667	-222	0.08%	-155	0.09%	-101	0.08%
World	**Biodiesel - Rapeseed**	-10508477	873	-0.04%	685	-0.04%	-656	0.06%
World	**Biodiesel - Total**	-23063272	-4961	0.09%	-3285	0.09%	-2194	0.09%
	TOTAL	-127568139	-98254	0.33%	-156180	0.81%	-85317	0.65%

Note: “Lev var” designates difference between the mandate scenario and the mandate + 5% subsidy scenario on the selected crop. “Marginal adj var” designates the marginal variation after being adjusted to correspond to a 1 Mtoe increase under a specific crop subsidy.

Indirect effects are very different among crops. Subsidizing wheat or corn has no strong indirect effect because the elasticity of supply for this feedstock is low at the world level and this feedstock can be produced through substitution effect. This is not the case for sugar beet which is little traded, and producers tend to import directly ethanol rather than processed sugar. As a consequence, the environmental effect of subsidizing wheat or maize is positive whereas it is negative for sugar beets in terms of indirect emissions.

Table 18. Indirect marginal emissions flows implied by the use of a specific feedstock (tCO2eq - extra emissions are positive values)

		2020 Mandate Level	2020 Wheat Subs Lev var	2020 Wheat Subs Marginal adj. Var	2020 Maize Subs Lev var	2020 Maize Subs Marginal adj. Var	2020 Sugar Subs Lev var	2020 Sugar Subs Marginal adj. Var
Net CO2 Emission from forest	**Oceania**	243531	-6581	*-11.53%*	3610	*9.76%*	12134	*48.61%*
	China	793405	1260	*0.68%*	2620	*2.17%*	19447	*23.91%*
	RoOECD	227259	605	*1.14%*	-929	*-2.69%*	607	*2.61%*
	RoAsia	151154	272	*0.77%*	-146	*-0.64%*	1232	*7.95%*
	Indonesia	288515	390	*0.58%*	-96	*-0.22%*	770	*2.60%*
	SouthAsia	26406	-168	*-2.71%*	-183	*-4.57%*	-21	*-0.77%*
	Canada	527520	4410	*3.57%*	-588	*-0.73%*	1	*0.00%*
	USA	4995189	2397	*0.20%*	1861	*0.25%*	5436	*1.06%*
	Mexico	177627	-902	*-2.17%*	-126	*-0.47%*	1639	*9.00%*
	EU27	5188693	-13001	*-1.07%*	-18414	*-2.34%*	102369	*19.25%*
	LACExp	775339	1285	*0.71%*	417	*0.35%*	3036	*3.82%*
	LACImp	1197847	-11449	*-4.08%*	-9496	*-5.22%*	1692	*1.38%*
	Brazil	20405887	-6540	*-0.14%*	4924	*0.16%*	1944	*0.09%*
	EEurCIS	-295501	-382	*0.55%*	1042	*-2.32%*	1389	*-4.59%*
	MENA	10960	-1924	*-74.86%*	425	*25.50%*	922	*82.04%*
	RoAfrica	2133758	5258	*1.05%*	-2851	*-0.88%*	11774	*5.38%*
	SAF	-3079	1070	*-148.20%*	765	*-163.63%*	632	*-200.13%*
	World	36844509	-24000	*-0.28%*	-17167	*-0.31%*	165002	*4.37%*
Net CO2 Emission from cultivated soil	**Oceania**	323572	6289	*8.29%*	-1751	*-3.56%*	-2345	*-7.07%*
	China	68978	681	*4.21%*	-532	*-5.08%*	-1014	*-14.34%*
	RoOECD	95403	432	*1.93%*	-497	*-3.43%*	-474	*-4.85%*
	RoAsia	66454	-97	*-0.62%*	-54	*-0.54%*	118	*1.73%*
	Indonesia	103045	89	*0.37%*	28	*0.18%*	45	*0.43%*
	SouthAsia	15103	1119	*31.59%*	168	*7.34%*	-77	*-4.97%*
	Canada	636670	5067	*3.39%*	-728	*-0.75%*	-582	*-0.89%*
	USA	2337186	3806	*0.69%*	-1346	*-0.38%*	-2129	*-0.89%*
	Mexico	47854	148	*1.32%*	-178	*-2.45%*	31	*0.64%*
	EU27	9761720	-15273	*-0.67%*	-17602	*-1.19%*	212775	*21.27%*
	LACExp	1534026	2577	*0.72%*	2857	*1.23%*	-454	*-0.29%*
	LACImp	270306	-6473	*-10.21%*	-4206	*-10.24%*	-1821	*-6.57%*
	Brazil	5437886	-4326	*-0.34%*	1498	*0.18%*	-1475	*-0.26%*
	EEurCIS	1567410	7117	*1.94%*	-5283	*-2.22%*	371	*0.23%*
	MENA	106210	3389	*13.61%*	-713	*-4.42%*	-681	*-6.26%*
	RoAfrica	488427	1183	*1.03%*	-569	*-0.77%*	1522	*3.04%*
	SAF	82814	-8277	*-42.63%*	-5783	*-45.97%*	-3623	*-42.68%*
	World	22943065	-2550	*-0.05%*	-34691	*-1.00%*	200186	*8.51%*
Total	**World**	59787574	-26550	*-0.19%*	-51858	*-0.57%*	365187	*5.96%*

Note: “Lev var” designates the difference between the mandate scenario and the mandate +5% subsidy scenario on the selected crop. “Marginal adj var” designates the marginal variation after being adjusted to correspond to a 1 Mtoe increase under a specific crop subsidy.

The total variation (Table 19) reflects the trends observed for direct and indirect marginal effects. Use of extra wheat and extra corn for ethanol appears as preferable feedstocks in terms of total environmental effects. They can be provided from the international market at lower costs, where as intensification of sugar beet production generates more pressure on land cultivation in the EU. Maize appears particularly efficient (+5.1% of saving on the mandate per additional Mtoe, instead of 2.0% for wheat) because it is assumed to generate more direct savings (-56% for EU maize vs -45% for EU wheat).

Table 19. Variation of total emissions from a marginal increase in a selected ethanol feedstock (tCO2eq)

	2020 Mandate Level	2020 Wheat Subs Level var	2021 Wheat Subs Marginal adj. Var	2020 Maize Subs Level var	2020 Maize Subs Marginal adj. var	2020 Sugar beet subs Level var	2020 Sugar beet subs Marginal adj. var
Oceania	570747	3539	*2.64%*	4227	*4.88%*	11425	*19.53%*
China	928162	2763	*1.27%*	2538	*1.80%*	18795	*19.76%*
RoOECD	242601	11498	*20.22%*	5359	*14.54%*	4841	*19.47%*
RoAsia	251208	578	*0.98%*	67	*0.18%*	1848	*7.18%*
Indonesia	395605	463	*0.50%*	-78	*-0.13%*	871	*2.15%*
Malaysia	-606	0	*0.13%*	0	*0.15%*	0	*0.11%*
SouthAsia	-23244	26442	*-485.21%*	16565	*-469.15%*	11558	*-485.14%*
Canada	1176958	9500	*3.44%*	-1286	*-0.72%*	-576	*-0.48%*
USA	6814476	37407	*2.34%*	21097	*2.04%*	16318	*2.34%*
Mexico	226730	-401	*-0.75%*	-80	*-0.23%*	1812	*7.80%*
EU27	-16594853	-313072	*8.05%*	-308674	*12.25%*	148686	*-8.74%*
LACExp	2311419	3917	*0.72%*	3309	*0.94%*	2605	*1.10%*
LACImp	702853	64810	*39.33%*	40190	*37.64%*	38279	*53.13%*
Brazil	25838352	-9454	*-0.16%*	7436	*0.19%*	1077	*0.04%*
EEurCIS	1364581	14649	*4.58%*	-2176	*-1.05%*	3240	*2.32%*
MENA	178751	5672	*13.53%*	362	*1.33%*	703	*3.84%*
RoAfrica	2553633	16953	*2.83%*	3379	*0.87%*	18234	*6.97%*
SAF	43221	-68	*-0.67%*	-275	*-4.19%*	157	*3.55%*
World	26980595	-124804	*-1.97%*	-208039	*-5.08%*	279870	*10.12%*

Note: Marginal var designates the adjusted "marginal variation" corresponding to a 1 Mtoe increase under a specific crop subsidy. It corresponds to the variation between the two "Level" rows divided by the variation of ethanol production.

5.4 Sensitivity Analysis

We undertake this analysis under different sets of assumptions. This allows us to evaluate which parameters are important for the results and to take into account the uncertainty which characterizes the estimation of some of the behavioral parameters of the study. This is particularly important as we cannot infer strict policy recommendations from this study in terms of environmental impact: as we will see the conclusions are much dependent on the choices that we have to make about two parameters on which it is rather difficult to gather precise information needed to feed a worldwide model.

The sensitivity analysis for the study concerns two key dimensions. Firstly the elasticity of land supply in developing countries, and secondly the elasticity of substitution between land and fertilizers. If land supply is inelastic and in case of increased demand if farmers use more fertilizers, the production processes become more intensive and we can expect more limited indirect land use effects from European biofuel policies. On the contrary if land supply is elastic and thus the use of fertilizers inelastic, indirect land use effects should be large.

A first set of results has been established under a central case study where these parameters are given their most relevant values. The parameters on fertilizers elasticity were based on IFPRI's partial equilibrium model IMPACT. The IMPACT information is interesting because of the distribution of these parameters across regions and crops. However, because we use these elasticities in a dynamic CGE framework, we had to revise the absolute values of these estimates downwards to take into account the saturation effect in fertilizer use. That is why elasticities for developed countries were set very low in the central case (close to 0.05).

Another feature of this central case was a low level of land supply elasticity around the world. Two sets of countries were distinguished, one keeping a low elasticity of land supply because of limited arable land availability, the other with a higher level of land supply elasticity, due to extended land availability and the restrictions imposed by environmental protection measures. In the central case study (subsection 5.1), these elasticities were set at 0.05 and 0.1.

Table 20. Variation of land use per sector (thousand ha) – Impact of the European mandate and trade liberalisation in 2020 under three scenarios – SC for Central Scenario

		2020			2020		
		Mandate			TradeLib'n		
		SC	F+	L+	SC	F+	L+
Wheat	**USA**	*-0.82%*	*-0.21%*	*-0.69%*	*-1.13%*	*-0.69%*	*-1.00%*
Wheat	**EU27**	*3.90%*	*3.64%*	*3.78%*	*2.75%*	*2.21%*	*2.60%*
Wheat	**LACExp**	*-1.97%*	*-1.07%*	*-1.12%*	*-2.20%*	*-1.46%*	*-1.40%*
Wheat	**LACImp**	*0.20%*	*0.37%*	*0.49%*	*0.11%*	*0.19%*	*0.34%*
Wheat	**Brazil**	*-4.65%*	*-2.53%*	*-2.19%*	*-5.83%*	*-4.18%*	*-3.51%*
Maize	**USA**	*-1.44%*	*-1.16%*	*-1.28%*	*-1.06%*	*-0.76%*	*-0.94%*
Maize	**EU27**	*3.73%*	*3.21%*	*3.61%*	*2.53%*	*1.93%*	*2.39%*
Maize	**LACExp**	*-1.13%*	*-0.78%*	*-0.34%*	*-1.15%*	*-0.79%*	*-0.42%*
Maize	**LACImp**	*-0.13%*	*-0.10%*	*0.14%*	*-0.09%*	*-0.07%*	*0.12%*
Maize	**Brazil**	*-2.67%*	*-2.08%*	*-0.74%*	*-2.95%*	*-2.35%*	*-0.98%*
OilseedBio	**USA**	*4.36%*	*3.25%*	*3.90%*	*4.29%*	*3.23%*	*3.86%*
OilseedBio	**EU27**	*15.88%*	*15.30%*	*15.67%*	*16.54%*	*16.03%*	*16.34%*
OilseedBio	**LACExp**	*3.74%*	*2.71%*	*4.30%*	*3.75%*	*2.77%*	*4.30%*
OilseedBio	**LACImp**	*1.74%*	*1.28%*	*1.80%*	*1.78%*	*1.32%*	*1.80%*
OilseedBio	**Brazil**	*7.91%*	*6.16%*	*11.03%*	*7.28%*	*5.59%*	*10.43%*
Sugar_cb	**USA**	*-1.05%*	*-0.87%*	*-0.93%*	*-1.03%*	*-0.82%*	*-0.91%*
Sugar_cb	**EU27**	*15.88%*	*13.31%*	*15.92%*	*8.36%*	*6.39%*	*8.18%*
Sugar_cb	**LACExp**	*-0.86%*	*-0.74%*	*-0.11%*	*-0.70%*	*-0.54%*	*0.00%*
Sugar_cb	**LACImp**	*0.79%*	*0.66%*	*1.14%*	*0.31%*	*0.27%*	*0.52%*
Sugar_cb	**Brazil**	*-0.35%*	*-0.31%*	*1.70%*	*4.16%*	*4.24%*	*6.73%*

We now undertake two sensitivity analyses. The first considers the hypothesis of a relatively high elasticity of substitution between land and fertilizers (closer to the actual IMPACT model values): this is scenario F+. This would give estimates of the impact of European biofuel policies when production processes in agriculture are more prone to become more intensive in response to increased agricultural prices. The second incorporates larger cross-country variability in terms of the elasticity of land supply. In this analysis, we envisage a case where rich countries/regions have the same land supply elasticity while poor countries see this elasticity multiplied by 5 between 0.25 and 0.5: this is scenario L+. The idea is that land supply is regulated by agricultural policies and therefore responds in only a limited way to changes in prices in rich countries, while in developing countries, land supply can be much more reactive to prices.

Table 20 shows the results for the sensitivity analysis for the four products most affected by the biofuels policies. It is evident that land use increases more in developing countries under a more elastic land supply assumption.

Under the mandate, for example, Brazilian oilseeds sees an 11% increase in land use compared to 7.9% in the central scenario (SC). In consequence, the increase in land use in the EU is reduced under this scenario, especially for oilseeds.

Looking at the scenario of greater substitution between land and fertilizers (F+), the differences are less striking, although, in general, this assumption would result in slightly lower land use than the central scenario, particularly in the oilseeds for biodiesel sector. For example, the mandate entails an increase of the land use for oilseeds for biodiesel by 15.3% in Europe in 2020 under an increased elasticity of substitution between land and fertilizers, instead of 15.9% in the central scenario.

Under the trade liberalization policy shock, we see once again that, especially in the sector where the impact is the greatest – sugar – the change in land use is higher in the central scenario than in L+ for the EU and the inverse is true for developing countries.

Looking at scenario F+ we see once more lower increases in land use than in the central scenario. For example, land allocated to sugar in the EU increases by ‘only’ 6.4% compared to 8.4% in the central scenario, while in Brazil the increases are 4.2% and 6.7%, respectively.

Although the implications of these changes in percentage terms may seem rather small, the implied differences in CO2 emissions are large, especially between the central scenario and the L+ scenario, where displacement of forests results in significant supplementary emissions. Calculating the indirect effects of CO2 emissions on the basis of these figures results in emission levels in L+ scenario which are almost 2.4 times those in the central scenario (see Table 21). The effect is particularly large as far as net CO2 emission from forest is concerned. In contrast, the emissions are lower in F+, but not significantly (nearly by 20%).

Table 21. Indirect land use emissions related to land use change at the World level (Mio tCO2eq - extra emissions are positive values) – Three scenarios – 2025

			2020	2020	
			SC	F+	L+
MandateEU2_	**Net CO2 Emission from forest**	**World**	22.8	18.4	68.1
MandateEU2_	**Net CO2 Emission from cultivated soil**	**World**	21.9	18.3	36.8
TradeLib_	**Net CO2 Emission from forest**	**World**	22.8	18.5	68.8
TradeLib_	**Net CO2 Emission from cultivated soil**	**World**	20.8	17.2	35.9

On the other side direct emissions do not remain constant under these alternative set of parameter values. But they do not change that much. Table 22 combines direct and indirect emission effects for the sensitivity scenarios. It clearly illustrates how marginal are changes in direct effects from one set of parameter values to the other: the mandate implies a reduction in direct CO2 emissions by 34 Mios tons in 2020, while this figure is close to 38.5 Mios as far as the trade liberalisation scenario is concerned. While the supplementary CO2 emissions related to indirect land use effect are reduced by 20% (from 44.7 Mios down to 36.6) when considering a higher value for land – fertilizer elasticity, they are multiplied by 2.5 when the land supply elasticity is increased: considering a relatively high value for this parameters entails an augmentation of 60 Mios tCO2eq of emissions, two-thirds of this amount coming from deforestation in Brazil (+40 Mios tCO2eq) and 20% from new net emissions from cultivated soils (+12 Mios tCO2eq). Therefore agriculture in Brazil causes around 86% of these supplementary net CO2 emissions related to indirect land use change.

In conclusion, the sensitivity analysis indicates that the evaluated impact of European policy shocks on CO2 emissions, according to the methodology used in this study is indeed sensitive to the elasticity of land supply in developing countries, less sensitive to the elasticity of substitution between land and fertilizers. However these assumptions do not generally change the direction of the results although they do change their magnitude. Most specifically, the assumption of relatively low elasticity of supply in land in developing countries may underestimate indirect land use effects on CO2 emissions significantly.

Table 22. Direct emissions effect of biofuel use and Indirect emissions related to land use implied by various European policies (Mios tCO2eq - extra emissions are positive values)

	Central Scenario		F+		L+	
	2020 Mandate	2020 TradeLib'n	2020 Mandate	2020 TradeLib'n	2020 Mandate	2020 TradeLib'n
Direct effect	-34.13	-38.20	-34.52	-38.53	-34.42	-39.20
Indirect effect	44.66	43.58	36.62	35.66	104.82	104.66
Total	10.53	5.38	2.10	-2.87	70.41	65.46

5.4 Comparison of results with other studies

In this section we provide a brief comparison of our results with those obtained by other similar studies.

This study finds that the impact of biofuel programs on world prices is found to be negligible. Only oilseeds for biodiesel and sugar cane/sugar beet experience a non-marginal increase in their world prices of between 3 and 4% in 2015 depending on the policy shocks, while the increase is less than 1% for other crops. These results are close to those obtained by Hertel et al. (2008)[15] and Banse et al. (2008), while they differ significantly from results obtained through partial equilibrium models (Rosegrant, 2008) or 'back of the envelope' calculations (Mitchell, 2008). These latter studies found biofuel programs to have a very substantial impact on world agricultural prices. This could be attributed to the fact that that CGE assessments do not account for short to medium term imbalances and dynamics, but focus on long run equilibrium, where markets work efficiently and react fully to shocks. However, our results do confirm the fact that the largest impact of biofuels on world agricultural prices will be in the oilseeds sector.

In terms of crop production, we find a substantial increase in the production of oilseeds (for biodiesel) and sugar beets, and less so for wheat (for ethanol) in Europe and in Brazil, with results varying across policy shocks. This also agrees with the results obtained by Hertel et al. (2008) and Banse and al. (2008). The order of magnitude varies however, reflecting different policy shocks and different behavioral parameters. For example, Hertel et al.(2008) find an increase of 50% in oilseed production in Europe in 2015 thanks to the mandate while in our study oilseed production increases only by 19.5% by the same date. In the same way, we find a significant increase in agricultural cropland used for biofuels and a very substantial increase in European imports of ethanol as found in Boeters et al. (2008). We also confirm an important conclusion in terms of environmental policy: the most efficient means to reduce CO2 emissions is through trade liberalization, as it encourages the production of biofuels from the most efficient crop: sugar cane in Brazil. This was also a major conclusion of OECD (2008).

Our study shows that European support for production and/or consumption of biofuels can have substantial impact on land use. In particular the European mandate is found to result in an increase of more than 15% in

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[15] Results on prices are not outlined in Hertel et al. (2008)' paper, but at the GTAP conference in Helsinki during presentation of his work Tom Hertel conceded that the impact of biofuel support programs on world agricultural prices are not evaluated as significant according to the modeling done.

land used for oilseeds for biodiesel and for sugar beets. This result is very similar to the conclusions of both Eickhout et al (2008) and the OECD (2006). The latter study concluded that the EU biofuels mandate will require two-thirds of the land area currently harvested for oilseeds, cereals and sugar. Our study confirms this point as far as oilseeds is concerned while we conclude that the share of land acreage used for biofuel production would reach only one quarter in the case of wheat and one third in the case of sugar beets in 2020 in Europe. However OECD (2006) acknowledges a significant bias in their methodology in that they fail to take into account the impact of trade and technological improvements. These elements could explain the differences in these studies. Finally, it is noteworthy that our study's results in terms of total land used for crops and/or pasture looks much more conservative than that found in Hertel et al. (2008). Once again this may reflect differences in methodological choices as in their model the potential land sources of increased production of feedstock for biofuels to pastureland or forests are restricted. In that sense our results could be considered as more realistic. Moreover, our study confirms that an important element to be considered is whether or not increased agricultural prices result in increased use of fertilizers and thus to a substantial increase in yields. However the order of magnitude revealed by the sensitivity analysis on this issue is not that large: the impact on land use of an increase in the elasticity of substitution between land and fertilizers is not very substantial.

Finally our study confirms the reservations expressed by de Santi (2008), Searchinger et al (2008), Mortimer (2008) and the Gallagher review (2008) that the expansion of the production of biofuels may ultimately be detrimental in terms of CO2 emissions, as indirect land use effect are greater than direct effects. As stated previously, we do not take into account by-products like DDGS in our study and uncertainty remains about the value of critical parameters like the elasticity of substitution between land and fertilizers in the process of agricultural production. This important conclusion must therefore be seen in this light and the results treated with prudence.

In conclusion, our findings do not differ significantly from the economic literature even if it is difficult to compare results coming from different methodologies, databases and behavioral parameters.

6. Conclusions

This study has assessed the implications of a European mandate on biofuels incorporated in fuels for transportation with targets of 5% in 2010 and 10% in 2020. It has focused on the consequences on agricultural production and prices, agricultural value-added, welfare, land use and CO2 emissions. Different means of achieving this mandate have been studied. Firstly through a simple blending obligation; secondly through a trade liberalization scenario.

Our results indicate that a European mandate could have a clear stimulation effect on world production of biofuels and agricultural feedstocks. It is projected to increase the production of ethanol and biodiesel particularly in Europe and of oilseeds, sugar cane and sugar beet in numerous countries. Production of oilseed crops is especially encouraged by an implementation of these policies. Agricultural value-added is likely to be very positively affected. Moreover it has implications for land use. In particular EU support for biofuel production could imply a significant reallocation of land in favor of sugar cane/sugar beet for ethanol and oilseeds for biodiesel sectors, in Europe and/or in South America. For example, in the European Union, land allocated to the cultivation of sugar beet could be increased by 11% under an EU mandate, while in Brazil land for sugar cane could be increased by 3.5% under an EU trade liberalization scenario.

In terms of world agricultural prices, we do not find a substantial impact from programs supporting the biofuel sectors in the European Union. This conclusion is similar to the results obtained by other studies using CGE models, like Hertel et al. (2008) or Banse et al. (2008), and are very different from the conclusions obtained by studies using a partial equilibrium approach or 'back-to-the-envelope' calculations, which have tended to find a strongly positive impact of biofuels policies on agricultural commodity prices.

In terms of the environmental impacts of these changes, the direct effects of biofuels policies in terms of CO2 emissions are usually positive while indirect effects are negative. However, the indirect land use effects of the various policies are usually high enough to offset the direct emissions reduction effects. Thus if the direct and indirect CO2 emissions changes are combined, the mandate is forecast to result in an additional increase in CO2 emissions of 14.5 million tons of CO2eq in 2015 and 10.5 millions in 2020. The trade liberalization scenario is less negative, as this is forecast to lead to an increase in global emissions of CO2eq by 12.0 million tons a year in 2015 and 5.4 million in 2020. The trade liberalization scenario is more efficient in terms of the impact on direct emission reduction as it stimulates more ethanol production from more efficient sources, especially sugar cane.

The results in this draft report must nevertheless be treated with caution for several reasons.

Firstly they are based on a global database that still needs improvement. The development of new sectors like ethanol, biodiesel, corn, oilseeds for biodiesel, fossil fuel, fertilizers for all regions is a huge task, which is very demanding in terms of information gathering. While the expanded database used in this study has gone further in scope than other similar CGE-based assessments of biofuel policies, it still needs further development and refinement.

Second the modeling of land use, land supply and demand for energy has been improved as compared to the previous version of the MIRAGE model. It is grounded on some careful choices that are nevertheless imperfect and on some reasonable but still rather arbitrary choices for critical parameters, like the elasticity of land mobility, the elasticity of land supply and the elasticities of substitution between land and fertilizers in agricultural production. Current knowledge within the field of agricultural and international economics does not provide more robust values of these critical parameters and this study has shown that a change in the value of these parameters can significantly impact on the results. Moreover, even if we get more reliable information on these parameters, Armington elasticities also play an important role as the expansion of the European biofuels sector will require more feedstock and consequently implies a substantial increase in European imports of agricultural commodities. The parameters which govern such developments are not perfectly known and a change in the geographical structure of European imports of agricultural feedstocks may have a decisive role in the environmental efficiency of European biofuels policies.

This study is also grounded in numerous specific assumptions and necessary simplifications in the modeling process. The by-products of biofuel production and second generation biofuels are not included in this evaluation. The expansion of ethanol production could imply a parallel expansion in the production of by-products (such as DDGS), which would reduce the pressure on demand for land as DDGS constitutes a source for animal feed. Inclusion of second generation biofuels could change the picture in terms of the impact of these policies on the environment and on agricultural markets quite drastically. The modeling does not account for intertemporal representation of forest management behavior, nor of water management, nor of distinctions between intensive and extensive pasture management. These elements are important in the debate about the economic and environmental impact of biofuels and inevitably mean that our conclusions are tentative.

Nevertheless, we believe that this study brings worthwhile insights into the debate. In particular it improves our understanding of the effects of biofuels on agricultural markets and the environment. It also improves the existing databases that are critical to the study of this issue. At the same time it is important to acknowledge that the study of the implications of biofuels policies on trade, agricultural production and environment needs further research in order to fully understand all these linkages at the global levels. The interactions are complex and, in some cases, only imperfectly understood and thereby require further efforts.

ANNEXES

Annex 1. The Construction of the Global Biofuels Database

The MIRAGE general equilibrium 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. We 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.[16] The database was then modified to accommodate the sectoral changes made to the MIRAGE model for this study. Six new sectors were carved out of the GTAP sector aggregates -- the liquid biofuels sectors (ethanol and biodiesel), major feedstock sectors (maize, oilseeds used for biodiesel), the fertilizer sector, and the transport fuels sector. The modified global database with six new sectors was created by sequentially splitting existing GTAP sectors with the aid of the SplitCom software.[17]

We compiled external data for 2004 on production, trade, tariffs and processing costs of ethanol, biodiesel, maize, various oilseed crops and fertilizers for use in splitting these sectors from GTAP sectors. The primary feedstock crops used in the production of liquid biofuels in the major producing countries were identified from available literature. The input-output relationships in each biofuels producing country in the GTAP database were then examined to determine the feedstock processing sector from which the new ethanol and biodiesel sectors should be extracted. Thus, depending on the country producer, the ethanol sector was carved out either from the sugar (SGR) sector, the other food products (OFD) sector, or the chemicals, rubber and plastics (CRP) sector and then aggregated to create just one ethanol sector. Some GTAP sectors, such as OFD and CRP, were split more than once to accommodate the creation of the new sectors. Table 23shows the GTAP sectors that were split, the intermediate sectors that were created and a listing of the new and modified sectors in our new global database. The data sources, procedures and assumptions made in the construction of each new sector are described below.

Ethanol

Data on ethanol production for 2004, in millions of gallons, were obtained from industry statistics provided by the Renewable Fuels Association for annual ethanol production by country.[18] The data covers 33 individual countries plus a sum for “other countries”. Production data for the other countries were shared out to other ethanol producers based on export shares information for the ethanol exporting countries that are not covered in the production data. To be consistent with the GTAP global database which carry data in value flows, ethanol production data was converted to US$ millions using 2004 price data from the OECD (OECD, 2006) from which data on ethanol processing costs for the major ethanol producers (USA, Brazil, EU) were compiled. Bilateral trade for ethanol in 2004 was obtained from the reconciled BACI trade database which is developed and maintained at CEPII. Tariff data on ethanol were obtained from the Market Access Maps (MAcMap-HS6) database.

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[16] Detailed documentation on the GTAP 7 Database is available in Narayanan and Walmsley, Eds. (2008) and at: https://www.gtap.agecon.purdue.edu/databases/v7/v7_doco.asp.

[17] SplitCom, a Windows program developed by J.M. Horridge of the Center for Policy Studies, Monash University, Australia, is specifically designed for introducing new sectors in the GTAP database by splitting existing sectors into two or three sectors. Users are required to supply as much available data on consumption, production technology, trade, and taxes either in US dollar values for the new sector or as shares information for use in splitting an existing sector. The software allows for each GTAP sector to be split one at a time,each time creating a balanced and consistent database that is suitable for CGE analysis.

[18] See: http://www.ethanolrfa.org/industry/statistics/#EIO citing F.O. Licht. Renewable Fuels Association, Homegrown for the Homeland: Industry Outlook 2005, (Washington, DC: 2005), p. 14.

Table 23. GTAP Sector Splits and the New Sectors in the Modified Biofuels Database

GTAP Sector	Description	Intermediate Sector Splits	Final New** or Modified* Sectors
GRO	Cereal grains, nes.	MAIZ: maize	MAIZ **
		OGRO: other grains	OGRO*
OSD	Oilseeds	BOSD: biodiesel oilseeds	BOSD**
		OSDO: other oilseeds	OSDO*
SGR	Sugar	ETH2: sugar ethanol (production)	ETHA**
		SGRO: other sugar	BIOD**
OFD	Other Food Products	ETH1: grain ethanol (production)	SGRO*
		BIOD: biodiesel (production)	OFDO*
		OFDO: other OFD	B_TN*
B_T	Beverages and Tobacco	ETH1: grain ethanol (trade)	FERT**
		ETH2: sugar ethanol (trade)	CRPN*
		ETH3: other ethanol (trade)	TP_C**
		B_TN: other beverages and tobacco	OP_C*
CRP	Chemicals, Rubber, and Plastics	ETH3: other ethanol (production)	
		FERT: fertilizers	
		BIOD: biodiesel (trade)	
		CRPN: other CRP	
P_C	Petroleum and Coal	TP_C: transport fuels	
		OP_C: other fuels	

Ethanol producers were first classified according to the primary feedstock crops used in production. The input-outputs accounts in the GTAP database were then examined for each ethanol producer to determine which processing sector used a large proportion of the feedstock as intermediate input. This is then the processing sector that is split to create the ethanol sector in that country. For example, a large share of sugarcane production in Brazil goes to an established sugar ethanol processing sector, which is incorporated in GTAP's chemicals, rubber and plastic (CRP) sector in the Brazilian I-O table. Thus CRP is therefore the sector that was split in Brazil to extract the sugar ethanol sector. However, similar analysis indicated that it was the sugar processing (SGR) sector that should be split in other sugar ethanol producing countries in Latin America. Production of grain-based ethanol in the United States, Canada and in the European Union was introduced in the data by splitting the other food products (OFD) sector where wheat and cereal grain processing takes place. Table 24 shows the classification of ethanol-producing GTAP regions according to major feedstock and processing sector.

Table 24. Ethanol Producers, Major Feedstock, and Processing Sectors

GTAP Regions	Primary Feedstock	Processing Sector
New Zealand, Rest of Oceania, China, South Korea, Rest of East Asia, Canada, United States, Mexico, Czech Republic, Hungary, Poland, Spain, Croatia, Georgia, Egypt, Morocco, Nigeria, South Africa, Rest of SACU	maize	Other Food Processing (OFD)
Germany, Sweden, Switzerland, Russian Federation, Ukraine, Rest of Europe, Turkey, Rest of Western Asia	wheat	Other Food Processing (OFD)
Australia, France, Romania, Armenia, Tanzania, Uganda	sugarcane\beets	Other Food Processing (OFD)
Japan, Taiwan, Indonesia, Philippines, Thailand, Vietnam, Indian, Pakistan, Sri Lanka, Rest of South Asia, Argentina, Bolivia, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela, Rest of South America, Costa Rica, Guatemala, Nicaragua, Rest of Central America, Caribbean, Italy, United Kingdom, Belarus, Iran, Senegal, Rest of Western Africa, Rest of Central Africa, Malawi, Mauritius, Zambia, Zimbabwe, Rest of Eastern Africa	sugarcane\beets	Sugar (SGR)
Brazil	sugarcane\beets	Chemicals, Rubber and Plastics (CRP)

Total consumption of ethanol in each region was computed from the data on production, total exports and total imports. Ethanol was assumed to go directly to final household consumption and not as an intermediate input into production. Production cost data in terms of the share of feedstock, energy and other processing costs were used to construct technology matrices for ethanol. These vary by country depending on the primary feedstock used in production. The external data on consumption and production technologies (and trade) for the ethanol sector in each country were adjusted as needed depending on the value totals for each flow for the sector that was being split. For example, the production of ethanol from wheat for country X is constrained by the total value of wheat going with other food processing in the country.

The international trade of ethanol is classified in the Harmonized System (HS) under HS6 codes 270710 and 220720 which cover undenatured and denatured ethyl alcohol, respectively. We used the sum of trade for the HS6 sectors for each bilateral flow. Although ethanol production from different feedstocks is introduced spliting the appropriate food processing sectors (SGR, OFD, CRP), as guided by the input-output relationships for each region, ethanol trade is actually classified under trade of the GTAP beverages and tobacco (B_T) sector. It is the B_T sector that we split to take ethanol trade and tariff information into account.

Ethanol production (e.g. split from OFD) and ethanol trade (split from B_T) are then aggregated to create a grain ethanol sector. A similar procedure was followed to create a sugar ethanol sector from the GTAP SGR sector and the special case of sugar ethanol sector (from CRP) for Brazil. A single ethanol (ETHA) was then created by aggregating the three ethanol sectors together.

Biodiesel

Data on biodiesel production in the European Union, in million tons, were obtained from published statistics of the European Biodiesel Board.[19] Biodiesel production data for non-EU countries for 2004 was estimated based on 2007 production data for these countries, obtained from F.O. Licht[20], deflated using 2004-2007 biodiesel production average growth rate for the EU. The volume data were converted to US$ millions using

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[19] Available online at: http://www.ebb-eu. org/stats.php.

[20] As cited in OECD (2008).

2004 price data. Information on biodiesel processing costs was obtained from the OECD (2006). Data on total exports and total imports of biodiesel in 2004 were obtained by deflating 2007 biodiesel trade data in OECD (2008). Since international trade in biodiesel is a more recent phenomenon, we were not able to obtain consistent bilateral trade data for biodiesel.[21]

Unlike ethanol, the feedstock crops used in biodiesel production (e.g. rapeseed, soybeans) are all classified under one GTAP oilseeds (OSD) sector. As documented below, the OSD sector was also split to separately treat oilseed crops that are used in biodiesel production. The input-output accounts in the GTAP database were examined to determine which processing sector the feedstock primarily goes to as an intermediate input in each biodiesel production sector. Although some processing of oilseeds takes place in the GTAP vegetable oils and fats (VOL) sector in many countries, the creation of a biodiesel sector was more readily supported by splitting the OFD sector since a larger proportion of oilseeds produced in each region are used as intermediate inputs in the OFD and not the VOL sector in the EU countries.

Total consumption of biodiesel in each region was computed from the data on production, total imports and total exports. Similar to ethanol, it was assumed that biodiesel goes directly to final household consumption and not as an intermediate input into production. Production cost data in terms of the share of feedstock, energy and other processing costs were used to construct technology matrices for biodiesel. These vary by country depending on the primary feedstock used in production, in this case oilseed crops or a combination of oilseed crops and processed vegetable oils.

Trade in biodiesel is classified under HS 382490 which falls under the GTAP CRP sector. Hence, we perform a separate split for biodiesel production under OFD and biodiesel trade under CRP. These two biodiesel sectors are then aggregated into one biodiesel sector (BIOD).

Maize and Oilseeds for Biodiesel

The most important feedstock crops for biofuel production have to be treated separately in the database in order to more accurately assess the impacts of biofuels expansion on feedstock production, prices and on land use. Wheat and sugarcane\sugarbeet are both separate sectors in the GTAP database. Maize (corn) and oilseeds, however, both belong to sectors which also include crops that are not used as feedstock in biofuels production. We apply similar methodology and assumptions in introducing maize and oilseeds for biodiesel as new sectors in the database. The GTAP cereal grains (GRO) sector was split to create the maize (MAIZ) and other cereal grains (OGRO) sectors and the GTAP oilseeds (OSD) sector was split to create the oilseeds for biodiesel (BOSD) and other oilseeds (OSDO) sectors.

Maizeproduction volume and price data for 2004, as well as production data for other cereals (barley, buckwheat, canary seeds, fonio, millet, mixed grains, oats, and cereal grains, nes) were compiled from FAO Production Statistics.[22] This allowed us to compute the shares of maize production to total cereal grains production in each country. Similarly, bilateral trade data from the BACI trade database for maize and for the GTAP GRO sector allowed us to compute trade shares for maize trade to total GRO trade for each bilateral trade flow. We then used the production shares information and trade shares information to split the GRO sector into MAIZ and OGRO. We assume that the production technology for MAIZ and OGRO in each country are the same as those used for the original sector, GRO.

For oilseeds, we compile 2004 production volume and prices data from FAO Production Statistics for oilseed crops used for biodiesel production (rapeseed, soybeans, safflower seed, cottonseed, palm kernel, sunflower seed) as well as for other oilseed crops (castor oil seed, coconuts, copra, groundnuts, linseed, melonseed, mustard seed, poppy seed). Bilateral trade data for oilseeds used in biodiesel, as well for the GTAP OSD

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[21] The HS codes on which biodiesel in traded is not yet clear, especially for the United States. Bilateral trade information obtained for chemical products and preparations of the chemical or allied industries (HS code 382490) is not limited to biodiesel only and the trade values were deemed too large incompatible with the production data.

[22] Available online at: http://faostat.fao.org/site/567/default.aspx

sector, were obtained from the BACI trade database. As for the maize sector, the production share information and trade share information were used to split the OSD sector into BOSD and OSDO. We also assume that the production technology for BOSD and OSDO in each country are the same as those used for the original sector, OSD.

Fertilizer

Fertilizers are part of the large CRP sector in GTAP. A separate treatment of fertilizers is necessary to more adequately assess the implications of biofuels expansion on the interactions between fertilizers and land in crop production. The production values for 2004 for nitrogen, phosphate and potash fertilizers were obtained from production and prices data from the FAO Resource Statistics and published data.[23] Bilateral trade data for fertilizers and for the GTAP CRP sector were obtained from the BACI database. Tariff data were obtained from the 2004 MAcMap database. The fertilizer production values and trade shares information were used to split the CRP sector into FERT and CRPN. We assume that the production technologies for FERT and CRPN in each country are the same as those for the original sector, CRP. However, we assume that unlike CRPN, FERT is used only as an intermediate input in the crop production sectors.

Transport Fuel

Fuels used for transport are part of GTAP's petroleum and coal sector (P_C). A separate treatment of transport fuels is necessary to provide a better assessment of the likely substitution between transport biofuels and transport fuels from fossil fuels. Data on the value of consumption of fossil fuels[24] was used along with trade data to obtain the value of transport fuel production by country. Bilateral trade data and tariffs for transport fuel were obtained from the BACI and MAcMap databases, respectively. The transport fuel production values and trade shares information were used to split the P_C sector into TP_C and OP_C. We assume that the production technologies for TP_C and OP_C in each country are the same as those for the original sector, P_C. However, we assume that in contrast to OP_C, TP_C is the main fuel product comprising 90 percent of fuels used as intermediate input in the GTAP transport sectors (land, water and air transport) and in final household demand. TP_C and OP_C are equally split as fuel inputs used in the production of all other sectors.

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[23] FAO fertilizer production data available online at: http://faostat.fao.org/site/575/default.aspx. Price data obtained were from: http://www.farmdoc.uiuc.edu/manage/newsletters/fefo08_13/fefo08_13.html.

[24] From national fuel consumption data reported in International Fuel Prices 2005, 4th edition, available at: http://www.international-fuel-prices.com.

Annex 2. Modeling energy and agricultural processes of production

The MIRAGE model has been expanded to address its shortcomings in the energy sector and thus better adapt it to the specific needs of the study. It has been undertaken following a literature review. This review reveals the existence of two main approaches to energy modeling in the literature.

The "top-down" approach focuses on the modeling of macroeconomic activity and international trade and derives energy demand from the activity implied by this modeling. Burniaux and Truong (2002) for example develop an energy version of the GTAP model (the GTAP-E model) and use it to study the impact of alternative implementations of the Kyoto Protocol on welfare and terms of trade in eight regions of the world.

A bottom-up approach places a lot of emphasis on the technical description of the energy sector and provides a more realistic and detailed modeling of energy efficiency. It selects the most efficient process of energy production corresponding to a certain level of energy demand. For example the MEGABARE model (ABARE, 1996) makes use of the technology bundle approach which introduces substitutability between different technologies (for example between the electric arc furnace and the basic oxygen furnace in the steel industry) while the use of a specific technology implies a Leontief combination of primary factors and intermediate consumption.

Although this kind of approach is much more difficult to implement on a large scale, it provides very interesting elements. For example the substitutability of capital and energy depends on whether the model is used in a short or long term perspective. Following an energy price increase, in the short term energy and capital are complementary while in the long term a new technology could be adopted which utilizes more capital and less energy. Attention needs to be paid to this aspect.

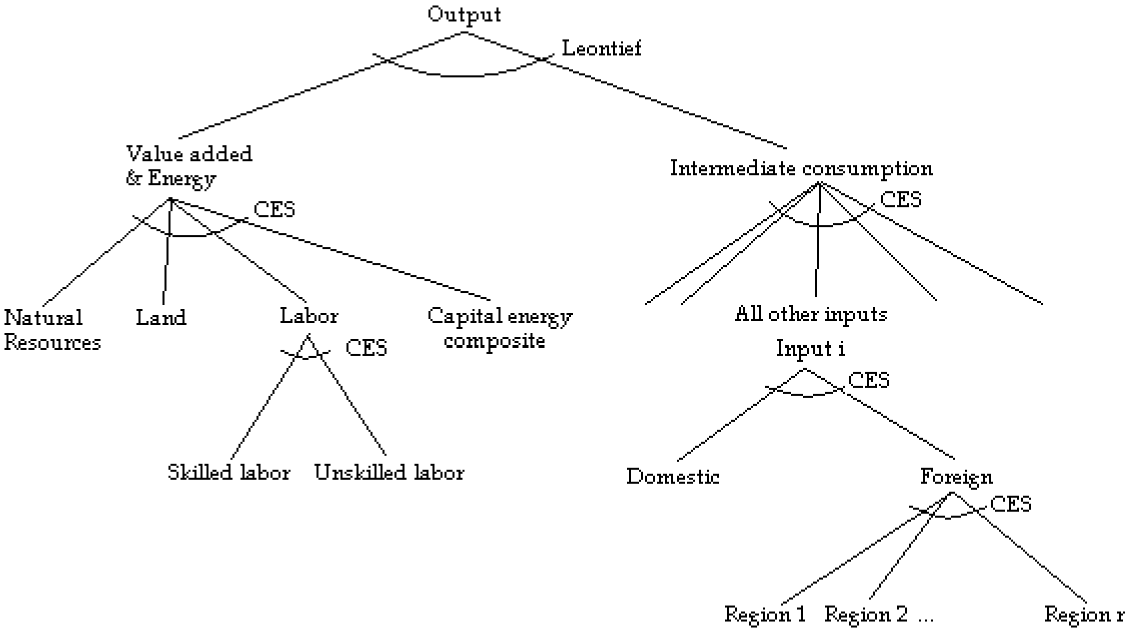
Finally it is possible to envisage combining the two approaches. The CETM model for example (Rutherford et al., 1997) manages to combine the top-down and bottom-up approach. In this model, a partial equilibrium model of the energy sector is developed and linked to a general equilibrium model through energy price and quantity variables.

The bottom-up approach is obviously much more realistic but at the same time it is very demanding in terms of both data and behavioral parameters. In addition, it has been shown that the top-down approach provides a better assessment of economic agents' actual responses to changes in prices. As this project focuses on the potential impact of biofuel mandates on world prices, exports and imports of energy and agricultural commodities and worldwide changes in land use, a top-down approach appears to be much more suitable for the purpose of this study.

The GTAP-E model is a typical example of the top-down approach. It includes a modeling of production processes as illustrated by Figures 2 and 3. This model introduces complementarity between intermediate consumption and a composite of Value-Added and Energy (see Figure 2). It is noteworthy that intermediate consumption does not include here energy inputs (gas/oil/coal/electricity/petroleum products), although it includes energy feedstock.

The details of the Value-Added and Energy composite are represented in Figure 3. This modeling approach has four main advantages. Firstly inside the energy composite, the demands for each source of energy (electricity/coal/gas/oil/petroleum products) can have different degrees of substitutability. In particular demand for gas, oil and petroleum products are relatively substitutable while demand of each of these three energy sources is only moderately substitutable with coal and electricity. Secondly in the standard GTAP model, as well as in the standard MIRAGE model capital is as substitutable with energy as skilled labor due to the inclusion of all energy inputs in the intermediate consumption branch of the nesting. In the GTAP-E model the inclusion of energy inputs in the Value Added branch of the nesting allows for the differentiation of substitutabilities. Thirdly this representation can account for the fact that investment in capital may reduce the demand for energy and that the intensity of this relation can vary by sector.

Figure 3. Structure of production in the GTAP-E model

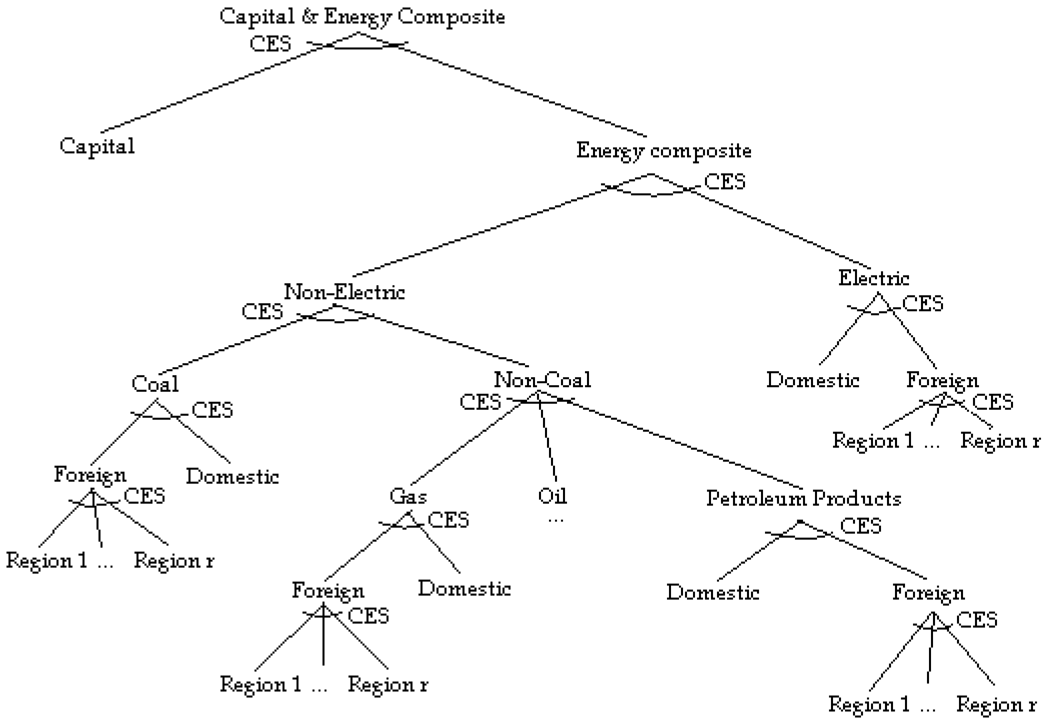


Fourthly this representation of productive process can take into account both a short-term complementarity between capital and energy and a long-term substitutability. Both the GTAP and the MIRAGE models are based on the 'Putty-Clay hypothesis' which holds that old capital is sector-specific while new capital is mobile. Thus following an increase in energy price the substitution between capital and energy is rather limited, as in the short term most of the capital is sector specific. However, in the long run, if the price shock is permanent, the degree of substitution is much larger. Thus the GTAP-E model takes into account both the rigidity in energy use in the short term and its flexibility in the long term.

While the GTAP-E model represents a major progression in terms of energy modeling we do think that it is not fully satisfactory in this case, for several reasons.

Firstly a key issue of the debate around the development of a biofuels sector and its impact on food prices and CO2 emissions is what the literature calls the 'indirect land use effect'. In other words because the allocation of land to the production of agricultural feedstock for non-food purpose decreases food supply, it exerts pressure on agricultural prices. This has a tendency to encourage an increase in land supply, either from forest or livestock utilization and this change in itself contributes to increased CO2 emission. One decisive element in this mechanism is how increased agricultural prices translate into increases in land supply. In fact, faced with higher demand farmers can either chose a more extensive production process (increased land supply under a constant yield) or a more intensive production process (increased yield under a constant land supply). The modeling of agricultural processes has to take this mechanism into account. This is the reason why we adopt a new nesting, as illustrated in Figure 4.

Figure 4. **Structure of the capital & Energy composite in the GTAP-E model**



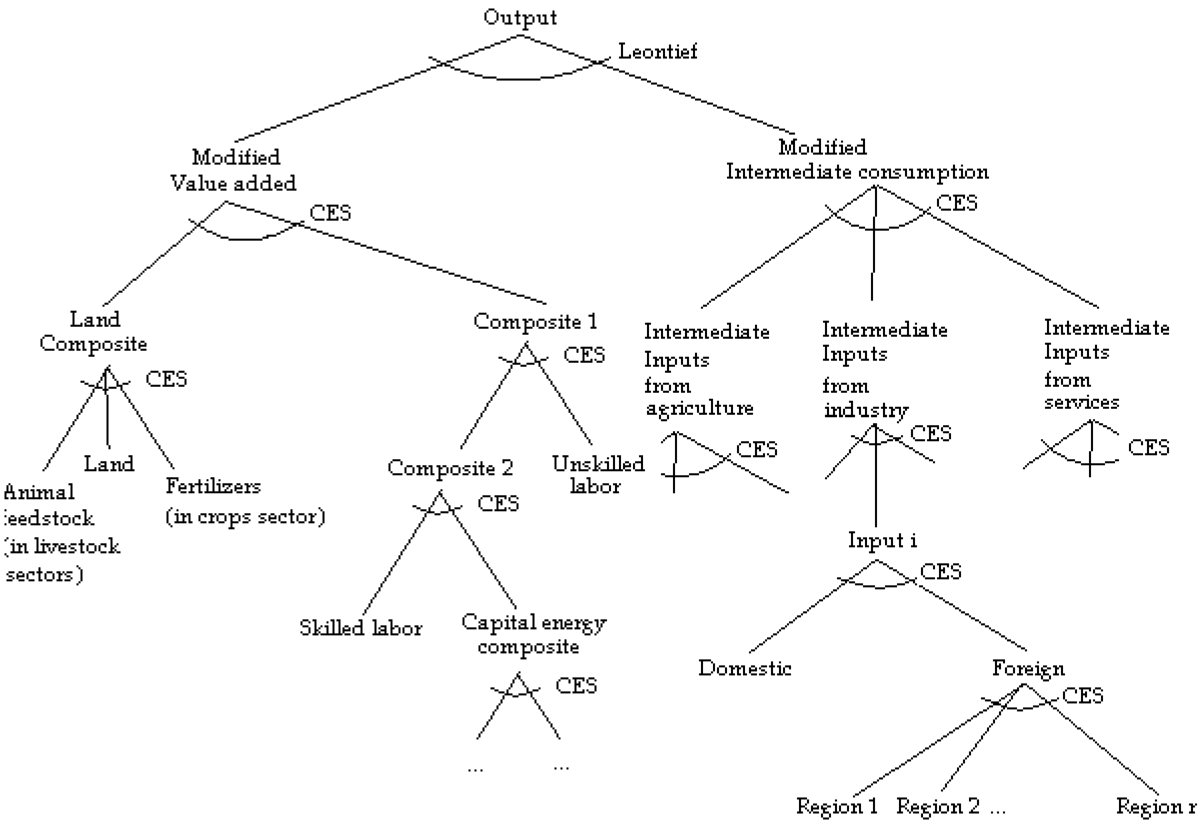
In agricultural sectors the output is a Leontief combination of a “modified Value Added” and a “Modified Intermediate Consumption”. We use the term ‘modified’ as from the Value Added side it incorporates all primary factors, plus the energy products, plus other products like fertilizers and animal feedstock. From the intermediate consumption side it does not incorporate all commodities used as intermediate consumption in the production process.

This “Modified Value Added” is a combination of two composites taking into account the traditional MIRAGE assumptions on the elasticity of substitution, which is 1.1 in this case. The first one is a composite of land and either animal feedstock in livestock sectors or fertilizers in crops sectors. It enables the key issue of choice between intensive and extensive production processes to be tackled. The elasticity of substitution for this CES function vary between 0.1 and 2 according to the GTAP database, except for Northern countries in agricultural sector for which the default elasticity is fixed to 0.1. The other composite is a combination of the standard MIRAGE approach and the GTAP-E approach:

- It incorporates a capital-energy composite according to which investment in capital can reduce the demand for energy;

- As only new capital is mobile, the degree of substitutability between capital and energy is greater in the long term;
- In Figure 4, under the Capital-energy composite we incorporate the nesting illustrated in Figure 3 which incorporates different degrees of substitutability between coal/oil/gas/electricity/petroleum products.
- Skilled labor and the capital-energy composite are rather complementary while both can be substituted for unskilled labor.

Figure 5. Structure of the production process in agricultural sectors in the new version of the MIRAGE model



The paper Burniaux and Truong (2002) was the inspiration for the elasticities of substitution of the different CES nesting levels described above. The elasticity of substitution between capital and energy is 0.15. Between energy and electricity it is 1.1. Between energy and coal it is 0.5 and between fuel oil and gas it is 1.1.

Finally it is noteworthy that a distinctive feature of this new version of MIRAGE is in the grouping of intermediate consumptions into agricultural inputs/ industrial inputs/services inputs. This introduces greater substitutability within sectors, for example substitution is higher between industrial inputs (substitution elasticity of 0.6), than between industrial and services inputs (substitution elasticity of 0.1). At the lowest level of demand for each intermediate, firms can compare prices of domestic and foreign inputs and as far as foreign inputs are concerned, the prices of inputs coming from different regions.

In non-agricultural sectors demand for energy exhibits specific features which are incorporated as follows:

- In transportation sectors (Road transport and Air and Sea Transport) the demand for fuel which is a CES composite of fossil fuel, ethanol and biodiesel, is rigidified. The modified Value Added is a CES composite with very low substitution elasticity (0.1) between the usual composite (unskilled labor and a second composite which is a CES of skilled labor and a capital and energy composite…) and fuel which is a CES composite with high elasticity of substitution (1.5) of ethanol, biodiesel and fossil fuel.

- In sectors which produce petroleum products, intermediate consumption of oil has been rigidified. The modified intermediate consumption is a CES composite (with low elasticity, 0.1) of a composite of agricultural commodities, a composite of industrial products, a composite of services and a composite of energy products which is a CES function (with low elasticity) of oil, fuel (composite of ethanol, biodiesel, and fossil fuel with high elasticity, 1.5) and of petroleum products other than fossil fuel. The share of oil in this last composite is by far the biggest one. This implies that when demand for petroleum products increases, demand for oil increases by nearly as much.

- In the gas distribution sector the demand for gas has been rigidified. It has been introduced at the first level under the "modified intermediate consumption" composite, at the same level as agricultural inputs, industrial inputs and services inputs. This CES composite is introduced with a very low elasticity of substitution (0.1).

In all other industrial sectors we keep the production process illustrated in Figure 4, except that there is no land composite and that fuel is introduced in the intermediate consumption of industrial products.

Table 15 summarizes our assumption about elasticities in the MIRAGE model for biofuels.

Table 25. Elasticities of Substitution assumed for the MIRAGE model for biofuels.

Elasticities of substitution	Description	Rule	Source	Remarks / Exceptions
Supply side				
sigma_VA(j)	VA elasticity of substitution	1,1	MIRAGE Standard assumption	
sigma_CAP(j)	H-K elasticity of substitution	0,6	MIRAGE Standard assumption	
sigma_C(ctype,r)	C elasticity of substitution in CES within ct good types	2	Authors' assumption	Effective only in the baseline (no mandate)
sigma_CT(r)	CT elasticity of substitution in LES-CES between ct types	calibrated	computed from USDA and FAPRI	
sigma_IC	IC elasticity of substitution	0,6	MIRAGE Standard assumption	Use of energy: 0,1; Agri in Ethanol: 2; Agri in Biodiesel: 0,1
sigma_ICT	ICT elasticity of substitution	0,1	MIRAGE Standard assumption	
sigma_KG	KG elasticity of subsitution	0,6	MIRAGE Standard assumption	
sigma_FF(i,r)	Fix factor elasticity (land, natural resources)	0.1< <2	derived from GTAP values	North and agri: 0,05
sigma_TEFS(j)	Elasticity of land-feedstock-fertilizer composite	calibrated	Based on IMPACT model data	For North, set to 0.05 by default
sigma_FS(j)	Animal feed elasticity of substitution in supply	1,1	Study specific assumption	
sigma_TE	Elasticity of CES substitution for AEZ between zones	20	Golub et al. (2007)	
sigma_ICTFUEL	Elasticity between different fuel types for intermediary consumption	0,1	Study specific assumption	
sigma_CBIOF(r)	Elasticity between biofuels with mandate for final consumption	2	Study specific assumption	Effective only in the baseline (no mandate)
sigma_ICBIOF(j,r)	Elasticity between biofuels with mandate for intermediate consumption	2	Study specific assumption	Effective only in the baseline (no mandate)
sigma_KE(j)	Capital and Energy elasticity of substitution	0,15	Burniaux and Truong (2002)	
sigma_ENERG(j)	Second Energy bundle and electricity elasticity of substitution	1,1	Burniaux and Truong (2002)	
sigma_NELEC(j)	Third Energy bundle and coal elasticity of substitution	0,5	Burniaux and Truong (2002)	
sigma_HYDROC(j)	Fuel oil gas elasticity of substitution	1,1	Burniaux and Truong (2002)	pcp:0,5 ; elecgas: 0,9
Demand side				
sigma_GEO(i)	Quality elasticity of substitution		derived from gtap values	
sigma_ARM(i)	Armington elasticity of substitution		derived from gtap values	ethanol:5; simple gtap values
sigma_IMP(i)	Import elasticity of substitution	Gtap values	Hertel (2006)	
sigma_VAR(i)	Variety elasticity of substitution		not used here	
Factors				
sigma_L	CET Labour elasticity of substitution	0,5	MIRAGE Standard assumption	
sigma_TEZ(z,izh,r)	CET Land elasticity of transformation (first level - high substitution)	0.2< <0.6	based on OECD PEM model	
sigma_TEZH(z,izm,r)	CET Land elasticity of transformation (second level - medium high substitution)	0.1< <0.35	computed as average	
sigma_TEZM(z,izl,r)	CET Land elasticity of transformation (third level - medium substitution)	0.1< <0.25	based on OECD PEM model	
sigma_TEZL(z,r)	CET Land elasticity of transformation (fourth level - low substitution)	0.1 or 0.05	based on OECD PEM model	
sigma_LANDEXT(izm,r)	Land extension elasticity	0.1 or 0.05	set sameas as sigma_TEZL(z,r)	

Annex 3. Land use and land allocation

Because of the importance of the interaction between biofuel production and land use change, this MIRAGE version for biofuels analysis incorporates a more detailed description of land use and land use change dynamics, based on the most recent work on this issue in general equilibrium models.

The first characteristic of this design is a designation of by agro-ecological zone (AEZ) following the framework proposed by Golub et al. (2008). This allows us to account for the fact that not all land can be used for all purposes. The second characteristic is the incorporation of the possibility of extension in total land supply through an explicit land supply curve, following Tabeau et al's (2006) approach. This allows for a stronger linkage with the physical bases of crop production, while land substitution and extension can be tracked with respect to price variations in each region.

MIRAGE land use module

A - Data

Land is usually represented in CGE models as a fixed factor endowment within the production function, expressed in value, whose remuneration is attributed to the household representative agent. Therefore, land data are usually not expressed in physical dimensions but in value and some assumptions need to be made in order to relate the physical quantity of land with the volume expressed in dollars within the model.

In the present study, we rely on rent values using the data provided by Lee et al (2007) and based on a description of national land differentiated by agro-ecological zones based on raw data from Monfreda et al. (2007). However, our rent values allow computation of changes in physical land occupation. Land is therefore described in physical units relying on the Food and Agriculture Organisation (FAO) information and nomenclature. More details about the distribution of land use among the AEZ is derived from the Monfreda database, providing a more comprehensive description of land use. Changes in land rent allocation can then be applied on the physical land occupation by assuming consistency between the two databases.[25]

i) Land areas and global occupation

We rely in this study on the FAO description of global land use, as provided by the database "FAOSTAT – ResourceSTAT – Land".[26] Land identified in this database is classified in the following main categories. The area of each category are reported or estimated by FAO staff every year:

- Arable land
- Permanent meadows and pasture
- Permanent crops
  (These three categories constitute Agricultural land in FAO nomenclature.)
- Forest area (plantation and natural forest)
- Other land

More categories are provided for some specific regions (temporary meadows, irrigated land, and pasture land differentiated by natural or cultivated) but the lack of information for many regions makes it un-usable at the global scale.

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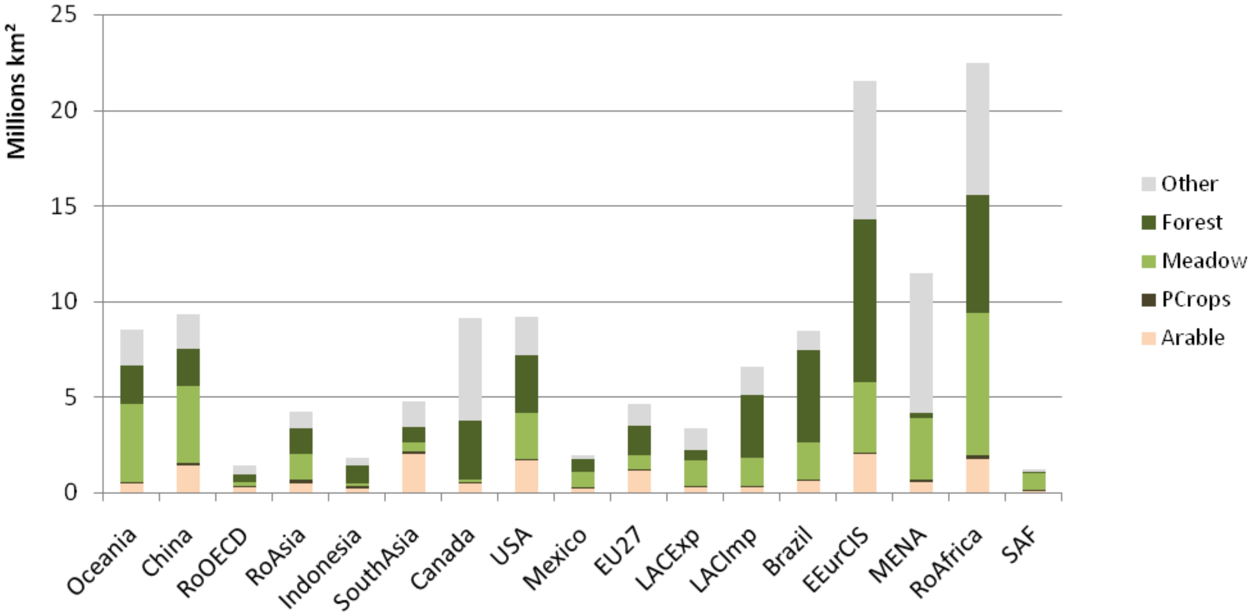
[25] Such consistency can be questioned to some extent because the variance in land rents per hectare can be high in this framework. However, we have chosen the most integrative approach to take into account at the same time balanced data on production provided by the GTAP database and physical information describing the real occupation of land. The most relevant alternative framework would consist of rebuilding a global database using a bottom-up approach and incorporating quantities instead of volumes. This task would be an enormous undertaking beyond the means of this project.

[26] http://faostat.fao.org/site/377/default.aspx

Figure 6. World land occupation by region according to FAO data



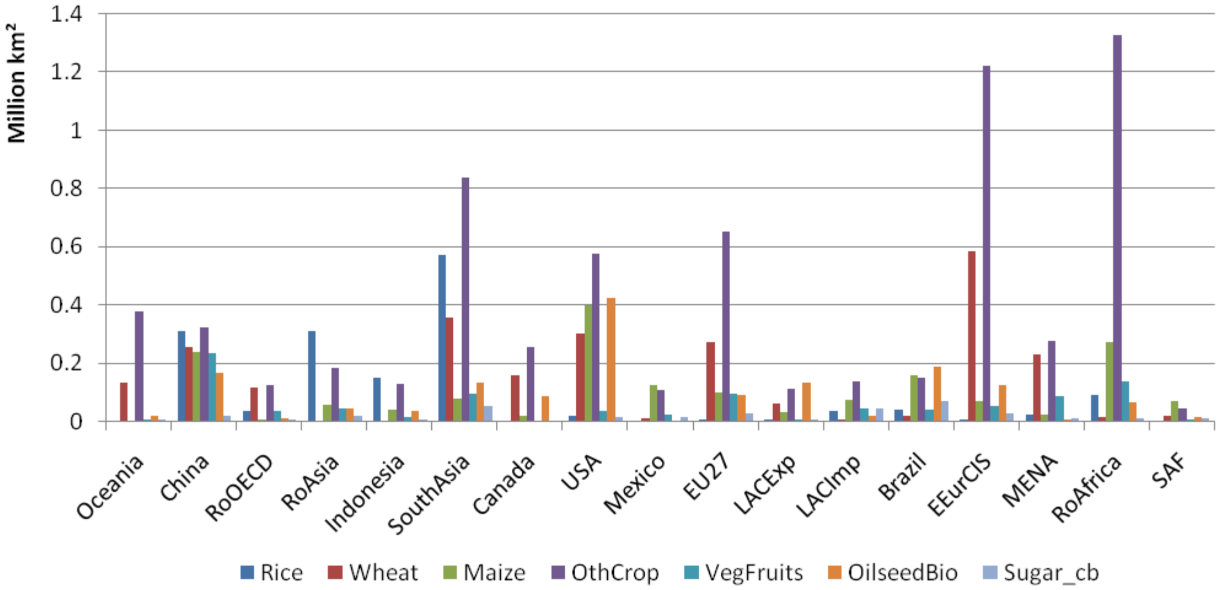
In our modeling framework, we choose to rely on FAO data because this constitutes a unified database which provides time series data for land use from 1990 to 2005. This allows us to take into account dynamic trends in land use.

The nomenclature used in this study is therefore:

- **Cropland** (including permanent crops), which falls into:
    - Rice land
    - Wheat land
    - Maize land
    - Sugar crops land
    - Vegetable and fruits land
    - Biofuel oilseeds land
    - Other crops land
- **Pastureland** (including permanent meadows) divided into:
    - Cattle meat land
    - Cattle milk and fibers land
- **Managed** forest
- **Unmanaged** forest
- **Other land** (shrubland, urbanized land, desert, ice)

Cropland corresponds to FAO Arable land and is decomposed into subcategories respecting the shares shown in Monfreda's tables.

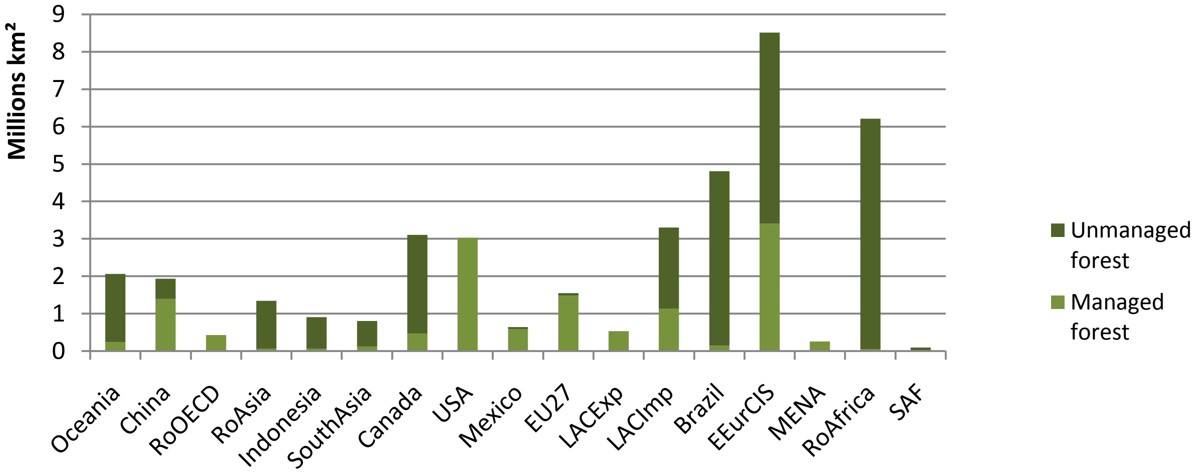
Figure 7. Description of world cropland occupation by region according to FAO data



Pastureland is derived from FAO data and distributed among different uses using GTAP information assuming that rents are the same for all cattle lands.

FAO data relative to **forest** areas are distributed between managed and unmanaged forest using data from Sohngen et al. (2007) on forest management practice. Tropical and forests with limited accessibility are considered to be unmanaged whereas temperate mixed forests with accessibility and forest plantations are considered to be managed forests. This distinction will be useful for assessing lands' economic values (unmanaged lands have no economic values) and to take rents into account in the model. Unmanaged forests also contain more carbon stock that can be released in the case of their destruction.

Figure 8. Managed and unmanaged forests by region



ii) Land occupation in AEZ

In order to better take into account interactions between land use and spatial information, we used the database provided by Monfreda and used by Lee et al (2007) to distinguish land use across agro-ecological zones. These zones differentiate lands by 3 different climates (tropical, temperate and boreal) and 6 different humidity levels, corresponding to different lengths of growing periods.

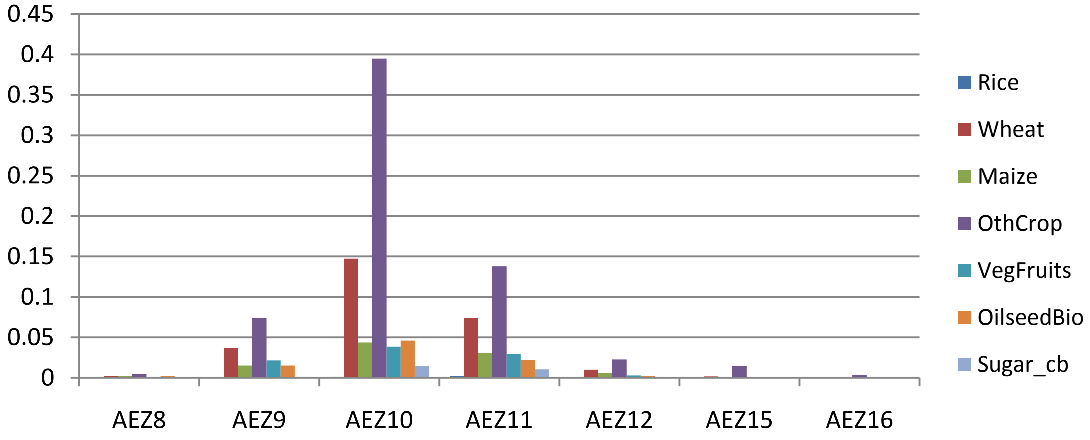
Table 26. Definition of Agro Ecological Zones in Monfreda et al

Length of Growing Period (LGP) / Climate	LGP1 0-59 days	LGP2 60-119 days	LGP3 120-179 days	LGP4 180-239 days	LGP5 240-299 days	LGP6 More than 300 days
Tropical	AEZ1	AEZ2	AEZ3	AEZ4	AEZ5	AEZ6
Temperate	AEZ7	AEZ8	AEZ9	AEZ10	AEZ11	AEZ12
Boreal	AEZ13	AEZ14	AEZ15	AEZ16	AEZ17	AEZ18

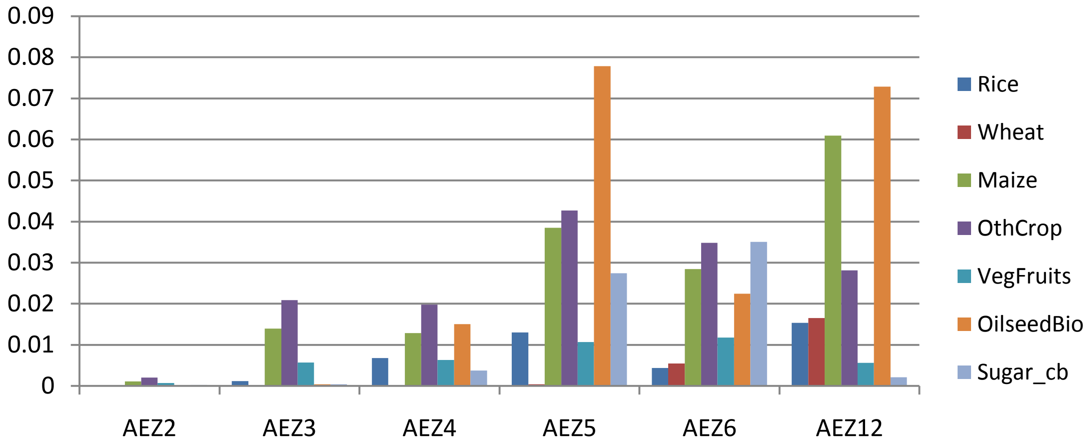
Monfreda's database provides data on area harvested and production for a selection of 175 crops in 226 regions and in each AEZ, which helps us to determine the spatial distribution of crops within each country. This information was used at the more aggregated level of the study.

Figure 9. Examples of AEZ distribution in selected countries (Mio km²)

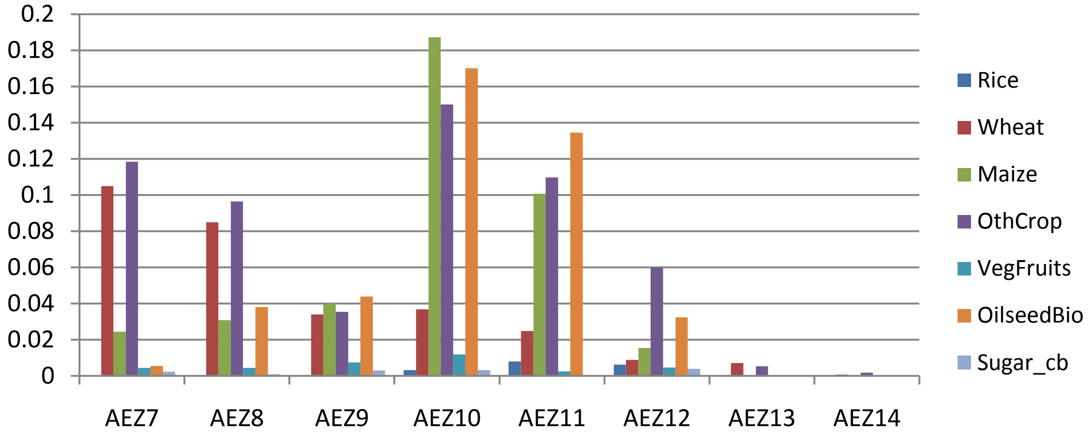
EU27



USA



Brazil



iii) Land rent values

In the GTAP database on which the MIRAGE model is based some land rent values are proposed. However, it appeared more interesting in this case to represent the different substitution possibilities by disaggregating land rents by AEZ zone in the same way as Golub et al. (2006). Following Lee et al's (2007) approach, we therefore decomposed land rent values in GTAP 7 among different AEZ respecting the following rules:

- For crops, land rents were assumed to have the same distribution as in GTAP 6.
- For pasture in each region, land rents associated with pigs and poultry were removed from the data and reallocated to capital for this sector.
- For forest, natural resources endowments were removed and transformed into a land rent of the same value

For new sectors such as maize and oilseeds for biofuels, land rents were split and distributed among AEZ using the data from Monfreda directly at the crop level.

As the Monfreda database only provides data for the year 2004, this means that the assumption had to be made that the distribution of crops remained unchanged among AEZs for a single region between 2000 and 2004. However, as the production of each region can vary differently, the distribution at the world level can change.

iv) Land available for crops

In order properly take account of the possibility for land extension, we use physical data from the AEZ 2000 database (IIASA – FAO), which provides estimates of the surface available for rain-fed crop cultivation, per country.[27] Several sets of data can be used depending of the level of input (low input, intermediate input and high input) and the degree of suitability (very suitable, suitable, moderately suitable, and marginally suitable). We choose as a reference level for available land the group of very suitable, suitable and moderately suitable land, under a mixed input level (a filter provided by IIASA applying different levels of input to different levels of suitability).

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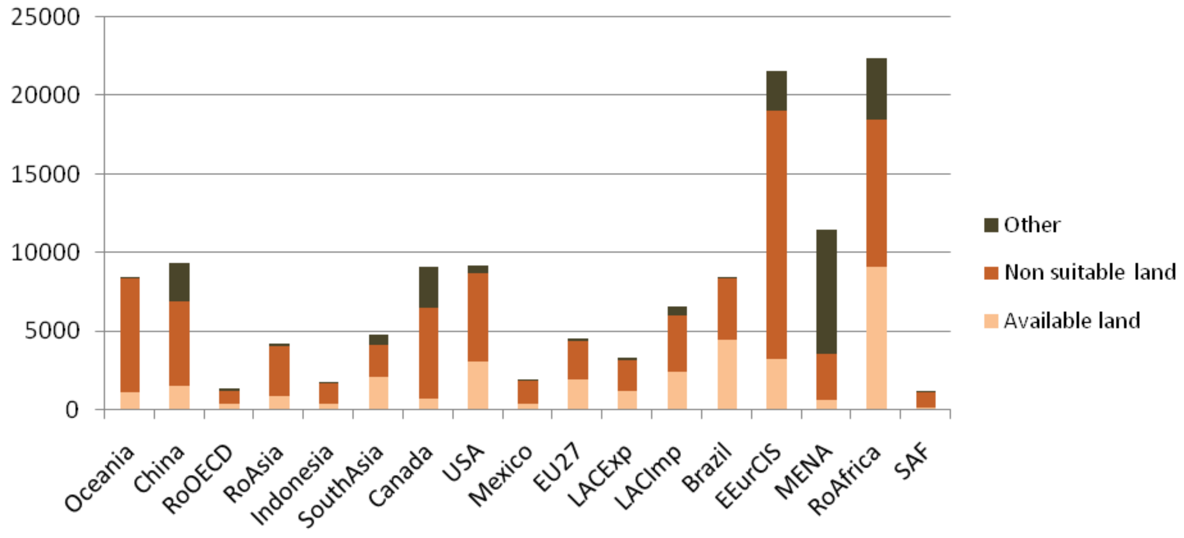
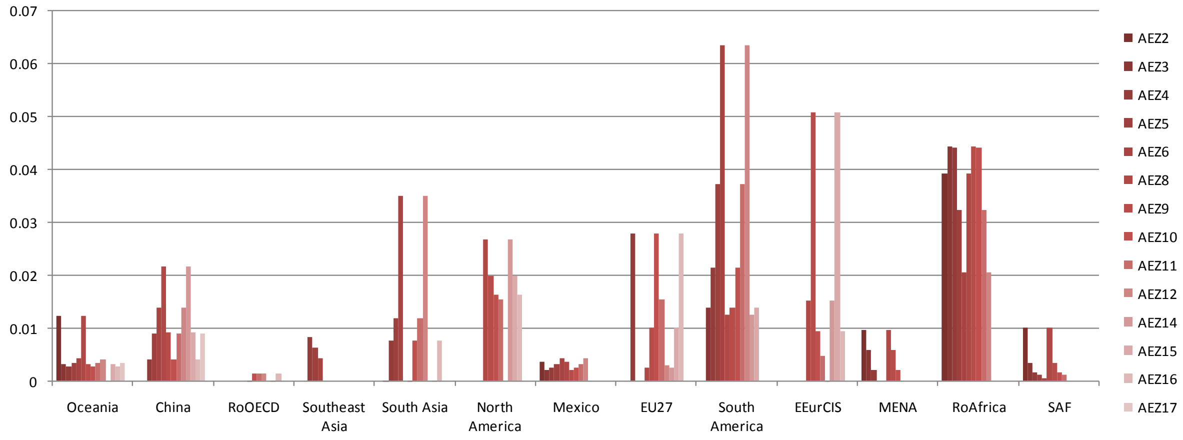
[27] Data and methodology are available at http://www.iiasa.ac.at/Research/LUC/GAEZ/index.html

Figure 10. Land available per macro-region



This information can also be used by AEZ at the level of macro-regions and as will be explained later, we also incorporate this information into the modeling in order to differentiate the possibilities of land extension amongst the AEZ. This information is not used as a value but only as an indicator of the location of available land (as seen from the proportion of each AEZ in the available land pool). Therefore, we used land available under moderate constraint as an indicator.

Table 27. Figure 1 *Land available per AEZ in macro-regions*



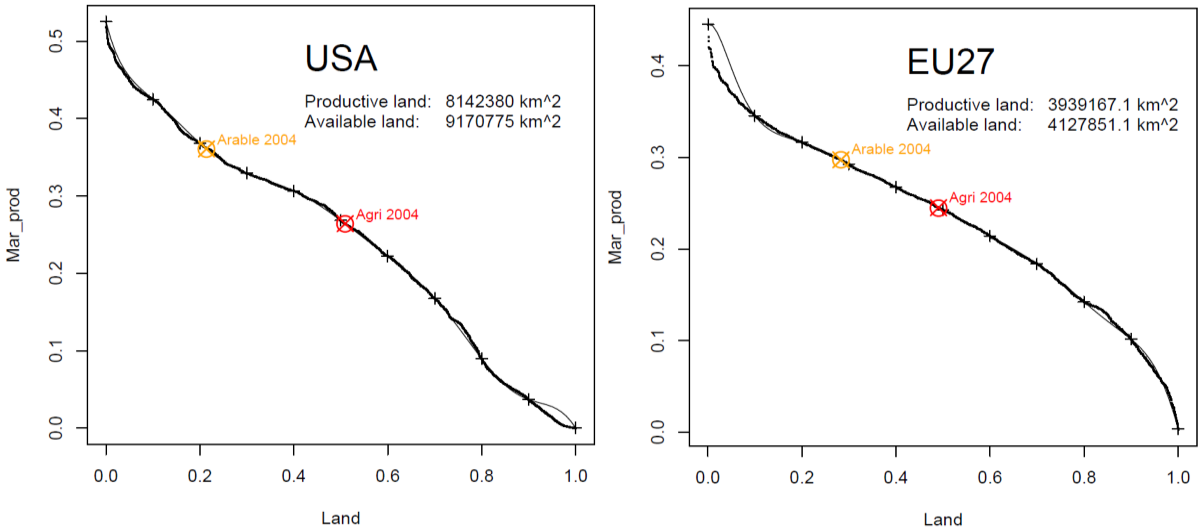
v) Marginal productivity of land

The fact that there are possibilities for extension in land availability should not mask the fact that best lands (in the IIASA nomenclature, the very suitable and suitable land) are generally already in cultivation. Marginal land is therefore intrinsically of lower quality and marginal productivity is therefore expected to decrease with land extension.

In order to reproduce this phenomenon in the modeling, we used a methodology similar, to the one developed in Tabeau et al. (2006), but adapted to our needs. In this work, the authors introduced a land supply curve that they built from marginal land productivity information used in the IMAGE model. We also used land supply curves here but these are built on different principles, as we only took into account the information on marginal productivity to compute the effective value of additional hectares put in production.[28]

Land marginal productivity profiles were introduced in the model by approximation using polynomial interpolation at a sufficient degree.

Figure 11. Example of marginal productivity profiles introduced in the model



vi) Times series data on land use change

Computable general equilibrium models usually aim at displaying the effects of policy shocks by relying on a single calibration year and endogenizing all behaviors. However, when addressing issues such as land use change in a dynamic framework, a number of issues which impact on the land use dynamic, but are independent of commodity market effects, cannot be properly reproduced. This is the case, for example, for measures related to environmental protection, land management, urbanization, etc…

In the model, we take into account these effects in the baseline by considering that land use change for the main land categories (cropland/meadows-pastures/forest) follows the patterns reported in FAO time series already used for global land use occupation (see section i)). Variation rates are computed using observed variation from 2000 to 2004.

This information is also significant as future land use changes are assumed to take place in locations which underwent changes in the past. In other words, variation in cropland is related to the established variation in other types of land, which allows us to infer what type of land might be most affected by further land extension.

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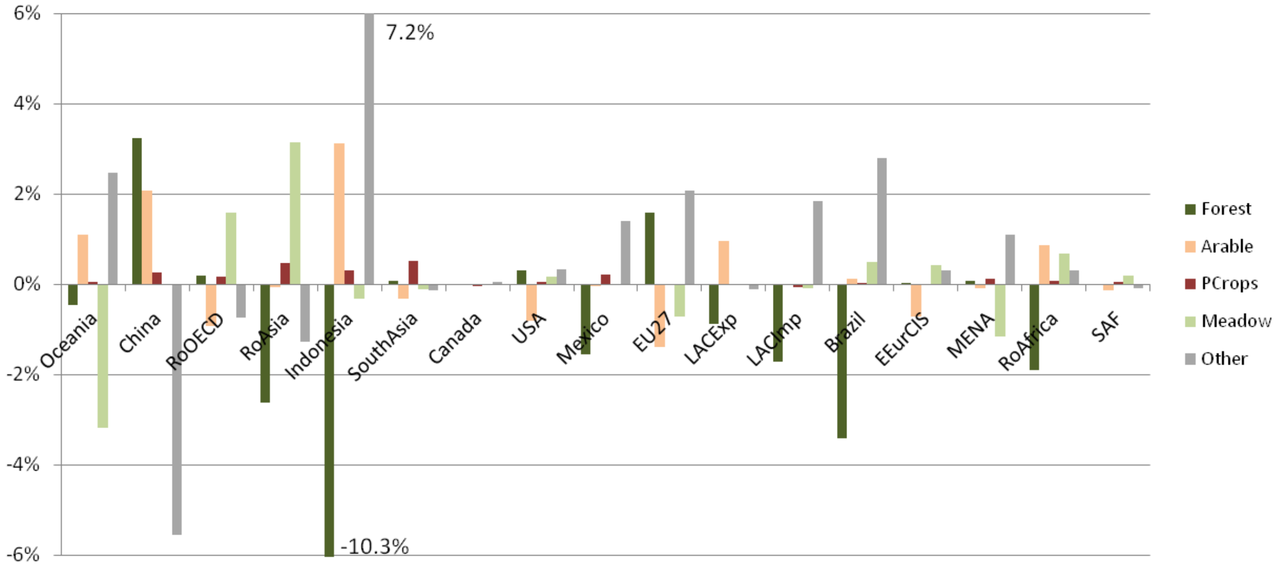
[28] We are grateful to IMAGE and LEITAP teams to have made these information available to us.

Figure 12. Figure 2 Land use change rates in the period 1995-2005



B - Land use change modeling

Land use change relative to agricultural production can be analysed in the context of two main dynamics:

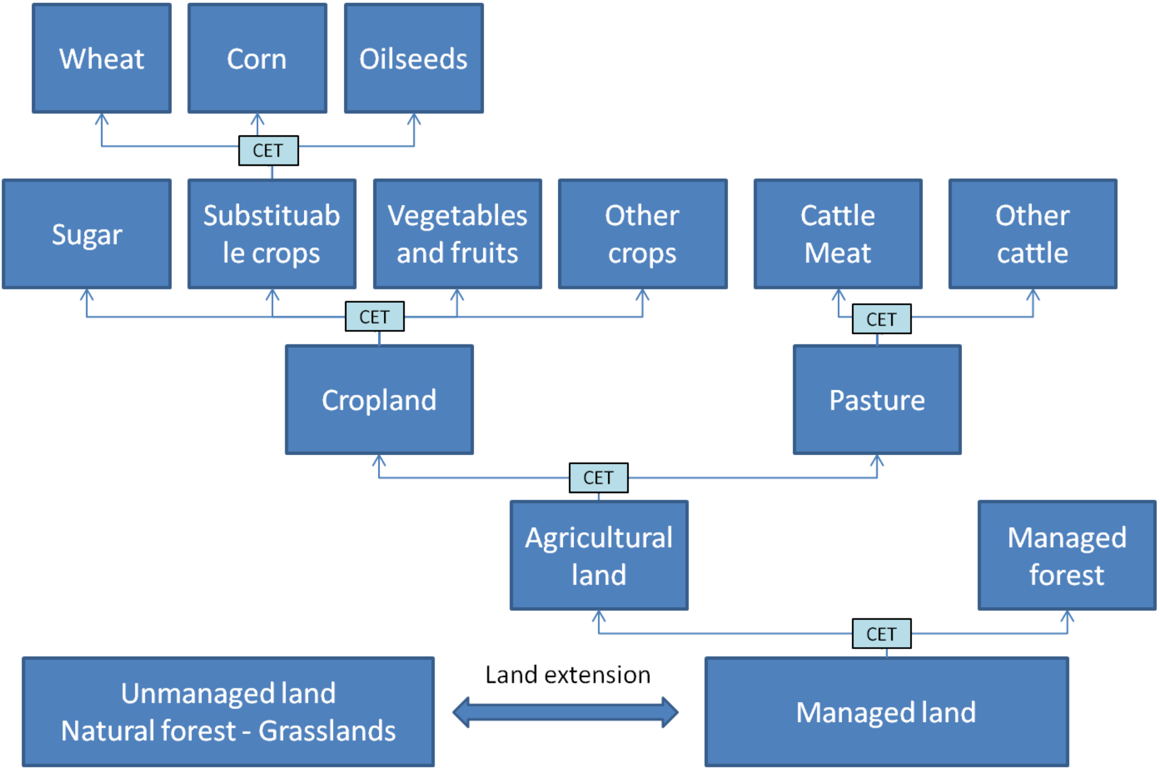
1. The change in land use distribution between different crops on existing arable land
2. The extension of arable land made available for cultivation and impact on other types of land

The substitution effect

In order to represent properly the impact of demand for land on allocation choices, we rely in this model on a neo-classical approach assimilating the land allocation decision to an optimization program for the producer. For this, we use the Constant Elasticity of Transformation function which supposes that the producer maximizes its utility under a revenue constraint, by adapting their cultivation choices to changes in land rent levels.

This optimization is done within each AEZ and country. Four levels can be distinguished - substitutable crops, crops, pasture and forest - each of which has a different elasticity. This substitution tree contains as ‘leaves’ the different productive sectors represented in the model with land endowments. As production functions are national, land endowments are aggregated across CES using a Constant Elasticity of Substitution function, with a high degree of substitution (elasticity set to 20), reflecting the indifference of the producer to the location within the country.

Figure 13. Land substitution structure used for each AEZ



The design by different AEZ allows a better representation of the substitution incompatibilities across cultures, when climate and environmental conditions differ. However, attributing elasticities to such a tree is a delicate exercise which will inevitably be to some extent arbitrary given the high variance in the elasticities provided by econometric analysis (see Salhofer (2000) and Abler (2000)). We choose here to base our parameters on the estimates chosen by the OECD for the PEM model (Policy Evaluation Model), used as a reference for the determination of agricultural support. However, because our model introduces several AEZs, substitution within AEZ has to be higher, as part of the rigidity is incorporated within this segmentation. Therefore, for each region, we run the model with a single AEZ and then with all AEZs to determine a segmentation factor to apply to the initial values of elasticities. A second limit to our data source is that OECD model only covers developed countries plus Mexico, Turkey and Korea. We consequently had to assume certain similarities for several countries.

Table 28. The elasticities used in AEZ

	σ_{TEZ}	σ_{TEZH}	σ_{TEZM}	σ_{TEZL}	Source
Oceania	0.59	0.35	0.17	0.05	OECD
China	0.23	0.22	0.21	0.05	*Set similar to RoOECD (inc. Korea)*
RoOECD	0.2	0.15	0.11	0.05	OECD (Japan)
RoAsia	0.23	0.22	0.21	0.05	*Set similar to RoOECD (inc. Korea)*
Indonesia	0.59	0.30	0.11	0.1	*Set similar to Mexico*
SouthAsia	0.59	0.30	0.11	0.1	*Set similar to Mexico*
Canada	0.58	0.32	0.14	0.05	OECD
USA	0.55	0.32	0.15	0.1	OECD
Mexico	0.59	0.30	0.11	0.1	OECD
EU27	0.23	0.22	0.21	0.05	OECD (EU15)
LACExp	0.59	0.30	0.11	0.1	*Set similar to Mexico*
LACImp	0.59	0.30	0.11	0.1	*Set similar to Mexico*
Brazil	0.59	0.30	0.11	0.1	*Set similar to Mexico*
EEurCIS	0.23	0.22	0.21	0.05	*Set similar to EU27*
MENA	0.35	0.24	0.15	0.05	OECD (Turkey)
RoAfrica	0.35	0.24	0.15	0.05	*Set similar to MENA*
SAF	0.35	0.24	0.15	0.05	*Set similar to MENA*

Land extension effect

The land extension module of the model is aimed at determining for each AEZ what extension of arable land can replace other uses of land. One of the biggest difficulties is that land use change cannot be projected in the future at the AEZ level because FAO time series are only available at the national level. Consequently, we decide to decompose the problem into two steps:

Firstly, we determine the land use extension at the regional level and compute what land types are converted to arable land or the reverse, following changes in the relative prices of land. Demand for new land will raise the price of land at the national level and lead to arable land extension. This extension is therefore driven by a unique price and a unique elasticity for each country.

The equation driving this mechanism is displayed below:

$$LAND_{Crops,r,t,sim} = LandTrend_{Crops,r,t} * \left(\left(\frac{P_{Cropland,r,t,sim}}{P_{r,t,sim}} \right)^{\sigma_r^{Landext} * \left(\frac{Land_{avail_r} - LAND_{Crops,r,t,sim}}{Land_{avail_r} - LAND_{Crops,r,t0}} \right)} \right)$$

Where

$LAND_{Crops,r,t,sim}$ *is Cropland used after extension and before adjustment with other economic usages in region 'r' at time 't' in scenario 'sim'*
$LandTrend_{Crops,r,t}$ *is the exogenous Land evolution trend based on historical data*
$P_{Cropland,r,t,sim}$ *is the price of Cropland*
$P_{r,t,sim}$ *is the consumer price index of the region*
$\sigma_r^{Landext}$ *is an elasticity of cropland extention*
$Land_{avail_r}$ *is the area of land available for rain-fed crops in region r*

For a given quantity of increase in arable land the corresponding reduction in other land types is computed respecting the following principle: land is removed proportionally to the amount of land gained or lost as a result of observed past cropland extension (whatever the sign of the variation, as the rationale assumes land removal in those types which have shown the highest change activity in land use). If cropland decreases, land is added following the opposite mechanism.

Secondly, we distribute the extra land use gained in cropland across AEZ regions, which contributes to lower prices for cropland and compensates for the extra demand and the pressure for expansion.

The determination of the share of extra cropland allocated to each AEZ is function of several parameters:

- The quantity of cropland in the AEZ
- the quantity of remaining land, not already used as cropland
- the share of the land for rain-fed crops available at the regional that is located in the AEZ

This is summarized by the following formula that allocates extra arable land across AEZ:

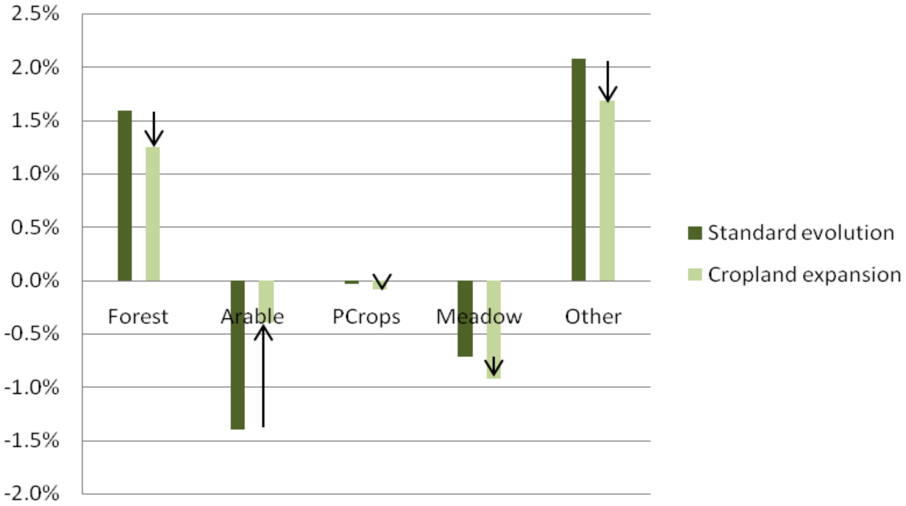
$$\frac{LANDZ_{z,Crops,r,t,sim}}{LANDZ_{z,Crops,r,t0}} = exp\left(\frac{LandsoilZ_{z,r} - LANDZ_{z,Crops,r,t,sim}}{LandsoilZ_{z,r} - LANDZ_{z,Crops,r,t0}} * share\_avail\_AEZ_{z,r} * \gamma_{r,t,sim}\right)$$

Where

$LANDZ_{z,Crops,r,t,sim}$ *is Cropland used after extension and before adjustment with other economic usages in region 'r' at time 't' in scenario 'sim' in agro-ecological zone 'z'*
$LandsoilZ_{z,r}$ *is total soil area in agro-ecological zone 'z' and region 'r' deserts and ice excluded*
$share\_avail\_AEZ_{z,r}$ *is the share of available land in the AEZ for the reference macro-region*
$\gamma_{r,t,sim}$ *is an expansion controller ensuring that the following relation is verified:*

$$LAND_{Crops,r,t,sim} - LAND_{Crops,r,t0} = \sum_z \left(LANDZ_{z,Crops,r,t,sim} - LANDZ_{z,Crops,r,t0}\right)$$

Figure 14. Land extension mechanism



Thirdly, we compute the equivalent productive-land that is associated with the extra surface of land made available. For this, we use marginal productivity curves, which we integrate to approximate the real rental value of extra land. An important assumption here is that we always consider cropland to be installed on the most productive land, whereas managed forests and pasture are assumed to occupy the second best lands. Other types are assumed to be installed on lower value land. This hierarchy can appear artificial but a choice must be made in order to use information on marginal productivity.

The Environmental effects of land use change

Reduction of greenhouse gases is one of the three objectives of biofuels policies (along with fossil fuel dependency reduction and reform of agriculture). However, the environmental efficiency of cultivating crops to replace fossil fuel has been widely questioned. As indicated in the literature review, several studies have tried to calculate the emissions associated with each type of crop cultivation, however, different process in different regions can lead to various results in life cycle assessments.

In this study, we aimed at using the most authoritative sources for direct emissions related to biofuels. Our first source of data is the European Commission Renewable Energy Directive,[29] which provides reduction coefficients to be applyed in such methodologies. Two types of values are provided for different feedstocks and production pathways. Most of the time we used typical values rather than default values because we wanted data representing the state of the current industry rather than marginal inefficient producers. For the EU, we assumed the use of more effective transformation processes.

For a certain number of feedstocks or regions, we used additional sources to obtain more relevant data (maize for the USA and for other regions of the world). We relied on the data provided by the last report on the *State of Food and Agriculture* (FAO, 2008b). We also used an article often cited from Zah et al. (2007) providing information for soya.

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[29] Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources, http://ec.europa.eu/energy/climate_actions/doc/2008_res_directive_en.pdf

Table 29. Reduction of CO2 associated with different feedstocks – Values used in calculations

Feedstock	Coefficient	Source	Note
Wheat (EU)	-45%	EU Dir (2008)	Typical value - natural gas with conventional boiler
Wheat (Other)	-21%	EU Dir (2008)	Typical value
Maize (EU)	-56%	EU Dir (2008)	
Maize (USA)*	-12%	FAO (2008)	
Maize (Other)*	-29%	FAO (2008)	
Sugar Beet	-48%	EU Dir (2008)	Typical value
Sugar Cane	-74%	EU Dir (2008)	
Other crops **	-6%	Zah et al (2007)	
Soya **	-44%	Zah et al (2007)	
Rapeseed	-44%	EU Dir (2008)	Typical value
Palm Oil	-57%	EU Dir (2008)	Process with no methane emissions to air at oil mill

Sources: European Commission, (2008). Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources. FAO (2008b),The State of Food and Agriculture ** Zah et al (2007) data were used when FAO and OECD data were missing: Zah R., Boni H., Gauch M., Hischier R., Lehmann and Wager P. (2007), Life Cycle Assessment of Energy Products: Environmental Assessment of Biofuels*

For each country, the reduction of emission associated with one ton of fossil fuel equivalent of ethanol or biodiesel was computed with consideration to the proportion of feedstock used by the national industry and with respect to the origin of feedstocks (domestic production or imports).

Indirect emissions associated with land use

One of the strength of the modeling used in this report is the representation of land use change, allowing us to assess the emissions from biofuel indirect effects. Indeed, conversion from forest to cropland or from pasture to cropland generates emissions, which can partly or completely alter the overall environmental impact of biofuel production.

We restricted our analysis to two types of land use emissions - emissions from converted forest to other types of land and emissions associated with the cultivation of new land. We did not considered the effect of agricultural inputs, although N2O releases are recognized as significant contributors to greenhouse gases emissions. This means that our assessment is conservative and may well be an underestimate of the real value of land use emissions associated with biofuels.

In order to determine greenhouse gases emissions, we relied on IPCC guidelines for National Greenhouse Gas Inventories.[30] We used Tier 1 method which does not require knowledge of the exact CO2 stock in each region but provides generic estimates for different climate zones that can be matched with the agro-ecological zones in the model.

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[30] http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html See in particular 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Volume 4 Agriculture, Forestry and Other Land Use

Table 30. Carbon stock in forest for different climatic regions (tons dry mat per hectar)

	Natural forest	Forest plantation	Below ground ratio
AEZ1	70	30	40%
AEZ2	70	30	40%
AEZ3	130	60	30%
AEZ4	130	60	30%
AEZ5	180	120	22%
AEZ6	300	150	37%
AEZ7	70	30	32%
AEZ8	70	30	32%
AEZ9	120	100	30%
AEZ10	120	100	30%
AEZ11	155	110	30%
AEZ12	220	140	22%
AEZ13	0	0	30%
AEZ14	15	15	30%
AEZ15	50	40	30%
AEZ16	50	40	30%
AEZ17	50	40	30%
AEZ18	50	40	30%

Source : adapted from table 4.4 and table 4.12 of the IPCC Guidelines.

Consequently, we determined the quantity of carbon per hectare corresponding to each AEZ in the model for primary forest and for managed forest, both above ground and below ground. When forest is converted to another use, we assume that the stock of carbon in this type of forest is released completely (both above ground and below ground stock). In order to compare these emissions with flows emitted or saved each year, they can be converted to flows by dividing the variation of stock on the period considered by the length of the period.

The second type of emission that was considered is emission from soil carbon. We used tier one methodology and indicative release of carbon relative to different management practice to determine the additional emissions induced by the cultivation of new land. The different practices we identified were non cultivation of land, cultivation of land with full tillage, rice cultivation and land set-aside. The level of input was considered to be medium for each case (emission factor equal to unity).

Table 31. Carbon stock in soil and emission factors used in the model

	Carbon in soil (t C per ha)	Emission factors		
		Cultivation	Land set aside	Rice
AEZ1	38	0.58	0.93	1.1
AEZ2	38	0.58	0.93	1.1
AEZ3	38	0.58	0.93	1.1
AEZ4	38	0.58	0.93	1.1
AEZ5	47	0.48	0.82	1.1
AEZ6	60	0.48	0.82	1.1
AEZ7	38	0.8	0.93	1.1
AEZ8	50	0.8	0.93	1.1
AEZ9	95	0.69	0.93	1.1
AEZ10	95	0.69	0.93	1.1
AEZ11	66.5	0.69	0.82	1.1
AEZ12	88	0.69	0.82	1.1
AEZ13	0	0.8	0.93	1.1
AEZ14	68	0.8	0.93	1.1
AEZ15	68	0.69	0.93	1.1
AEZ16	68	0.69	0.93	1.1
AEZ17	68	0.69	0.82	1.1
AEZ18	68	0.69	0.82	1.1

Source: adapted from table 2.3 of the IPCC Guidelines

By applying emission factors to carbon in soil, it was possible to compute the quantity of carbon released after 20 years. This figure was then divided by 20 in order to compute the annual flow associated with the given management practice.

These two calculations together make it possible to compare the direct effect of biofuel cultivation with the indirect effect of land use changes induced by this energy policy.

Annex 4. Biofuels policy

Introduction

EU Biofuel policies

The European Biofuel policy is quite complex because it is driven not only by the Biofuel Directive, but also by others directives and regulations related to Energy, Fuels Quality, Agriculture and Trade Policies.

The Biofuel Directive[31] introduces some constraints on the substitution requirements of fossil fuels by biofuels. The main goal of this policy is to reduce greenhouse gas emissions particularly in transportation and to lessen dependence on fossil fuels by diversifying energy sources, especially towards environmentally friendly technologies. For this purpose, this Directive prescribes several mandates for biofuel blending with current fuels at different dates. The first objective was, for each EU member to have a 2% market share for biofuels in 2005, then 5.75% in 2010. With the recent Renewable Energy Directive, a target of (at least) 10% in 2020 was added.

In order to help EU members with the implementation of the previous Directive, the Energy Tax Directive authorises the EU countries to introduce some tax reductions and exemptions for biofuels.[32] The application of both directives differs from one EU country to another. Austria, Belgium, Germany and Luxembourg have obtained the best results in response to the targets of the Biofuels Directive. They have reached a 2.5 to 2.75 % market share for biofuels. Moreover, other developing EU members have also attained the 2005-target: Slovenia (2.5% in 2006), Latvia (2.75% in 2006), Greece (2% in 2005 and 2006) and the Czech Republic (3.7% in 2005 and 1.78% in 2006). However, some other EU members have not yet fulfilled their biofuel commitments, despite various incentives (e.g. United Kingdom, Malta, Cyprus, etc.). For instance, the United Kingdom, although it has not applied any energy tax reduction/exemption, has favouring production subsidies and capital grants for biofuel projects. Austria, Germany and France have all taken similar approaches, reducing or exempting biofuel production from taxes imposed on mineral oils, depending on the biofuel type (e.g. ethanol or biodiesel) and the level of blending (i.e. Austria exempts 100% tax for pure biodiesel but only slightly reduces this tax for 5%-ethanol gasoline).

The Common Agricultural Policy also plays an important role in encouraging biofuels production. Since the 2003-CAP Reform, the supply of energy crops has benefited from direct payments and decoupled support without any set-aside obligation and without any loss of income support. Moreover, these energy crops also benefit from a premium over the price received by producers and following the Common Market Organisation regulation, sugar beet production for ethanol is exempted from production quotas.

EU trade policies also affect domestic biofuel production as well as reducing export opportunities and production incentives for foreign biofuel producers (e.g. USA, Brazil, Indonesia, Malaysia, etc.). The Most Favourite Nation (MFN) duty for biodiesel is 6.5%, while for ethanol tariff barriers are higher (€19.2 /hectolitre for the HS6 code 220710 and €10.2 / hectolitre for the code 220720). Even if tariffs for biodiesel were to be reduced, trade would still have to face more restrictive non-tariff barriers (NTBs) in the form of quality and environmental standards, which already mostly affect developing country exporters.

Nevertheless, some European partners already benefit from a duty-free access for biofuels under the Everything But Arms Initiative, the Cotonou Agreement, the Euro-Med Agreements and the Generalised System of Preferences Plus. Many ethanol exporters, such as Guatemala, South Africa and Zimbabwe, use this free access opportunity. However, most ethanol imports come from Brazil and Pakistan under the

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[31] Directive 2003/30/EC of 8 May 2003 concerning biofuel promotion for transport use.

[32] Energy Tax Directive 2003/96/EC of 27 October 2003.

ordinary European GSP without any preference for either since 2006. Concerning European biofuel exports, the EU has a preferential access for ethanol in Norway through tariff-rate quotas (i.e. 164 thousand hectolitres for the code 220710 and 14.34 thousand hectolitres for 220720).

Trade liberalisation for biofuels is a contentious issue in the multilateral negotiation of the Doha Round (being relevant both to discussions on agricultural trade liberalisation and trade and environment) as well as in the bi-lateral negotiations between the EU and the Mercosur countries. Clearly key countries, products and interests are common to both.

Brazilian Biofuel policies

Ethanol policies have been implemented in Brazil since the mid-70s and today blending obligations for ethanol are up to 20-25% for gasoline. More recently, Brazil has introduced biodiesel blending targets of 2% in 2008 and 5% in 2013, similar to the EU's.

In order to reach these obligations, Brazilian federal and state governments grant tax reductions/exemptions. The level of advantage varies on the basis of the size of the agro-producers and the level of development of each Brazilian region.

The Common External Tariff (CET) of Mercosur also protects domestic biofuel production, with ethanol duties of 20% and biodiesel 14%. These tariffs could be eliminated or significantly reduced under the Doha and/or the EU-Mercosur negotiations. Furthermore, no non-tariff barriers constrain Brazilian imports of biofuels (e.g. no TRQ on biofuels in Mercosur).

Another important explanatory factor in the growth of the ethanol sector in Brazil is the role of foreign investment. Most recent investments come from Europe and the United States. They not only concern distillation plants but also sugar cane production. The competitive prices of raw materials and the high level of integration in the process explain the lower costs for ethanol production in Brazil and the motivation of the foreign investors.

US Biofuel policies

In the USA, as in Brazil, Biofuels policies date back to the 70s. However they are as complex as those of the EU because fiscal incentives and mandates vary from one state to another and differ from federal ones. The Energy Tax Act of 1978 introduces tax exemption and subsidies for the blending of ethanol in gasoline. In contrast, biodiesel subsides are more recent, they were introduced in 1998 with the Conservation Reauthorization Act.

Concerning mandates on biofuels consumption, they were instigated by the Energy Policy Act of 2005 at the federal level, although obligations for biofuel use existed at the state level (e.g. Minnesota introduced a mandate on biofuels before the federal government, which it increased to 20% in 2013). This 2005 Act sets the objective of the purchasing of 4 billion gallons of biofuels in 2006 and 7.5 billion gallons in 2012.

The current biofuels policies in the USA consist of three main tools output-linked measures, support for input factors and consumption subsidies. Tariffs and mandates benefit biofuels producers through price support. Tariffs on ethanol (24% in equivalent ad valorem) are higher than biodiesel (1% in equivalent ad valorem) which limit imports especially from Brazil. Moreover, producers benefit from tax credits based on biofuels blend into fuels. The Volumetric Ethanol Excise Tax Credit (VEETC) and the Volumetric Biodiesel Excise Tax Credit (VBETC) provide the single largest subsidies to biofuels, although there are additional subsidies linked to biofuel outputs.[33]

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[33] E.g. a federal small producer tax credit - equivalent to a 10% tax credit per gallon on the first 15 million gallons produced -, blenders' credits, supplier tax refunds and other subsidies at the state level

Investments in biofuels also receive financial support from the government, as a kind of capital subsidies. Support is also provided for labor and land used in biofuel production in some states (e.g. Washington). Input subsidies are another important element in biofuel support in the USA. US ethanol production overwhelmingly uses corn which is one of the most heavily subsidized crops in the country. In contrast, soybeans, which are the main feedstock used for biodiesel production in the USA, are not very subsidized in the USA, which means that prices are not inflated and production is less attractive for farmers. Finally, indirect biofuel consumption is also supported by the federal government through investment in infrastructure for transport, storage and distribution (Koplow, 2006; Koplow, 2007).

Modelling Biofuels Policies

In order to calibrate the model and to run the different simulation scenarios for the European biofuel policies, we need to build a "policy" data set and to identify some technical requirements to be incorporated into the model.

- **Obligations in Substitution Requirements for Biofuels**

The EU members are required to report to the Commission on their implementation of biofuel policies. Considering the development disparities, the implementation of these policies is largely developed in larger countries such as France, Germany or Austria and not in small countries such as Malta and Cyprus. However, the EU mandate for the share of biofuel in fossil fuel according to their energy content is compulsory for all countries. Only 5 of 27 EU members have reached the 5% target for 2005. One year later this number had doubled and today it shows a positive trend.

Using the national reports to the European Commission relating each country's biofuel policies, we have built a new database that contains the real percentage of biofuels in fuels according to their energy content (from 2003 to 2006) and the national and European targets for the years up to 2020. For a better use of this database, we differentiate between biodiesel and ethanol with details of how much these percentages in energy content terms represent in percentage of the final product (by volume), in order to have better information for the model calibration.

Table 20 shows detailed information about the past application of the biofuels mandates for the European Union since 2003 and the prospective application and targets up to 2020.

Table 32. Biofuel Use and Mandates in the European countries (% of energy content)

Countries	GTAP Consumption weight	2003	2004	2005		2006	2007	2008	2009	2010		2020	
				use	EU target					use (*)	EU target	use (*)	EU mandate
Austria	0,015	0,06	1,28	2,5	2	2,5	4,3	5,75	5,75	5,75	5,75	10	10
Belgium	0,028	0	1	2	2	2,75	3,5	4,25	5	5,75	5,75	10	10
Bulgaria	0,003	0	0	0	2	0	0	0	0	0	5,75	0	10
Cyprus	0,001	0	0,5	1	2	1	1	2	2	2	5,75	10	10
Czeck Republic	0,012	1,12	2,41	3,7	2	1,78	1,63	2,45	2,71	3,27	5,75	10	10
Germany	0,2	1,18	2,54	3,9	2	2	5,75	7,15	7,88	8,6	5,75	10	10
Danemark	0,009	0,17	0,24	0,27	2	0,39	1,73	3,07	4,41	5,75	5,75	10	10
Spain	0,079	0,76	1,38	2	2	3,34	4,62	6	7,26	8,66	5,75	10	10
Estonia	0,001	0	0,1	0,2	2	2	2,13	2,25	2,38	2,5	5,75	10	10
Finland	0,005	0,1	0,1	0,1	2	1,75	3,37	5,05	6,63	8,35	5,75	10	10
France	0,176	0,68	1,34	2	2	1,75	3,5	5,75	6,25	7	5,75	10	10
Great Britain	0,16	0,03	0,3	0,3	2	0,73	1,15	2	2,8	3,5	5,75	10	10
Greece	0,012	0	0,35	0,7	2	2,5	3	4	5	5,75	5,75	10	10
Hungary	0,012	0	0,4	0,6	2	1,63	2,66	3,69	4,72	5,75	5,75	10	10
Ireland	0,006	0	0,03	0,06	2	1,14	1,75	2,24	4,18	6,12	5,75	10	10
Italy	0,129	0,5	0,75	1	2	2	2	3	4	5	5,75	10	10
Lituania	0,002	0	1	2	2	2,75	3,5	4,25	5	5,75	5,75	10	10
Luxembourg	0,002	0	0	0	2	2,75	2,75	2,75	2,75	5,75	5,75	10	10
Latvia	0,002	0,21	1,11	2	2	2,75	3,5	4,25	5	5,75	5,75	10	10
Malta	0	0	0,15	0,3	2	1,92	3,5	5,15	6,7	8,38	5,75	10	10
Netherdlands	0,027	0,03	1,02	2	2	2	2	2,94	3,88	5,75	5,75	10	10
Poland	0,03	0,49	0,5	0,5	2	1,5	2,3	3,16	4,03	5,75	5,75	10	10
Portugal	0,022	0	1	2	2	2	3	5,75	5,75	5,75	5,75	10	10
Romania	0,006	0	0	0	2	0	0	0	0	0	5,75	0	10
Slovakia	0,006	0,14	1,07	2	2	2,5	3,2	4	4,9	5,75	5,75	10	10
Slovenia	0,003	0	0	0	2	1,2	2	3	4	5	5,75	10	10
Sweden	0,019	1,33	2,17	3	2	3,55	4,1	4,65	5,2	5,75	5,75	10	10
EU27		0,54	1,2	1,81	2	1,8	3,18	4,47	5,21	6,05	5,75	9,59	10

Source: Source: Cepii's calculations based on European Commission - National Reports

Notes: (*) calculated based on national targets and mandates

National incorporation rates will need to be aggregated at the EU27 level in order to be used with the model aggregation, first in the baseline up to 2007 and then in scenarios up to 2020.

In the baseline scenario, we also need to take into account the mandates for biofuel blending in other important countries, such as Brazil and the United States. According to the IEA databases and ACG (2005), Brazilian bio-ethanol consumption ratio between 2005 and 2010 should increase and, according to the forecast, lead to about a 40% increase in production. Today Brazil blends between 20-25% of bio-ethanol with gasoline. Since 2005, the Brazilian government has been trying to repeat their ethanol policy with biodiesel and new mandatory targets for biodiesel blending have been set for 2008, increasing up to 2013 (see Table 33). For the United States, some mandatory incorporation has also been ruled out.

Table 33. Current official targets on share of biofuel in total road-fuel consumption

Countries	Official Targets	Year	Products
India	5%	In near future	Biofuels
Japan	500 million litres	2010	
China	15%	2020	total renewable fuels
Thailand	2%	2010	Biofuels
Brazil	20-25%	2006	Ethanol
	40% increase in production	2005-2010	Ethanol
	2%	2008	biodiesel
	5%	2013	biodiesel
Indonesia	2% of total fuels	2010	biodiesel (palm oil)
	5% of total fuels	2025	biodiesel (palm oil)
Malaysia	5%	In near future	biodiesel (palm oil)
USA	2.78%	2006	Ethanol
Canada	3.5%	2010	Ethanol

Source: IAE database; ACG (2005); USDA Brazil report (2007); IFQC Biofuels Center (2006).

The modelling of the mandates requires firstly splitting the petroleum and coal product sector (p_c) from the GTAP database into the petroleum and coal sectors (p_c_fuels and p_c_others). This aspect was essential to introducing the consumption obligations for fuels in the transport sector.

Secondly, even if the biofuel demand without mandate is calibrated assuming a CES function, the introduction of the mandate implies removing substitution possibilities and using a Leontief structure. As a consequence, for our different mandate scenarios, we will impose fixed shares between each biofuel and fossil-fuels. Moreover, we interpret the blending requirement for each biofuel in a different way, which means that the mandate is global but rather there is a specific mandate modelling by biofuel type.

- **Tax Incentives for biofuels**

The implementation of biofuel consumption mandates is coupled with other support measures. Each European country can chose their policy tools independently in order to facilitate and encourage biofuel consumption. More specifically, each European member state can grant tax reductions/exemptions on biofuel production or consumption in order to reach the European mandatory consumption target. However, there is no prescription for implementing these tax incentives (e.g. type of biofuels, blending level, taxes, investment grants, etc.), and each member state can design its own policy in line with its tax system and the national context. This discretionary implementation of tax incentives makes it harder to represent the total biofuel support at the European level.

National reports of each Member State detail national taxes/subsidies support at the production and consumption level and these can be used to build a database for implementing the baseline and different scenarios in our model. Once the EU database on different biofuels support measures was completed, we calculated an equivalent ad valorem tax/subsidy on consumption, to get an estimate of the effect of support measures at the European level.

Table 34. Diesel and Biodiesel excise taxes in the European Union ($/liter).

		Diesel tax 2004 dollar/liter			Biodiesel tax exemption 2004 dollar/liter			Biodiesel tax 2004 dollar/liter		
	GTAP Consumption weight	2005	2006	2007	2005	2006	2007	2005	2006	2007
AUT	0,015	0,371	0,368	0,368	0,397	0,409	0,403	-0,025	-0,041	-0,035
BEL	0,028	0,407	0,423	0,407	0,000	0,459	0,202	0,407	-0,036	0,204
BGR	0,003									
CYP	0,001									
CZE	0,012	0,411	0,435	0,435	0,384	0,409	0,411	0,027	0,026	0,025
DEU	0,200	0,583	0,583	0,583	0,583	0,508	0,000	0,000	0,074	0,583
DNK	0,009	0,502	0,501	0,501	0,037	0,434	0,440	0,464	0,067	0,061
ESP	0,079	0,365	0,365	0,374	0,335	0,335	0,335	0,030	0,030	0,040
EST	0,001									
FIN	0,005	0,396	0,396	0,396	0,000	0,000	0,396	0,396	0,396	0,000
FRA	0,176	0,517	0,517	0,531	0,409	0,409	0,310	0,108	0,108	0,221
GBR	0,160	0,304	0,304	0,342	0,000	0,000	0,322	0,304	0,304	0,020
GRC	0,012	0,859	0,857	0,879	0,397	0,360	0,358	0,462	0,497	0,521
HUN	0,012	0,409	0,399	0,399	0,422	0,422	0,422	-0,012	-0,022	-0,022
IRL	0,006	0,456	0,456	0,456	0,459	0,459	0,456	-0,002	-0,002	0,000
ITA	0,129	0,506	0,512	0,516	0,471	0,512	0,474	0,035	0,000	0,042
LTU	0,002									
LUX	0,002	0,339	0,345	0,360	0,057	0,062	0,000	0,281	0,283	0,360
LVA	0,002									
MLT	0,000									
NLD	0,027	0,453	0,453	0,460	0,000	0,384	0,378	0,453	0,068	0,082
POL	0,030	0,320	0,362	0,363	0,000	0,310	0,322	0,320	0,052	0,041
PRT	0,022	0,386	0,389	0,451	0,000	0,000	0,000	0,386	0,389	0,451
ROM	0,006									
SKV	0,006	0,466	0,482	0,482	0,434	0,434	0,476	0,032	0,048	0,006
SLK	0,003									
SWE	0,019	0,472	0,491	0,498	0,459	0,484	0,484	0,013	0,007	0,015
EU27		0,439	0,442	0,454	0,311	0,338	0,260	0,128	0,105	0,193

Source: Cepii's calculations based on European Environment Agency, OCDE (for diesel tax) and Biofuels at what cost? EU, IISD (for biofuels tax exemptions).

Table 35. **Gasoline and Ethanol excise taxes in the European Union ($/liter).**

		Gasoline tax 2004 dollar/liter			Ethanol tax exemption 2004 dollar/liter			Ethanol tax 2004 dollar/liter		
	GTAP Consumption weight	2005	2006	2007	2005	2006	2007	2005	2006	2007
AUT	0,015	0,517	0,517	0,517	0,533	0,533	0,552	-0,016	-0,016	-0,035
BEL	0,028	0,682	0,734	0,734	0,000	0,732	0,438	0,682	0,002	0,296
BGR	0,003									
CYP	0,001									
CZE	0,012	0,489	0,518	0,518	0,372	0,037	0,037	0,117	0,481	0,481
DEU	0,200	0,812	0,812	0,812	0,806	0,806	0,123	0,006	0,006	0,690
DNK	0,009	0,672	0,677	0,677	0,347	0,347	0,000	0,325	0,330	0,677
ESP	0,079	0,491	0,491	0,491	0,459	0,459	0,461	0,032	0,032	0,030
EST	0,001									
FIN	0,005	0,729	0,729	0,729	0,000	0,000	0,000	0,729	0,729	0,729
FRA	0,176	0,730	0,730	0,753	0,471	0,471	0,409	0,259	0,259	0,343
GBR	0,160	0,367	0,367	0,410	0,000	0,000	0,000	0,367	0,367	0,410
GRC	0,012	0,859	0,857	0,879	0,347	0,347	0,358	0,512	0,510	0,521
HUN	0,012	0,498	0,486	0,486	0,508	0,508	0,513	-0,011	-0,022	-0,027
IRL	0,006	0,549	0,549	0,549	0,546	0,546	0,549	0,004	0,004	0,000
ITA	0,129	0,686	0,699	0,699	0,000	0,000	0,000	0,686	0,699	0,699
LTU	0,002									
LUX	0,002	0,548	0,548	0,573	0,097	0,099	0,000	0,451	0,449	0,573
LVA	0,002									
MLT	0,000									
NLD	0,027	0,826	0,828	0,842	0,000	0,620	0,626	0,826	0,208	0,216
POL	0,030	0,429	0,444	0,525	0,000	0,459	0,484	0,429	-0,015	0,041
PRT	0,022	0,670	0,692	0,723	0,000	0,000	0,000	0,670	0,692	0,723
ROM	0,006									
SKV	0,006	0,498	0,516	0,516	0,459	0,459	0,461	0,039	0,057	0,055
SLK	0,003									
SWE	0,019	0,660	0,668	0,678	0,682	0,682	0,657	-0,022	-0,014	0,021
EU27		0,605	0,610	0,625	0,325	0,372	0,214	0,280	0,238	0,411

Source: Cepii's calculations based on European Environment Agency, OCDE (for fuel tax) and Biofuels at what cost? EU, IISD (for biofuels tax exemptions).

In the European Union other incentives do exist, but since excise tax exemption represents more than 60% of biofuel fiscal policy incentive we will run our scenarios based on this consumption tax/subsidy.

In the case of Brazil, there are many different consumption and production incentives. Production incentives for oilseed production include tax reductions and exemptions, especially federal taxes whose reduction level depends on the agriculture type and on the production regions (e.g. only subsistence agriculture from the North are exempted from federal taxes, while large agricultural producers from the South only benefit from a 32% tax reduction). Each biofuel project also benefits from loan assistance and there are also some tax reductions at the industrial level. Brazilian states also apply different tax incentives on consumption (e.g. 12% tax for biofuels and between 12-17% for fossil-fuels). There are also price control policies for biofuels as well as other policies to motivate the use of flex-fuel vehicles. Since it is important to introduce Brazilian supports into the baseline, it will be necessary to have a national measure taking into account these differences across states.

- **Trade Policy**

The information from MacMapHS6-v2 database from CEPII helps us to improve the integration of real protection levels in 2004 for our model to run the baseline scenario. This protection has been defined at a very detailed level (HS6 products and bilateral protection between countries) and then aggregated at the GTAP level of data aggregation according to the reference group scheme.

Table 36 and Table 37 show a brief description of MacMapHS6-v2 database on biofuel protection according to our GTAP data aggregation. Since MAcMap represents products at the 6-digit level, we will take the code 382490 for biodiesel and 220710 and 220720 for ethanol (denatured and undenatured respectively). Tariffs presented here are aggregated according to the reference group scheme by biofuel type and by partner, only keeping global protection for ethanol and biodiesel applied for each importer. Looking at tariff-rate quotas (TRQs) opened for biofuels, MAcMap only presents 3 TRQs on ethanol. Korea is one of the countries that have established an ethanol quota (only for denatured ethanol) and South Africa has established another ethanol quota for both denatured and undenatured ethanol. The three TRQs are totally filled and most competitive countries, such as Brazil, have the possibility to export even at the out-of-quota tariff (greater than 100% in ad valorem equivalent tariff).

Table 36. Bilateral protection for Biodiesel trade.

Biodiesel	Importers (in colums)																
Exporters (in rows)	Brazil	Canada	China	EEurCIS	EU27	Indonesia	LACExp	LACImp	Malaysia	MENA	Mexico	Oceania	Ro Africa	Ro Asia	Ro OECD	SAF	South Asia	USA
Brazil			0,055	0,104	0	0,053	0	0,042	0	0,011	0,104	0,046	0,059	0,049	0,032	0,008	0,158	0,006
Canada	0,148		0,012	0,102	0,004	0,053	0,145	0,123	0	0,055	0	0,045	0,07	0,02	0,028	0,008	0,17	0
China	0,148	0,023	0,059	0,087	0,004	0,053	0,146	0,008	0	0,198	0,13	0,046	0,073	0,059	0	0,008	0,152	0,009
EEurCIS	0,148	0,025	0,068	0,026	0	0,053	0,146	0,08	0	0,22	0,13	0,047	0,059	0,071	0,044	0,008	0,124	0,009
EU27	0,148	0,054	0,038	0,092	0	0,053	0,145	0,09	0	0,011	0,119	0,046	0,076	0,035	0,024	0,007	0,166	0,009
Indonesia	0,148	0,023	0,054	0,009	0		0,146	0,087	0,009	0,163	0,13	0,046	0,079	0,02	0,031	0,008	0,166	0,006
LACExp	0	0	0,065	0,099	0	0,053	0	0,005	0	0,169	0	0,046	0,075	0,087	0,038	0,008	0,17	0,006
LACImp	0,112	0,008	0,067	0,095	0,011	0,053	0,109	0,057	0	0,195	0,027	0,046	0,08	0,105	0,041	0,008	0,172	0
Malaysia	0,148	0,023	0,043	0,089	0	0,028	0,146	0,094		0,137	0,13	0,045	0,075	0,018	0,029	0,008	0,165	0,009
MENA	0,148	0,02	0,058	0,093	0	0,053	0,145	0,077	0	0,012	0,126	0,045	0,077	0,096	0,003	0,008	0,174	0,005
Mexico	0,118	0	0,044	0,1	0	0,053	0,011	0,048	0	0,124		0,045	0,067	0,039	0,03	0,008	0,164	0
Oceania	0,148	0,054	0,053	0,093	0,004	0,053	0,145	0,084	0	0,159	0,13	0,012	0,086	0,087	0,032	0,008	0,176	0,009
RoAfrica	0,148	0,019	0,057	0,08	0	0,053	0,146	0,086	0	0,16	0,13	0,034	0,068	0,106	0,032	0,002	0,175	0
RoAsia	0,148	0,035	0,064	0,09	0,036	0,044	0,146	0,081	0,028	0,02	0,13	0,043	0,001	0,05	0,039	0,008	0,162	0,008
RoOECD	0,148	0,052	0,054	0,089	0,037	0,053	0,146	0,087	0	0,17	0,13	0,046	0,07	0,047	0,048	0,008	0,155	0,001
SAF	0,148	0,023	0,044	0,091	0	0,053	0,015	0,083	0	0,125	0,13	0,046	0,08	0,133	0,029		0,178	0
SouthAsia	0,148	0,023	0,057	0,092	0,002	0,053	0,015	0,083	0	0,166	0,13	0,045	0,081	0,097	0,032	0,008	0,212	0,009
USA	0,148	0	0,049	0,102	0,004	0,053	0,145	0,065	0	0,124	0	0,046	0,069	0,042	0,031	0,008	0,16	

Source: MacMap-HS6v2 (2004). Note: applied protection rate for 2004 using the reference group scheme as aggregation method.

Table 37. Bilateral protection for Ethanol trade.

Ethanol	Importers (in colums)																
Exporters (in rows)	Brazil	Canada	China	EEurCIS	EU27	Indonesia	LACExp	LACImp	Malaysia	MENA	Mexico	Oceania	Ro Africa	Ro Asia	Ro OECD	SAF	South Asia	USA
Brazil		0,041	0,259	1,237	0,481	0	0	0,236	11,033	0,374	0	1,166	0,234	0,434	0,428	0,99	1,353	0,169
Canada	0		0,095	1,182	0,034	0	0	0,333	0,671	0,392	0	0,796	0,24	0,015	0,353	0,817	1,248	0
China	0	0,041	0,008	2,169	0,423	0	0	0,536	0,674	0,455	0	1,034	0,195	0,182	0,461	0,817	0,997	0,343
EEurCIS	0	0,041	0,368	0,657	0,371	0	0	0,227	4,855	0,522	0	1,131	0,191	0,869	0,033	0,885	1,426	0,308
EU27	0	0,042	0,138	1,557	0,031	0	0	0,467	11,025	0,415	0,003	1,174	0,211	0,186	0,47	0,874	1,142	0,328
Indonesia	0	0,041	0,25	2,212	0,384		0	0,032	4,287	0,501	0	1,19	0,201	0,331	0,398	0,876	0,436	0,181
LACExp	0	0,042	0,192	0,934	0,044	0	0	0,143	11,038	0,18	0	1,422	0,68	0,283	0,478	0,991	0,083	0,158
LACImp	0,181	0,018	0,318	1,072	0,042	0	0,188	0,215	11,082	0,471	0,009	1,414	0,002	0,655	0,42	0,1	1,004	0,001
Malaysia	0	0,041	0,257	1,966	0,038	0	0	0,024		0,525	0	1,154	0,197	0,082	0,356	0,908	0,276	0,327
MENA	0	0,042	0,011	1,13	0,371	0	0	0,429	1,08	0,15	0	1,166	0,223	0,268	0,428	0,998	0,451	0,322
Mexico	0	0	0,144	1,157	0,47	0	0,163	0,339	11,068	0,375		1,303	0,489	0,175	0,453	0,996	0,5	0
Oceania	0	0,042	0,337	1,369	0,472	0	0	0,206	9,993	0,414	0	0,019	0,331	0,07	0,41	0,969	0,066	0,335
RoAfrica	0	0,039	0,001	1,277	0,029	0	0	0,407	11,089	0,3	0	1,226	0,174	0,269	0,49	0,4	1,348	0,077
RoAsia	0	0,041	0,234	1,734	0,509	0,059	0	0,341	2,586	0,434	0	1,365	0,215	0,144	0,457	0,085	1,415	0,159
RoOECD	0	0,042	0,237	1,537	0,35	0	0	0,287	9,469	0,3	0	1,139	0,207	0,03	0,041	0,096	0,875	0,029
SAF	0	0,004	0,27	1,654	0,408	0	0	0,277	11,009	0,419	0	1,216	0,238	0,423	0,415		1,225	0
SouthAsia	0	0,041	0,197	1,872	0,08	0	0	0,391	11,089	0,446	0	1,129	0,212	0,287	0,402	0,1	0,639	0,186
USA	0	0	0,014	0,953	0,332	0	0	0,146	10,099	0,024	0	0,77	0,434	0,179	0,338	0,098	1,023	

Source: MacMap-HS6v2 (2004). Note: applied protection rate for 2004 using the reference group scheme as aggregation method.

The MacMap database not only provides tariff information but also tariff-rate quotas linked to biofuels. According to the recent improvements in the TRQ modelling in the Mirage model, we could also envisage to increase or create TRQs on biofuels as an alternative scenario of trade liberalisation (e.g. the EU proposal on ethanol in the EU-Mercosur negotiations).

In the EU, some environmental and quality requirements also create non-tariff barriers to trade. For environmental, operational and health reasons, the EU has imposed the standard EN590, which specifies that the percentage of blend cannot exceed 5% of biodiesel in diesel. This regulation constrains the growth of EU biodiesel production, but also in imports. Moreover, the EU does not permit the import of biodiesel made from soya, which almost completely excludes biodiesel exports from some countries, such as many Latin American countries.

The trade protection that applies to Brazilian imports of biodiesel is currently higher than for European or American imports, but it is the opposite for ethanol. The Common external tariff (CET) of Mercosur has recently been decreased since the 2004 data provided by MAcMap. The CET shows that ethanol imports are taxed at 20% since 2007, while biodiesel rates are 14%. Moreover, there is no other restriction linked to non-tariff barriers (no TRQs, no quality standard, etc.).

• Agricultural Policy

Since the 2003 CAP reform, decoupled policies have been applied to EU energy crops without any loss of income and without the initial restrictions due to set-aside obligations. Moreover, the production of energy crops benefits from a premium of €45 / hectare with a maximum of 1.5 million hectares. Biofuels production in the European Union is also encouraged by the special provision included in the CAP for agricultural inputs.

Concerning sugar beet for ethanol production, the CAP exempts this part of the supply from production quotas. This last policy is part of the last Common Market Organisation sugar reform.

Production quota exemptions for sugar and premiums on energy crops have to be taken into account in modelling EU biofuel support. The sectoral split between energy crops and food crops could be important to implementing these policies.

Biofuels policies considered in the Baseline scenario

For the baseline scenario we introduce the current biofuel policies in the EU27, the USA and Brazil into the model. These countries mandate a target blend ratio for the percentage of biofuels, which should be incorporated into fossil fuels. In order to reach their objectives these countries simultaneously implement various fiscal aids and grants, which are incorporated into the model.

In the EU27, as indicated in the discussion on policies above, there is no uniform biofuel policy. Although the EU set a 2% blend target for renewable fuels (not just biofuels) for 2005 and 5.75% in 2010, these figures remain indicative and not obligatory. Policy in this area is decided at Member State level. Biofuel blend targets are therefore compulsory for some countries, but not all. Today, only nine of the twenty-seven European countries have set a mandatory requirement for biofuel blend ratios. They couple these obligations with fiscal incentives, which also vary from one country to another. Most of them involve total or partial reductions in excise-tax on biofuel blended transport fuels or tax-free biofuels quotas. Others also include output or input subsidies, the latter supported by the Common Agricultural Policy (CAP). Finally, there are some countries that provide investment grants to biofuel development projects, such as flex-fuels cars or biofuels distribution infrastructure.

The heterogeneity in the European biofuels' policy makes it difficult to simulate scenarios at the EU level. For that reason we have introduced some assumptions into the simulations. In the case of the baseline scenario, we have introduced the EU targets for biofuel use (at least 2% in 2005 and 3.2% in 2007). At the country level, some countries, but by no means all, have reached the 2005 target. We construct our baseline scenario for the level of biofuels blending with fossil fuels on the basis of the mean (consumption weighted) development in blending shares at the EU27 level.

We modeled the excise-tax reduction by calculating the mean (consumption weighted) values for each year since 2004 at the EU27 level. For instance, in 2004 the average excise-tax credit was \$0.578 per liter of biodiesel and \$0.634 per liter of ethanol. In 2007 the tax credit for biodiesel was slightly lower (\$0.544 per liter) while that for ethanol was slightly higher (\$0.649 per liter) (Kutas et. al, 2007). For model calibration and for the baseline scenario we use the tax excise credit data from the existing literature because the values presented in Table 34 and Table 35 are very incomplete for the moment and in addition they are lower than those in other key papers. Although, as indicated above, there are several other more marginal policy measures which impact on the biofuels market and which could have been considered (energy crop payment, set-aside payment and market price support), we only model the excise-tax credit because it represent more than 60% of the total effective support for biofuels provided in the EU. The CAP is also modeled, but without taking into account certain detailed policies related to biofuels (e.g. the "no production quota" for sugar beet). Other key policies including biofuel trade protection are also considered and the mandate mechanism is explicitly modeled.

In the USA, both a federal mandate and state-level targets or mandates for biofuel blends exist. The federal objective is that 15.2 billion liters (equivalent to 2.78% of gasoline consumption) should be consumed in 2006 and 28.4 billion liters (equivalent to 5.2%) by 2012. At state level, these objectives may vary. For instance, Iowa State has set a target of 10% by 2009 and 25% by 2020. This is one of the highest targets in the USA, where targets do not generally exceed 20%. According to AgraFNP(2008) the ethanol industry is lobbying for a higher level of blending - up to 12 or 13%. However, so far levels have remained lower, so we only introduce a mandate of 10% for biofuel blending in the baseline.

Subsidies are an important policy tool. Since 2004 the federal and state governments replaced fuel-tax exemption for biofuels with volumetric subsidies or/and consumption mandates. At the federal level the volumetric excise-tax credit for ethanol is \$0.135 per liter and for biodiesel it is \$0.264[34]. Direct production subsidies are also significant. There is a federal small producer tax credit of \$0.026 per liter and subsidies to support biofuel production of \$0.05 per liter provided at the state level. Although there are other indirect support measures related to agricultural inputs or capital grants, we only consider the above policies support in the baseline scenario, since they together represent more than 65% of total biofuels support in the USA (Koplow, 2006; Koplow, 2007).

The third country we consider in the baseline is Brazil, where we also introduce detailed information about mandates and fiscal aids in the model. Historically Brazil has imposed a mandate for ethanol consumption, which presently varies between 20 and 25% depending on the ethanol price. The government officially launched the Biodiesel Program in 2004 and in 2005 the new law (LEI N°11097) authorized the voluntary blending of biodiesel with petrol diesel for the first 3 years, moving towards a mandatory target of 2% for biodiesel blending by 2008 and 5% by 2013 (Methanol Institute et. al, 2006).

Mandates in Brazil are therefore differentiated by biofuel type although our modeling does not include this distinction. In our baseline scenario however, we take the Brazilian ethanol mandate as representing the biofuel mandate. This is a realistic simplification given the predominance of ethanol (in the matrix, the biodiesel sector is currently almost nonexistent in Brazil). In modeling the fiscal support to biofuels, the excise tax reduction is the most significant element. For ethanol the excise tax levied is 67% lower than that applied to gasoline. Decomposing the ethanol excise tax credit by source we find that, in 2007, the federal element was \$0.135 per liter and the Sao Paulo state part \$0.224 per liter. The excise tax reduction for biodiesel was fairly stable over the 2004-2007 period. Initially it was \$0.0973 per liter while at the time of writing it has increased slightly to \$0.0992 per liter. Other tax exemptions linked to the type of feedstock and the feedstock origin also exist, but they are minor compared to the excise-tax credit (Jank et.al, 2007; FAO, 2008b).

Using this baseline scenario incorporating the main biofuels policies applied in the EU27, the USA and Brazil, we run the following three scenarios to test the impact of possible EU policies on biofuels.

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[34] Volumetric biodiesel excise-tax credit distinguishes two different products and thus subsidies: biodiesel derived from waste oil, which benefits from 0.132 US dollar per liter and biodiesel derived from agricultural fats and oils which receives 0.264 US dollars per liter. In our baseline scenario, we assume the second case since we do not have detailed information to model second generation biofuels.

Annex 5. Sector and geographic decomposition

Table 38. Sector decomposition

Code	Sector description
Rice	Rice
Wheat	Wheat
Maize	Maize
OthCrop	Other crops
VegFruits	Vegetables and fruits
OilseedBio	Oilseeds for biofuels
Sugar_cb	Sugar cane and sugar beet
CattleMeat	Cattle for meat
OthAnim	Pork, chicken and other animal products
OthCattle	Other cattle (milk, fibers)
Forestry	Forestry
Fishing	Fishing
Coal	Coal
Oil	Oil
Gas	Gas
Ethanol	Ethanol
Biodiesel	Biodiesel
OthMin	Minerals and other extraction
MeatDairy	Meat
OthFood	Other food and beverages
Manuf	Manufactured semi-final and final products
WoodPaper	Wood products and paper industry
PetrNoFuel	Non fuel refined petroleum products
Fuel	Refined fuel
Fertiliz	Fertilizer and agricultural chemicals
RawMat	Raw materials for industry
ElecGas	Electricity production and energy distribution
PrivServ	Private services
Construction	Construction
RoadTrans	Road transportation
AirSeaTran	Air and water transportation
PubServ	Public services
Housing	Dwellings

Table 39. Geographic decomposition

Code	Geographic description
Oceania	Oceania
China	China and Hong-Kong
RoOECD	Rest of OECD
RoAsia	Rest of Asia
Indonesia	Indonesia
Malaysia	Malaysia
SouthAsia	South Asia
Canada	Canada
USA	United States of America
Mexico	Mexico
EU27	European Union (27 members)
LACExp	Latin America - Exporting countries for crops
LACImp	Latin America - Importing countries for crops
Brazil	Brazil
EEurCIS	Eastern Europe and Former Soviet Union
MENA	Middle East and North Africa
RoAfrica	Rest of Africa
SAF	South Africa

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